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Special Issue Reprint

Public–Private Partnerships (PPPs) for Construction Project Deliveries

Edited by
Patrick S.W. Fong

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Guest Editor

Patrick S.W. Fong

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About the Editor

Patrick S.W. Fong

Patrick S.W. Fong, PhD, is an Associate Professor and Program Director of the Bachelor of Construction Management (Honours) at Griffith University's Gold Coast campus in Australia. He is a distinguished academic and experienced practitioner with over 30 years of expertise in construction management, knowledge management, and value management. A Chartered Quantity Surveyor by profession, Dr. Fong previously held various professional roles in the construction industries of the UK and Hong Kong before transitioning into academia. With a multidisciplinary background bridging construction and organisational behaviour, Dr. Fong has contributed extensively to scholarly publishing. He has held several editorial roles across prominent academic journals and possesses a strong editorial track record, having led and curated multiple interdisciplinary research initiatives and special issues. These include themes such as *Advanced Computing Methods and Related Technologies for Constructing Smart Cities; Knowledge Management, Innovation, and Learning Dynamics in Capital Projects; Psychological Dynamics in Knowledge Management: Cognitive, Emotional, and Social Influences; as well as Creativity, Innovation and Entrepreneurship: The Learning Science Towards Higher Order Abilities and The Pedagogical Innovation for Future Talents*. Widely regarded as a thought leader in both academic and professional circles, Dr. Fong is deeply committed to fostering cross-sectoral and international knowledge exchange. His scholarly leadership and dedication have significantly advanced the theory and practice of Public–Private Partnerships (PPPs) in construction management, positioning him as a key contributor to the evolving discourse on collaborative infrastructure delivery.

Preface

Public–Private Partnerships (PPPs) have emerged globally as a critical mechanism for delivering essential public infrastructure and services, particularly within the construction sector. By harnessing the expertise, efficiency, and financial capacity of the private sector, governments aim to bridge infrastructure gaps, accelerate project delivery, and manage public finances more effectively. However, the complexity, long-term nature, and multi-stakeholder environment of PPPs present unique challenges that demand rigorous analysis and innovative solutions.

This volume compiles eighteen insightful papers originally published in the *Buildings* Special Issue, "Public–Private Partnerships (PPPs) for Construction Project Deliveries". It offers a multifaceted exploration of the contemporary landscape of PPPs in the construction domain, bringing together diverse perspectives, methodologies, and geographical contexts. The collection delves into the critical factors that shape the success, sustainability, and resilience of these complex collaborations.

The contributions within this reprint can be broadly understood through several interconnected themes:

1. **Foundational Understanding and Evolution:** Several papers provide a macro-view, examining the historical development and broader trends in PPPs. This includes a comprehensive **bibliometric analysis** charting the evolution of PPP research and an **evolutionary analysis of China's PPP policies** that explores reasons for project stagnation, offering crucial context for understanding the current state of PPPs;
2. **Project Initiation, Planning, and Frameworks:** The critical early stages of PPP projects are explored through studies focusing on enhancing **business case development** (comparing China and New Zealand), improving **briefing processes** across mature PPP markets, and identifying **critical success factors** for PPP project briefs (specifically in the UAE). A **triadic competency requirement model** is also proposed to foster win-win optimisation from the outset;
3. **Risk Management and Assessment:** Recognising risk as a central element of PPPs, multiple papers tackle its identification, assessment, and allocation. This includes the development of a **risk assessment indicator system** for transportation infrastructure, the introduction of a knowledge-based qualitative risk assessment system named **'Riesgo'**, the identification of **critical risk factors** in specific sectors like Iranian water/wastewater facilities, exploring risk factors affecting **sustainable outcomes** from a stakeholder perspective, and identifying risks associated with various **PPP execution modes**;
4. **Performance, Dynamics, and Success Factors:** Beyond initiation and risk, the operational success of PPPs is examined. Papers investigate the **evolutionary mechanism of trust** when public participation is involved, the impact of **multi-dimensional incentives** on rail transit PPP performance, factors enhancing **sustainable performance** under environmental uncertainty, **critical success factors** for water and power PPPs in developing countries, and the **driving factors of concession periods** in healthcare PPPs;
5. **Specific Applications and Contexts:** The versatility of the PPP model is highlighted through case studies and sector-specific analyses, including its application in **urban regeneration projects** (using an Italian case study) and its potential role in building **urban community resilience** against hazards.

Collectively, these eighteen papers provide a rich tapestry of current research, addressing theoretical underpinnings, practical challenges, innovative tools, and empirical evidence from diverse global settings—including China, New Zealand, Italy, the UAE, Iran, and developing countries more

broadly. The insights span various infrastructure sectors like transport, water, power, healthcare, and urban development.

This reprinted collection serves as a vital resource for researchers, academics, practitioners, policymakers, and students engaged with infrastructure development and public policy. It offers critical perspectives on optimising PPP frameworks, mitigating risks, enhancing sustainability, and ultimately improving the delivery of construction projects through effective public–private collaboration. We hope this volume stimulates further research and informs better practice in the dynamic field of Public–Private Partnerships.

Patrick S.W. Fong
Guest Editor

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Review

Public-Private Partnership: A Bibliometric Analysis and Historical Evolution

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Abstract: The broad and extensive application of public-private partnership (PPP), as well as the divergent documented definitions and experiences, have led to a translucent perspective of PPP and strained academia and industry to reach a consensus on the major practice of this concept. Early contractor involvement (ECI), governance tools, and relational contracting are only a few of the frameworks attributed to PPP. This issue has received limited attention from researchers, despite the focus of review studies on different disciplines of PPP. Hence, this paper puts forward the idea of conducting a comprehensive review to not only shed light on the major practice of PPP but also provide a wider outlook on this concept based on the research carried out since 1979. A narrative review is initially accomplished to identify the major drivers and milestones that have contributed to the evolution of PPP. Employing bibliometric analysis in the following phase assists in conducting a multi-dimensional assessment of studies published within the last five decades. The economic and societal practices of PPP throughout its evolution path signified the dominant application of this concept as a business model. The bibliometric analysis revealed that PPP has contributed to various sectors, i.e., urban development, public infrastructure, transportation, health, and education, just to name a few. In addition, economic and organizational management of PPP was revealed as a major research stream that was accompanied by sustainable development. As a matter of fact, economic and environmental sustainability are the major cross-disciplinary elements that form an interplay between the drivers and attributes of PPP. Value for money (V*f*M), technology, and innovation, along with smart infrastructure (SI) and smart cities (SCs), are identified as the major directions for the future research agenda associated with PPP.

Keywords: public-private partnership; public service provision; public infrastructure; bibliometric analysis

1. Introduction

Provision of public services, development of urban areas, and rehabilitation of deteriorated infrastructure are only a few of the governmental agendas that demand extensive resource mobilization locally and nationwide. In this regard, the expansion of societies and advancements in living standards have burdened public authorities with even more sophisticated responsibilities. While achieving these goals is particularly resource-intensive, public-private partnership (PPP) have favored governments by involving the private sector not only as an executive axle but also as a means of sponsorship [1]. The advantages of this approach are, however, not limited to the financial aspects, as it has demonstrated promising values in partnership enhancement between the public and private sectors,

better risk management, and clearer government policies, just to name a few [2]. PPP, with extensive application in public infrastructure projects, is commonly referred to as an arrangement that engages private parties for the provision of public services under a contractual agreement [3]. A partnership of this form arguably involves distinct characteristics that distinguish PPP from the traditional approach, where the government is the main investor in the project. According to this model, the public and private sectors normally form a long-term contract in which, for instance, the contractor is in charge of supplying the fund, designing, building, operating the facility, and some other commonly considered responsibilities [4,5]. It is worthwhile to mention that PPP is recognized as an innovative alternative that suits 'particularly complex contracts', and embraces various decisions, e.g., project ownership, risk sharing, etc., that potentially vary across different project types [6,7].

According to the benefits delivered by PPP, many nations and public authorities have employed this approach over the last couple of decades, and this has led not only to variation in terminologies but also to the development of distinct experiences and definitions. For instance, P3 (in North America), Private Participation in Infrastructure (in Korea), and Private Finance Initiative (PFI) (originated in Britain but also used in Japan and Malaysia) are some of the most prominent terms that refer to the same subject [5]. The variation in the conceptualization of PPP, however, is rather divergent. In the United States of America (U.S.A.), the National Council for Public-Private Partnerships defines PPP as "a contractual arrangement between a public sector agency and a for-profit private sector concern, whereby resources and risks are shared for the purpose of delivery of a public service or development of public infrastructure" [4]. From a more holistic standpoint, the United Nations Economic Commission for Europe (UNECE) acknowledges PPP as a broad approach that comprises sharing the risk and responsibilities between public and private parties and leads to higher efficiency and quality in the provision of public services [8]. It is worthwhile to note that academicians and practitioners have highlighted and practiced various forms of agreements and contractual arrangements as an alternative to PPP. From a contractual perspective, Build-Operate-Transfer (BOT) is among the preliminary forms of PPP that was exercised by Hong Kong in the late 1950s for the construction of a vehicle tunnel [9]. Under this form of contractual agreement, the project investor (denoted as the *franchisee*) not only supplies the project fund but is also responsible for the construction and operation of the facility in the expectation of earning the revenue generated over a specified period of time [10]. PPP is also recognized as an innovative model that can be realized through various approaches. Inspired by the importance of constructing a collaboration on the basis of trust between partners, a research work regarding project partnering acknowledges that such collaboration could be achieved through relational contracting and recognizes this approach as a chapeau to PPP [11]. As a matter of fact, PPP is claimed to benefit from some of the principles of relational contracting or relational project delivery arrangements (RPDA), e.g., project partnering, alliancing, etc., even though the distinction between PPP and available alternatives in this context is rather blurry [12,13]. A review study highlights PPP as an approach towards early contractor involvement (ECI), accompanied by other 25 identified approaches to this concept, and presents a seven-tier framework for ECI implementation in which PPP is considered a project delivery arrangement [14].

The available definitions, approaches, and terminologies attributed to PPP are not limited to the concepts aforementioned in the above discussion, such as relational contracting, ECI, and so forth. There are numerous debates, categorizations, definitions, and practices pertaining to PPP that hinder deriving a concrete general comprehension of this concept [4]. Not to mention that this problem is also influenced by the distinct development of PPP in various nations, alongside its international application, which broadens the perceptions and characteristics of this mode of partnership. In other words, there is no consensus on how PPP is conceived or "what a PPP actually is" [15]. This signifies a lack of theoretical consistency within the realm of PPP. Linder [16] has recognized PPP as a governance tool

that acts as an instrument for six distinct purposes, i.e., risk shifting, restricting public service, power sharing, etc. This study, on the other hand, raises concern regarding another major attitude toward PPP by highlighting that it is also considered a novel tool for exercising conventional forms of privatization. PPP is also acknowledged as a means of contracting in favor of infrastructure projects [15,17]. There is a plethora of other distinct definitions that add building blocks of confusion to the translucent understanding of PPP. To that essence, PPP is merely recognized as a multi-dimensional topic, and scholars have put significant effort into investigating this topic from various perspectives and within different contexts, such as waste management [18], risk assessment [19], procurement and contracting [20], and so forth. On the other hand, there are a limited number of studies that seek to deliver a more solid perception of the major practice of PPP and to review this concept from a more holistic perspective. Hence, the main objective of this paper is *to study the industrial evolution of PPP and review the research carried out by academicians in order to represent a more transparent perspective on this concept*. To realize this goal, the following questions guide the phases of this study: (1) What major rudimentary elements, stimuli, and milestones have contributed to the development of PPP throughout history? (2) What are the fundamental themes and areas that have shaped the status quo of PPP literature?

To address the first research question, this paper primarily proposes to conduct a narrative review in order to explore and illustrate the evolution of PPP throughout history and present a generic outlook on this mode of partnership through the analysis of credible scientific studies and early reports discussing the structural development of PPP. In this regard, Section 4 of this study seeks to present a more transparent comprehension of PPP by elaborating on the major practices of this concept, especially as a commercial alternative. In practice, and according to the former discussion on the lack of consistency in the extant definitions, studying the decisive principles and milestones that have contributed to the evolution of PPP throughout the last couple of centuries favors identifying the fundamental pillars of this concept and paving the way for a better conceptualization of PPP. While this phase maintains a solid link with the assessment of the real-world practice of PPP, it is also of significance to reflect the academic efforts surrounding this model and enrich the industrial implications of PPP with illumination of the major areas that have been directed by the researchers. Given the reflection of this concern in the latter research question, the second phase aims at carrying out an extensive investigation of PPP literature through Sections 5 and 6, which is achieved by employing the 'bibliometric analysis' approach. To best benefit from the advantageous quantitative attributes of this method as well as fulfill the inclusiveness criteria regarding the findings and inferences, this phase incorporates the records of the scientific studies accomplished within the last five decades. This approach not only paves the way for thematic evaluation of the research works regarding PPP but also enables revealing the less investigated aspects of this model. Hence, the second phase is concluded by recommending a concise research agenda [in Section 7] that assists scholars in directing future research on PPP.

To accomplish this paper, Section 2 explains the methods utilized to conduct the literature review and, more importantly, to address the devised research questions. Section 3 provides a background study pertinent to the former review studies that have been particularly carried out by bibliometric analysis. Section 4 investigates the structural development of PPP over the last couple of centuries, and by capturing the fundamental milestones, it illustrates a timeline corresponding to the evolution of this model. In Section 5, the bibliometric analysis method is expounded, and it is accompanied by the preliminary numerical results of the literature search. In Section 6, the results of the bibliometric analysis are demonstrated and interpreted through extensive discussions. Section 7 presents an overall discussion of the results, and ultimately, by taking advantage of the bibliometric analysis, a research agenda for future academic efforts concerning PPP is recommended in this section. Section 8 concludes the paper.

2. Research Methods

According to the scope of this paper and in order to better reflect the contribution of the previous literature review studies, the keywords 'public-private partnership' and 'bibliometric' were combined to retrieve the relevant review papers from the online database of Scopus. The search was conducted on 1 April 2023, and it initially resulted in 51 documents. In order to navigate through pertinent subject areas, the list of retrieved research items was narrowed down based on the following fields, provided by Scopus: Engineering; Business, Management, and Accounting; Economics, Econometrics, and Finance; Decision Sciences; Environmental Science; and Energy. Applying this filter reduced the number of articles to 25, and it is noteworthy to highlight that all research items are written in English. It was deemed necessary to eliminate the research items that had limited compliance with the primary objective of this paper, which is the evaluation of PPP at a high abstraction level. In this regard, review studies with a specific focus pertaining to PPP, e.g., risk allocation and management, stakeholder management, sustainability, etc., were removed from the list. The same rule was also applied to disregard the articles with a particular geographical focus whose findings are limited to a specific nation or region, such as the bibliometric analysis conducted by Chen et al. [21], who have specifically focused on the market of China. The appraisal process led to the removal of 21 research items, and thus, the final list of review studies was reduced to four items. It is worthwhile to mention that to ensure a comprehensive procedure of document retrieval, the search process enabled the incorporation of terminological variations pertaining to 'public-private partnership', which will be thoroughly described in Section 5.

Academicians and practitioners, as explained in Section 1, have investigated PPP from several dimensions and attributed a variety of classifications to this concept. Not to mention the variations in definitions and characteristics that have hindered deriving a solid and transparent perception of this concept [4]. This divergent illustration reveals the shortage of understanding associated with the core practice of PPP in society, and it requires further attention to the rudimentary and major elements that have contributed to the structural development of this mode of partnership. In this regard, we perform a narrative review, and in order to present a holistic outlook of the PPP evolution, we initially refer to an excellent and profound analysis carried out by Beauregard [1]—discussed in the context of political economy—which is recognized as the major research work with respect to the historical framework of PPP [22]. This discussion is further extended by analyzing the credible scientific studies and early reports surrounding the practice of PPP and by considering the recent major milestones that have substantially impacted this concept, i.e., PFI, etc. Thus, we thoroughly analyze and articulate the interplay between the elements that have contributed to the evolution of PPP and the structural inherence of the major factors that have played a key role in this context. This assessment favors delivering a more transparent conceptual perception of the PPP practice.

Following the assessment of PPP development throughout history, the second phase of this study seeks to present a multi-dimensional analysis of the extant literature using bibliometric analysis. Bibliometric analysis is a quantitative method that provides researchers with analytical tools to study the bibliometric data associated with the published materials and satisfy various goals, for instance, to investigate the intellectual structure of a particular topic or to depict and identify the research trends within a field [23–25]. The underlying principle in this method is utilizing the bibliometric data, e.g., keywords, citations, publishers, etc., corresponding to the published articles to illuminate the implicit correlations between the research items pertinent to a specific topic. As a result, this method is underpinned by two major stages: data collection and quantitative examination. Given the pivotal role of data collection, Section 5 expatiates the process of systematic search, which is then accompanied by a description of the general framework, opted examinations, and utilized tool to accomplish the bibliometric analysis. In this regard, the results of each examination are presented, visualized, and meticulously interpreted throughout Section 6.

3. Former Literature Review Studies Using Bibliometric Analysis

Diversity in the conceptual mapping of PPP, along with variety in the definitions and characteristics, have hindered perceiving an integrated and solid comprehension of PPP, as discussed throughout Section 1. Although the contribution of review studies is vital to addressing such a theoretical gap, there is a shortage of effort in this regard. To better highlight this matter, and according to the scope of this study, this section aims to review the prior efforts from academia. In this regard, four review papers were collected—as explained in Section 2—and are represented in Table 1.

Table 1. Previous literature review studies regarding PPP employing bibliometric analysis.

Author(s)	Publication Year	Sample Size	Time Interval of Study	Database
Marsilio et al. [26]	2011	323	1990–2007	SSCI
de Castro e Silva Neto et al. [27]	2016	650	1990–2014	Web of Science
Ma et al. [28]	2019	1209	2008–2018	Scopus
Narbaev et al. [29]	2020	1970	1989–2018	Scopus

With a focus on individual efforts from authors contributing to PPP, Marsilio et al. [26] utilized a few bibliometric analysis examinations, e.g., author co-citation analysis, to illustrate the intellectual structure—defined by the authors as "the manner in which the conceptual items [of a field] are organized, interrelated, and displayed"—of this field on the basis of articles published between 1990 and 2007. This study basically relies on the background and expertise of the most contributing researchers, and after identifying the most influential documents, it attempts to elaborate on the fundamental topics of PPP. The sample size in this study is 323 records, which were retrieved from the Social Science Citation Index (SSCI), which is currently a product of Clarivate Analytics, through a bottom-up and explorative approach. Along with other inferences, the authors outlined four major themes regarding PPP studies: public administration, healthcare policy and services, planning and development, and urban studies.

By incorporating more examinations, de Castro e Silva Neto et al. [27] put forward the idea of providing researchers with an overview of PPP trends in academia. Similarly to Marsilio et al. [26], the bottom-up and explorative approach is considered to retrieve the relevant documents, and this resulted in 650 records from the Web of Science (WoS) online database, expanding along the temporal interval of 1990 to 2014. In addition to the investigation of journals and nations contributing to either PPP or PFI and according to the number of publications associated with each subject, this study sheds light on 14 major research areas, i.e., contract performance, qualitative costs and benefits, contract design and risk sharing, PPP/PFI political and institutional issues, etc.

The advancement of analytical tools and more systematic search and document retrieval techniques are significant factors in improving the reliability and inclusiveness profiles of studies using bibliometric analysis. In this regard, and compared to the previously discussed review studies, Ma et al. [28] extended the sample size to 1209 research works that have been carried out within a ten-year period (between 2008 and 2018). Utilizing the Scopus online database, authors have accessed the relevant studies according to a specific set of keywords, and in this case, they have combined five terminological variations of 'public-private partnership'. This study seeks to present a wider perspective of PPP extant literature through further quantitative elaboration of the corresponding examinations, i.e., keyword analysis, investigation of scholars and citations, and evaluation of contributing journals and countries. The findings of this study reveal that project governance and risk-oriented subjects are the most researched areas, which are followed by eight further domains, i.e., critical success factors, performance evaluation, PPP models and applications, etc., based on the number of papers published in each area of study.

Given the advantages of the systematic search, Narbaev et al. [29] combined the keywords "build operate transfer" with "public-private partnership(s)" and "private finance

initiative(s)", and retrieved 1970 records from the Scopus online database. Through an assessment of the most occurring and relevant terms, as well as the most contributing journals, corresponding to the articles published between 1989 and 2018, this study presents PPP as a multi-disciplinary subject that dominantly embraces construction management and economics, public administration and management, and transportation research disciplines. To aim at creating a knowledge map associated with PPP, the classification of research areas in this study indicates that sustainability, governance, and stakeholder management are among the emerging topics.

It is worthwhile to mention that systematic literature review (SLR) is another approach to conducting a review study (this statement does not imply dichotomizing the literature review methods) that has attracted academia in recent years. Although SLR has shown promising capabilities in the synthesis of accumulated knowledge, it does not fall within the scope of this paper from a methodological perspective. However, to shed light on the academic efforts in this regard, we combined the keyword 'public-private partnership' with 'systematic literature review' OR 'systematic review' in Scopus, which resulted in 97 records. Needless to mention, the search was conducted on 1 April 2023, and records were refined in accordance with the same filters applied earlier in this section. A preliminary assessment of this list shows that the majority of this type of review study has put emphasis on urban development and planning, water treatment, risk allocation and management, and sustainability. In fact, few studies have directed efforts toward holistic analysis of PPP, which can be found in Roehrich et al. [30], Xiong et al. [31], Zhang et al. [32], and Magalhães et al. [33].

Despite the vital contribution of literature review studies to the multi-dimensional assessment and upbuilding of the general comprehension of PPP, this concern has received limited attention from academia. According to the methodological focus and scope of this paper, only four review studies have taken advantage of bibliometric analysis, which have all been carried out within the last 12 years (between 2011 and 2020). This statistic depicts the shortage of research surrounding PPP, particularly with the aim of delivering a better understanding of this concept, even though it has been practiced and studied for many decades. Hence, compared to the previous review papers, this study puts forward the idea of conducting an extensive bibliometric analysis that could benefit the research community and industry from various perspectives:

- An impediment to delivering a more solid perception of PPP, as discussed earlier and emphasized by Akintoye et al. [4], is the divergence of the extant categorizations, definitions, and terminologies. Although the discussed review studies have contributed to providing a wider outlook on this concept, there is a shortage of attention to the core practice of PPP. For instance, Marsilio et al. [26] echoed this issue by pointing out the inadequate conceptual classifications associated with PPP, in which the practices, e.g., infrastructure, local development, etc., and concepts, e.g., governance approach, etc., are either mixed up or distinguished insufficiently. Therefore, we review the evolution and industrial application of PPP to not only capture the major drivers and milestones contributing to the development of this concept but also to shape the grounds for better comprehension and interpretation of the results derived from the bibliometric analysis.
- A significant element to minimize bias and deliver a rigorous literature review study, regardless of the review type, is external validity [34]. This is realized through inclusive coverage of the available and relevant literature pertaining to the topic [35]. As indicated in Table 1, the number of research items incorporated into the former review studies—ranging from 323 to 1970—is limited by several factors: (1) The search strategy and document retrieval process have notable impacts on the span of the retrieved articles. For instance, despite the systematic search favoring Ma et al. [28] and Narbaev et al. [29] to expand the sample size of their study—compared to Marsilio et al. [26] and de Castro e Silva Neto et al. [27]—their studies were limited by the considered time interval and the selected keywords, respectively. (2) Another

influential element is the choices of the retrieved document types, i.e., journal papers, conference proceedings, etc., and the scientific/practical fields that distinguish the domain of studies surrounding PPP, i.e., medicine, engineering, energy, etc. The literature review papers that were studied in this section have only focused on the journal articles, and they lack transparency regarding the domains of the incorporated research items. Hence, this study seeks to address the outlined issues to better satisfy the element of external validity and to conduct a more rigorous bibliometric analysis. In this regard, the available research works are collected with no binding condition on the time span, which constitutes the studies published within the last five decades (between 1979 and 2023, April). The search process benefits from search techniques, e.g., utilization of asterisk symbol, etc., to better consider the terminological variations of the selected keyword, which is 'public-private partnership'. The collected research items are not limited to the journal papers, and several fields of PPP studies are taken into consideration, such as social sciences, engineering, business, and so forth. The outlined factors enable this study to accomplish a comprehensive bibliometric analysis using a sample size of 11,700 research items.

4. The Evolution of Public-Private Partnerships

Governments have been the major actors in urban development, both nationally and at the regional level. This agenda was magnified throughout and even before the industrialization era, when an interweaving relationship between public authorities and economic elites gradually emerged. Beginning with the provision of public services in the early 1800s, e.g., police and fire services, public health, sewers and water treatment, etc., local governments introduced taxes to finance such services, and this went hand in hand with the desirability of the city to invest in and live in, which brought political and economic elites around the same table [1]. This bilateral bond between government and business leaders was developed in two phases: the reform of government [1] and the rise of industrialization [36]. Full-time politicians initially used their powers to supplement their meager earnings. However, they were prohibited from earning from direct contributions to commercial projects after the reform of governments in the mid-1800s, and this was a considerable factor that contributed to tightening the relationship between investors and public authorities [1]. In addition, and given the significant reciprocal link between the provision of public services and the growth of the public economy (and industrialization), the delivery of infrastructure projects, e.g., canals, railroads, etc., was promoted and benefited from the collaboration between government and private businesses, as discussed by McCraw [36] regarding the political economy of the United States of America (U.S.A.) in the 19th century.

Although these milestones made substantial impacts on major partnerships between public authorities and private sectors and satisfied their mutual benefits, they also contributed to the empowerment of private business owners, which in turn fed the debate surrounding the institutional distinction between private and public sectors for decades before the beginning of the 20th century [36]. A distinction that was deemed essential to provoke the condition for establishing the contractual partnership between the public and private sectors, known as public-private partnerships [1]. Ever since, and according to the advent of considerable economic powers that were not pertinent to the government, commercial relationships between public authorities and private sectors emerged with various forms of challenges that highlighted the necessity of corresponding legislation [22]. In response to such a phenomenon, partnership between government and economic elites turned into a feasible and official approach with more legal frameworks to not only address such an adversarial relationship but, more importantly, tackle civic challenges for the public's benefit [37]. This collaboration incited more ambitious goals in the community above the constructional and operational goals, which in turn provoked the alteration of societal roles in both the government and private sectors. As exemplified by Davis [37], public authorities are urged to play a supportive role rather than being 'tax collectors',

and private business enterprises are urged to contribute to the enhancement of society rather than being 'tax payers'. It is worth mentioning that this study also highlighted the contribution of grand business leaders of the time to the partnership with the government in several critical urban projects, such as David Rockefeller and James Rouse.

As a matter of fact, the contemporary comprehension and application of PPP are due to the procedural movements throughout the last couple of centuries, specifically after the industrialization era. In a thorough study, Beauregard [1] articulates this evolution precisely within the context of U.S. political economy and highlights four historical stages for PPP development, denoted as 'Historical Chameleons'. This development commences with the emergence of political machines in the mid-1800s, which were 'strong, centralized party organizations with disciplined workers, whose loyalty [is] guaranteed by the prospect of material rewards in exchange for work in the party' [38]. Patronage and access to governmental largesse generated political and financial support for political machines, and they extensively contributed to urban growth, which ultimately expanded the scale of this entity. This period involved promising collaborations between business owners and political machines, which led to a pervasive and implicit form of PPP known as *patronage partnerships*. In the 1890s, political machines paled as opposed to local governments, with the escalation of the belief that governments are more efficient and effective means of the common good. In the meantime, and as a consequence of the industrialization expansion, investors encountered chaotic troubles such as traffic congestion, inadequate waste disposal, and so forth, which were detrimental to their businesses. Hence, real estate and industrial elites became interested in city planning and joined local governments to better satisfy the need for further urban development. This boosterism movement was in place until the 1940s, and this period was labeled as *booster partnerships*. The Second World War (WW II), however, had a disruptive effect on urban life and development. Whereas the position and investments of political and economic elites were at risk, they established redevelopment authorities, which were an instrument to purchase the blighted properties and make them available to the private sector by taking advantage of renewal legislation, funds, and the power of local government. Rehabilitation of infrastructure in this period benefited economic elites and local governments from the viewpoint of growth in private investments and tax revenues and embraced successful collaborations until the 1970s, denoted as *redevelopment partnerships*. In the early 1970s, partnerships encountered opposition from business owners whose businesses were condemned and shrank by rehabilitation/development, as well as residents whose properties were a part of such plans. Concurrently with this situation, which had led to the atrophy of redevelopment partnerships, the interest of the central government in urban renewal and financial support faded away. To remedy this adverse status, President Carter introduced the Urban Development Action Grant (UDAG) program in 1977, a breakthrough that stimulated public officials by providing financial grants for expanding and empowering public-private partnerships [22]. Not to mention that increased interest in privatization and chronic fiscal stress in society were booster elements of this program in the early 1980s. The new wave of partnerships, unlike the earlier forms of partnerships, targeted a wider range of societal problems and forms of projects, e.g., parking garages, commercial space, housing, etc. [39]. To achieve this goal, non-profit development corporations presented themselves as the partnership vehicle of choice and engendered *growth partnerships* that addressed international relationships, long-range planning, school reform, economic development, and so forth.

The current application and comprehension of partnerships between government and private investors has a solid correspondence to the latest reform of partnerships discussed above, denoted as growth partnerships. Not only have many nations incorporated this approach into their development plans throughout the recent decades, but also many organizations and public unions have contributed to enriching this type of collaboration with more legislative frameworks. A noticeable milestone in this regard is the introduction of the Private Finance Initiative (PFI) in 1992 by the United Kingdom (U.K.). The core stimulus of PFI was the promotion of public service provision, provided that private

investment contributes to the reduction of the public deficit, and according to this scheme, the government was supposed to purchase, directly or indirectly, the services supplied by the constructed infrastructure [40]. Inspired by the growth partnership, which was the latest product of the U.S. political economy, PFI's agenda was set to support various types of projects such as transport, public health, education, and so forth. Although the underlying principle of PFI is the private sector's sponsorship, it has specific ties with other fundamental elements as per the partnership between the government and the private sector. As stated by Grout [40], PFI embraces the intention of transferring risk to the private sector, and more importantly, it aims at higher value for money (V*f*M) for the tax payer in comparison with the traditional model of project investment. The British government defines V*f*M as "the optimum combination of whole-of-life costs and quality to meet the user's requirements" [41]. The engagement of this attitude with PFI demonstrates a particular turning point for partnerships between the public and private sectors. On the one hand, the evolution of PPP within the political economy of the U.S.A. revealed that this alternative was rather employed as a commercial alternative in response to public financial deficits or civic challenges. On the other hand, with experiences earned and benefits delivered through decades of applying this mode of partnership, PPP turned into a feasible and efficient option for governments by which they not only took advantage of private investment and expertise but more importantly established a long-lasting collaboration that potentially increased the V*f*M and improved the provision of public infrastructure and services. Concurrently with the constitution of PFI by the U.K., various nations across the globe incorporated PPP into their policies of public infrastructure provision with more concrete structures and frameworks. Kennis-centrum PPPs in the Netherlands was established in 1999 within the Ministry of Finance to support and promote the application of PPP [3]. In China, the Ministry of Foreign Trade and Economic Cooperation, the Ministry of Power, and the Ministry of Transportation were among the preliminary entities that provided documentation to support Build-Operate-Transfer (BOT) projects [42]. These initiative entities and supportive agendas were not limited to national boundaries, and many unions emerged for international support of PPP. The European PPP Expertise Centre (EPEC), the International Project Finance Association (IPFA), and the United Nations Economic Commission for Europe (UNECE) are only a few of the established international and regional organizations that favor and lubricate the PPP application [43].

Decades of experiences in constructing public infrastructure in various nations under the scheme of PPP and the development of promotional and supportive entities and unions have turned this approach into an efficient means of public service provision with high quality [8]. As a matter of fact, leveraging higher V*f*M as one of the major drivers throughout the recent decades has paved the way to view PPP as a beneficial and efficient commercial option rather than a financial solution for satisfying the public budgetary deficits. This attribute signifies the element of *collaboration* or *partnership* between government and private sector, which had been emphasized by Davis [37] as the prominent property of PPP, as opposed to opting for this approach as an alternative to "budget gap filler". This turned out to be a persuasive agenda for the U.K. government to make reforms and adjustments to PFI in order to enrich this framework with more terms and conditions that contribute to better delivery of public services. Hence, His Majesty's (HM) Treasury [44] of the U.K. introduced Private Finance 2 (PF2) in 2012 as an updated and revised scheme for public-private partnerships and defined it as a means "to facilitate genuine partnerships between the public and private sectors". Not to mention that prior to this milestone, PFI experienced several stages of reform and adjustments to better satisfy public and private demands, such as the 'Operational PFI Savings Programme' to enhance transparency [44]. In principle, and in order to realize the primary goal of PF2, the major incentives of this scheme were devised to address some of the PFI drawbacks manifested by the U.K. government, such as the slow and expensive procurement process, the insufficient flexibility of PFI contracts during the operational period, the insufficient transparency of the future liabilities imposed by PFI contracts, and so forth [44]. In addition,

risk allocation—which has been characterized as one of the major features of PFI—was argued to had been accomplished inefficiently as the public sector was burdened with higher levels of risk [45].

The partnership between private investors and governments has evidently experienced several reforms and adjustments over the recent decades, and as discussed above, these have not been primarily for the benefit of public financial reservoirs but rather for better provision of public services and higher V*f*M. Referring to the primary concern of this paper, reviewing the evolution of PPP throughout history indicates that this scheme is beyond the structural frameworks that are attributed to this concept, as discussed in Section 1, such as relational contracting, ECI, procurement models, and so forth. However, this does not imply a negation of the bilateral connection between PPP and such concepts. As a matter of fact, PPP has been employed as a framework for commercial partnership between government and business leaders that has evolved and been modified in accordance with the needs of society, and as a result, it is widely recognized as a **business model**. This section articulates the history of PPP as well as the important milestones that played a substantial role in the transition to this business approach. In this regard, Figure 1 depicts the discussed stages, milestones, and phenomena associated with the PPP's development on a timeline to convey a more vivid and concrete image of the evolution of this model.

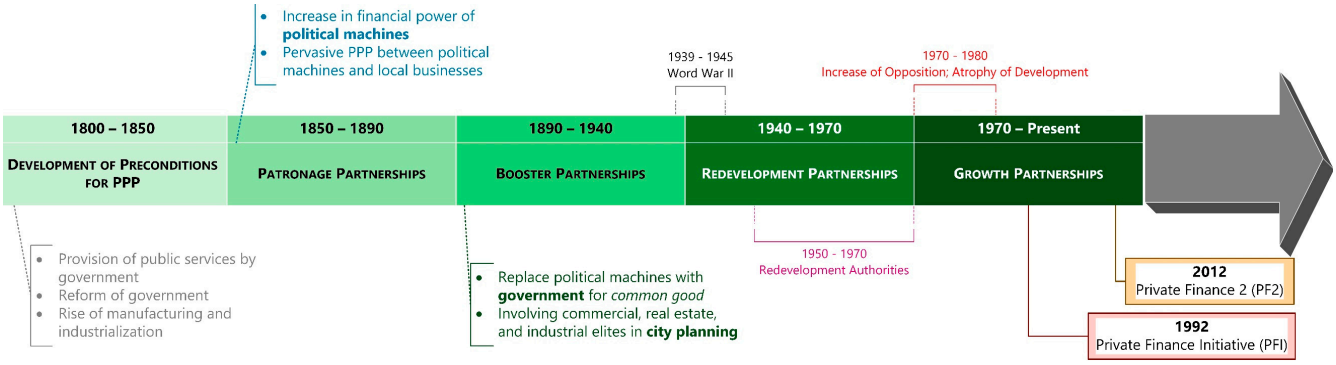

Figure 1. The timeline of PPP evolution, inspired by Beauregard [1].

5. Bibliometric Analysis: Methodology and Search Process

The accumulation of knowledge provides academia with promising potential for scientific development, and research efforts have provided fruitful achievements through literature review studies. Bibliometric analysis is a promising approach in this context, which is evoked by research in the library and information sciences in the presence of a significant volume of bibliographic material, and thanks to the recent developments of digital tools and rich databases, it has favored many research topics [46–48]. There are numerous examinations involved in this method, and in this paper we opted for keyword co-occurrence and bibliographic coupling, which are in the category of science mapping [47]. The former provides a substantially fruitful overview of the topic by analyzing the connection between the keywords that are used together in a document. The latter relates to "a link between two items that both cite the same document" [49], and in this study the *items* refer to *sources*, which are equivalent to *journals*. This examination not only facilitates the identification of journals with the highest contribution to the topic but also reveals the citation relationship between journals to enable the thematic evaluation and classification of studies surrounding PPP. To aim at these goals, VOSviewer (ver. 1.6.19) software is used, which is characterized by strong analytical capabilities and in-depth visualization features [50]. In addition to the outlined examinations, and according to the discussions regarding the evolution of PPP, it is also of benefit to analyze the publication trend of the accomplished studies, which facilitates an overview of the major patterns and trends in conjunction with impactful milestones.

This study puts forward the goal of presenting an inclusive evaluation of the studies regarding PPP, and in order to achieve this goal and avoid leaning towards any particular

direction, e.g., risk sharing, sustainability, etc., the systematic search is conducted by using only one keyword, which is 'public-private partnership'. In this regard, and to ensure extensive coverage of materials and bibliometric data, the search string is combined with an asterisk (*) symbol—known as truncation—to include terminological variants pertaining to the ending part of the search phrase, such as plural form. Moreover, the search string is placed between two double quotation marks ("") to satisfy an *exact* search and set a hard constraint for the search engine to consider the exact combination of the words that constitute the string. Therefore, and by taking the aforementioned points into account, we use "public-private partnership *" as the search string. Not to mention that the dash character (-) between the terms 'public' and 'private', has no bias effect on the search results, and this is treated either as a dash or as a space character by the search engine of Scopus, which is selected as the online database for this study. It is worthwhile to note that the search process scans the title, abstract, and list of keywords pertaining to each article based on the identified string. The search process was performed on 1 April 2023, and initially resulted in 20,239 records, which were further reduced to 19,240 after applying the filters of 'language' (set to English) and 'publication stage' (set to Final). The next important step is narrowing down the 'subject area' of the studies, which leads to increasing the relevancy of the papers and, ultimately, the reliability of the analysis. Based on the categorizations provided by Scopus, the search results are confined to the following areas: Social Sciences; Engineering; Business, Management, and Accounting; Environmental Science; Economics, Econometrics, and Finance; Energy; and Decision Sciences. This ultimate filter reduces the sample size to 11,700, which is considered the final list for further examination.

6. Results of the Bibliometric Analysis

6.1. Publication Trend

The review of the evolution of PPP throughout history revealed that it was particularly promoted after the 1970s [1,22]. The publication trend (see Figure 2)—including studies published since 1979—depicts that 80.1% of the publications fall into the period of the last 13 years. According to the broad scope of this study, it is primarily interpreted within the context of the global economy. It is significant to highlight that the fourth global recession over the last 70 years occurred in 2009, and according to the sophisticated budgetary issues within governments, the value of PPP was even more elucidated for public authorities to overcome the economic difficulties [51,52]. This is particularly observable from the sharp increase in publications in 2010 (which increased to 443) compared to 2009 (which stood at 350). Another impression from this examination is the introduction of PF2 by the U.K. government in 2012, which was explained in Section 4 as an important milestone within the context of PPP development. In this regard, the number of publications experienced a drastic boost in 2012 (557 publications) compared to 2011 (438 publications), and this was the beginning of an incremental trend. Last but not least is the radical change in the pattern of publication numbers between 2017 and 2022 (2023 is disregarded in this aspect for the sake of consistency of comparison). As shown in Figure 2, 2020 stands out as the most productive year by reaching the peak of 930 publications, whereas in this period, the lowest figure corresponds to 2022 with 792 publications. This signifies a consistent increase in academia's attention to PPP over the last six years and implies the importance of this approach on a global scale.

6.2. Keyword Co-Occurrence Analysis

One of the key advantages of bibliometric analysis is the quantitative examinations of keywords that are specified by the authors of published research works. This analysis, first and foremost, assists in identifying the dimensions that have been extensively studied by scholars and highlighting the most influential domains within the realm of PPP. Furthermore, by taking advantage of digital tools, the relationship between the most influential keywords is visualized to facilitate a thorough thematic assessment of the population of keywords and their relationships.

The initial examination in this regard is analyzing the frequency of each keyword, which determines the density of attention from academia to that particular domain. According to the sample size, the list of keywords constitutes 34,146 records, and it is dominated by the terminological variations of 'public-private partnership'. As depicted in Table 2, the adopted search process enabled access to seven variations of PPP, which are sorted by the frequency of their occurrence and collectively account for 8337 records. This is intrinsically predictable because the entire search process was based solely on this term, and thus, it dominates the list of keywords.

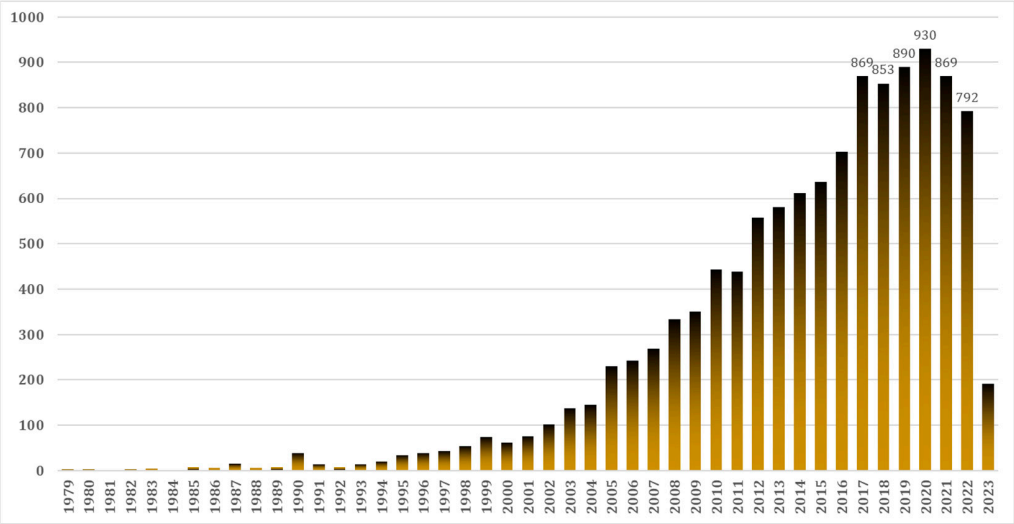

Figure 2. Publication trend of studies surrounding PPP between 1979 and 2023 (1 April 2023).

Table 2. The terminological variations of 'Public-Private Partnership' within the collected sample.

Nr.	Terminological Variations of PPP	Occurrences	TLS
1	Public-Private Partnership	3926	1369
2	Public Private Partnerships	2232	894
3	Public-Private Partnerships	1055	528
4	Public Private Partnership	331	178
5	Public/Private Partnerships	294	167
6	Public–Private Partnership	253	75
7	Public–Private Partnerships	246	73

With this fact accepted, the remainder of keywords are investigated regardless of this term, and the results of this part of the analysis depict that 'human/humans', 'mergers and acquisitions', 'investments', 'sustainable development', and 'economics' constitute the top five used keywords, respectively, with 1184, 677, 639, 572, and 503 occurrences. According to the frequency of occurrence, Table 3 represents the list of the top 10 keywords, led by the outlined terms. It is worthwhile to mention that utilizing each pair of keywords within an article generates a *link* between those keywords, and this connection has a property called *strength*, which is determined by the number of documents utilizing the same pair of terms. As a result, every distinct keyword has a property known as total link strength (TLS), which is calculated by aggregating the strength value of the links pertinent to that particular keyword. For instance, the TLS of 'investments' is derived by aggregating the strength value of the links between this specific term and other keywords of the sample that it is connected to, which is calculated as 3148.

Table 3. Top 10 keywords based on frequency of occurrence.

Nr.	Keyword	Occurrences	TLS
1	Human/Humans	1184	7683
2	Mergers and Acquisitions	677	3520
3	Investments	639	3148
4	Sustainable Development	572	2452
5	Economics	503	2870
6	United States	433	1854
7	Risk Assessment	413	2294
8	Decision Making	411	2059
9	Infrastructure	409	1458
10	Risk Management	390	2026

The initial contextual implication derived from the most frequently occurring keyword(s) is the benefits that PPP has delivered to society, particularly urban development, which was also discussed in Section 4 as the primary impact of this business model given its positive and innovative financial properties. According to the second and third most frequently occurring keyword(s), Table 3 signifies that organizational concerns, as well as financial and economic matters, have been constant research subjects in this realm. This is a reciprocal topic, embracing discussions regarding the economic advantages of PPP and debates associated with financial and institutional complexities to ensure higher V*f*M. Sustainability is considered another dimension that has received remarkable attention from academia. This is arguably significant given the fact that sustainability, particularly within the realm of PPP, maintains an interweaving link with financial issues and economic consequences. The appearance of the term 'economics', also signifies the importance of these two topics. Nevertheless, sustainability is not limited to economic matters and supports a wider range of concerns given the multi-dimensional impacts of PPP on society. The appearance of the United States within the list of top 10 keywords depicts the dominant contribution of this nation to the practice and conceptual development of PPP, which was articulated in Section 4. It is also noteworthy to highlight that the assessment of keywords reveals the considerable contribution of other nations and regions as well, even though they are not included in Table 3, such as the U.K., China, Europe, Australia, India, Africa, and so forth. As explained earlier, PPP is widely characterized by particular policies regarding risk sharing between government and private sector, which are specifically observable from Table 3, according to the terms 'risk assessment' and 'risk management'. Although many public authorities and policymakers have considered higher V*f*M as the main driver of PPP, e.g., PFI [40], decisions on PPP are engaged with a plethora of complexities and uncertainties. Thereby, decision-making forms an inseparable dimension of PPP that is dense in importance. The evaluation of PPP history in Section 4 depicts that better provision of public services is among the rudimentary motivations of PPP. In this regard, Table 3 implicates that this is still a viable driver according to the presence of 'infrastructure' in the list of top 10 keywords. It is worthwhile to mention that infrastructure projects are not limited in type and are dichotomized according to their function [5]: *economic* and *social* infrastructures. The former contributes to 'day-to-day' economic activities, e.g., transport, water, sewage, electricity distribution, etc., while the latter is essential for the structure of society, e.g., schools, hospitals, libraries, prisons, etc.

The second examination is co-occurrence analysis, which investigates the relationship between keywords based on the link between each pair of terms. In this regard, a higher value of TLS indicates higher utilization of the corresponding keyword with other keywords, which in turn implies the significance of that topic and its contextual relevance to other topics. To better benefit from such quantitative data and perform more in-depth analysis, Figure 3 illustrates the correlations between keywords, where the nodes represent keywords and the lines demonstrate the link between them. In this regard, the size of nodes is determined by the frequency of occurrence associated with each keyword, and the thickness of lines is sensitive to the strength of the link between each pair of keywords. The

underlying condition for the generation of this network is determining 'the minimum number of occurrences' associated with each keyword, which substantially impacts the network density. This study takes advantage of an extensive sample size, including 34,146 keywords, and we set the minimum number of occurrences for each keyword to 100, which results in a subset of 108 distinct terms. This setting not only ensures higher reliability of the analysis but also leads to more transparency in the network visualization.

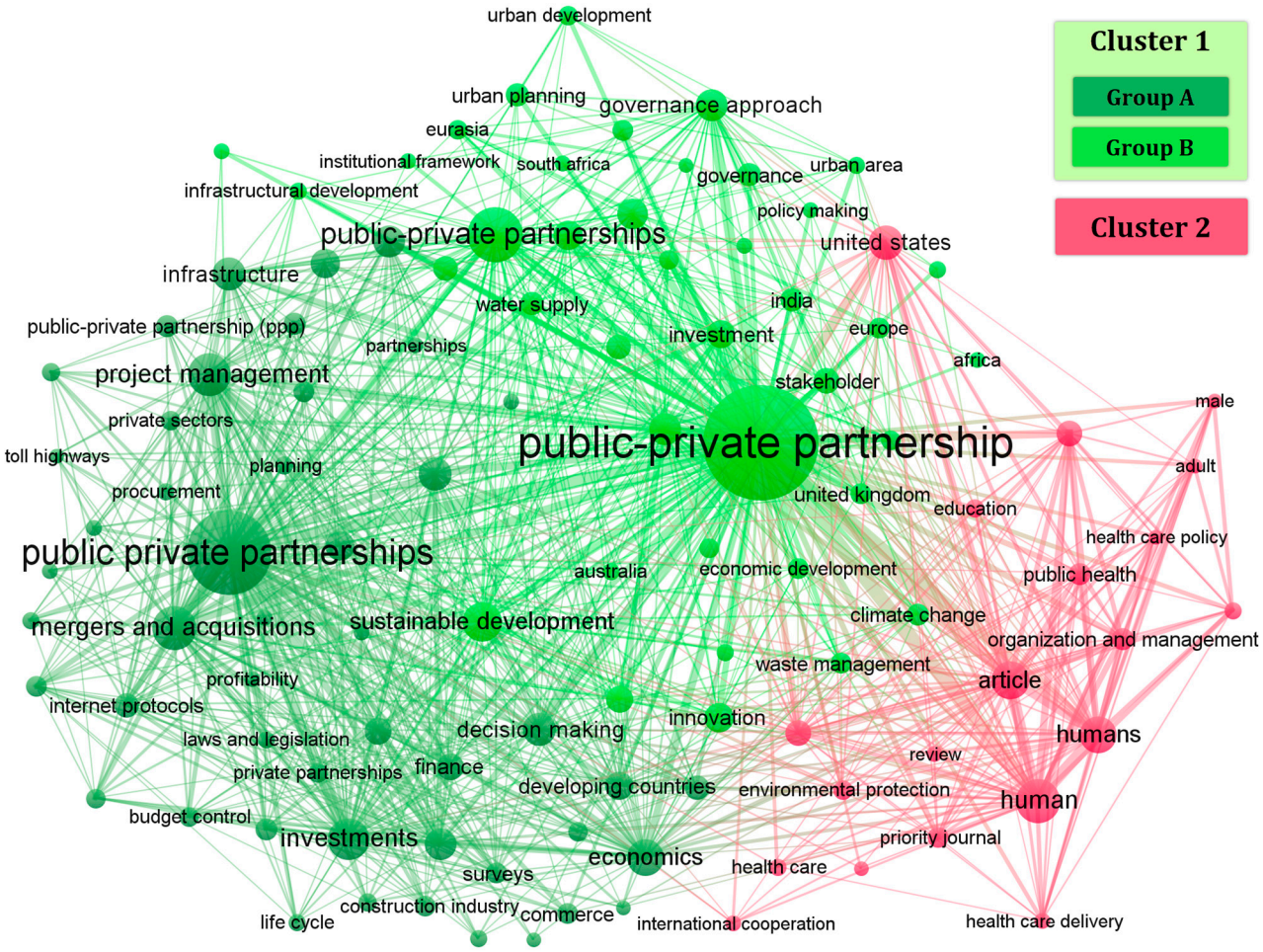

Figure 3. Network map of keyword co-occurrence analysis.

As depicted in Figure 3, the keywords are thematically distinguished by two major clusters. It was observed that Cluster 1 is composed of two subsets, denoted as Group A and Group B. These groups are separated based on the distinct links that different keywords maintain, with two major terminological variations of PPP corresponding to each group. As presented in Table 2, 'public private partnerships' and 'public-private partnership' are the most common variations of PPP, and as illustrated in Figure 3, they serve as two distinct *centers of gravity* for Cluster 1 and shape, respectively, Group A—situated on the left side of the network and highlighted by dark green—and Group B—situated on the middle of the network and highlighted by light green. Thus, in spite of the fact that each group conveys distinct aspects of PPP, they are contextually pertinent and lead to an overall outlook of PPP with respect to Cluster 1. It is worthwhile to note that the distribution of other terminological variations of PPP into the outlined groups is determined by the magnitude of the accumulated links that they have with the keywords of each group. For instance, 'public-private partnerships'—which is the third most common variation of PPP as presented in Table 2—is involved in Group B due to the higher impact of the links that it maintains with the keywords of this group.

Group A conveys a wide range of information associated with PPP, which briefly represents the characteristics of this business model. PPP is broadly recognized for its detailed risk allocation, be it more efficient or more complicated, as well as being referred to as a commercial alternative with a prominent role for the private sector as the investor. This is dominantly observable within Group A according to the links that connect PPP with highly utilized keywords in this context, such as risk assessment, risk allocation, investment, economics, finance, and so forth. In addition, and given the financial advantages of PPP, Group A represents the practicality of PPP for developing countries. Needless to mention, Group A affirms that an intense focus from academia has been directed to infrastructure projects, which is particularly one of the major applications of PPP, as also discussed in Section 4. The other dimension of Cluster 1, demonstrated by Group B, primarily depicts sustainable development concerns in conjunction with PPP. A closer evaluation of two major keywords in this context—sustainability and sustainable development—illuminates two directions within the scope of sustainability that have been investigated by academia in the realm of PPP: economic and environmental sustainability. According to Figure 3, economic sustainability is strongly revealed through extensive connections to the keywords of this context (involved in either Group A or Group B), such as investment, commerce, economics, budget control, finance, and so forth, and the latter embraces solid links to climate change and waste management. A practical overview of Cluster 1 also indicates that transportation, urban development, and water supply are the most prominent project sectors that have extensively benefited from PPP. Cluster 2 elucidates that PPP has been investigated and practiced for the enhancement of society, and this is specifically directed towards health and education. Human, health care delivery, public health, and education are only a few of the keywords that signify this fact. It is noteworthy to highlight that even though the keyword 'COVID-19' is not observable in Cluster 2, it has appeared 94 times within the sample, and it is notably close to the minimum threshold of occurrences for the generation of the co-occurrence network (which is 100). As a matter of fact, even though the unfortunate pandemic of COVID-19 took place in late 2019, there has been a considerable effort from academia in a period of 3 years, which indicates the potential of PPP in response to global health issues.

6.3. Bibliographic Coupling

Bibliographic coupling serves as another quantitative examination that investigates the relationship between items—an item refers to a journal in this study—through the identification of a document that has been cited by two distinct documents from two distinct sources. In other words, any pair of documents associated with two different sources are linked to one another provided that they have both cited the same reference, and this correlation generates a link between the sources pertaining to that pair of documents. In this context, the *strength* of a link between two sources is determined by the frequency of the pairs of documents that satisfy the explained condition. Thus, the TLS in this case is calculated by aggregating the strength values of the links associated with each source. The available sample comprises 4105 distinct sources, and this list is to be narrowed down according to two significant properties for network generation: the minimum number of documents pertaining to each source and the minimum number of citations that each source has received. We set both properties to 20, which limits the sample size to 66 distinct sources. To ensure higher reliability, the sources with TLS lower than 100 were removed, which resulted in the elimination of 12 further sources.

The results are illustrated in Figure 4, encompassing three clusters. In this visualized network, the size of nodes represents the magnitude of citations received by individual sources, and the thickness of lines is determined by the strength of the link between each pair of sources. Taking the number of citations received by a journal into account, the most cited sources that are involved in the sample have played a major role in the bibliographic network of Cluster 1. Considering 54 distinct sources that are incorporated into this examination, the top three sources with the highest number of citations are in-

cluded in this cluster: 'International Journal of Project Management' (IJPM), 'Journal of Construction Engineering and Management' (JCEM), and 'Sustainability (Switzerland)', respectively with 8412, 4669, and 3108 citations. These sources, according to their citations and TLS records, act as three centers of gravity that determine the conceptual orientations of this cluster according to their links with other sources. The connections between the sources of this cluster, which are not limited to the abovementioned journals, highlight two major directions in the studies of the research community: the organizational management of PPP and sustainability. The initial direction is led by IJPM and JCEM, which are inherently multidisciplinary journals based on their aims and scopes. In this regard, and according to the prominent connections between these journals and particular sources of Cluster 1, e.g., Journal of Management in Engineering (JME), Energy Policy, Utilities Policy, etc., it is revealed that there has been a noticeable effort from academia to upbuild the knowledge surrounding PPP from a strategical and administrative standpoint. This is, in fact, a promising aspect of academic efforts to foster the commercial properties of PPP and facilitate the better establishment of this business model. Secondly, the Journal 'Sustainability (Switzerland) has formed a cross-disciplinary network through a variety of connections with different sources. The immediate impression of this matter indicates the incremental trend of sustainability-related studies that are carried out in various directions and disciplines, particularly with respect to the strategic and policy-making studies corresponding to PPP. In addition, this journal substantiates the feature of sustainability within Cluster 1 and via solid links with other sources in this context, i.e., the Journal of Cleaner Production, Environmental Management, etc. It is worthwhile to mention that the strong link between the Journal 'Buildings' and the aforementioned journals sheds light on the significant contribution of two acknowledgeable publishers in the realm of PPP: 'The American Society of Civil Engineers (ASCE)' and 'Multidisciplinary Digital Publishing Institute (MDPI)'. The substantial contribution of 'Construction Management and Economics' (CME) and 'Engineering, Construction and Architectural Management' (ECAM), respectively, with 2857 and 1244 citations, has turned these sources into determining points of attention within Cluster 2. The bibliographic network surrounding these journals and their connections with other sources shed light on three major dimensions pertaining to the research works published by the journals of Cluster 2: economics, construction, and transportation. Finance and economy, as also described in Section 4, are the core driving factors of PPP that interact with other elements. Given PPP as a business model, the initial dimension of Cluster 2 signifies this vital and structural feature of PPP, which is observable through the connections of CME with other sources in this cluster. Furthermore, and without compromising the impact of CME, the latter direction of Cluster 2 is led by ECAM and reveals the research focus on the more practical and constructional aspects of PPP projects. Design, project lifecycle management, and architecture, just to name a few, are among the major streams of research in this context. Last but not least is the interweaving link between the outlined sources and journals, with a specific focus on the transportation sector. 'Research in Transportation Economics', 'Transport Reviews', and 'Transportation Research Record', respectively, with 748, 720, and 514 citations, are the prominent sources in this regard. The thematic concern of Cluster 3 relates to two major areas that can be addressed by PPP: urban life and societal demands. 'Habitat International', 'Public Management Review', 'Public Administration', and 'International Journal of Urban and Regional Research' are some of the most contributing journals in this regard, respectively with 1802, 1728, 1449, and 1185 citations. It is worthwhile to highlight that urban development and societal urges were studied as the major stimuli of PPP throughout Section 4, and Cluster 3 indicates the attention of scholars to these dimensions. A remarkable point to consider in this context is the connection of 'Sustainability (Switzerland)' with many of the sources of this cluster, e.g., 'Cities', 'Journal of Urban Affairs', etc., which represents the multidimensional impact of sustainability on PPP studies, particularly with regard to human life and public administration. Table 4 summarizes five of the most impactful sources in each cluster, which are sorted out according to their respective citation values.

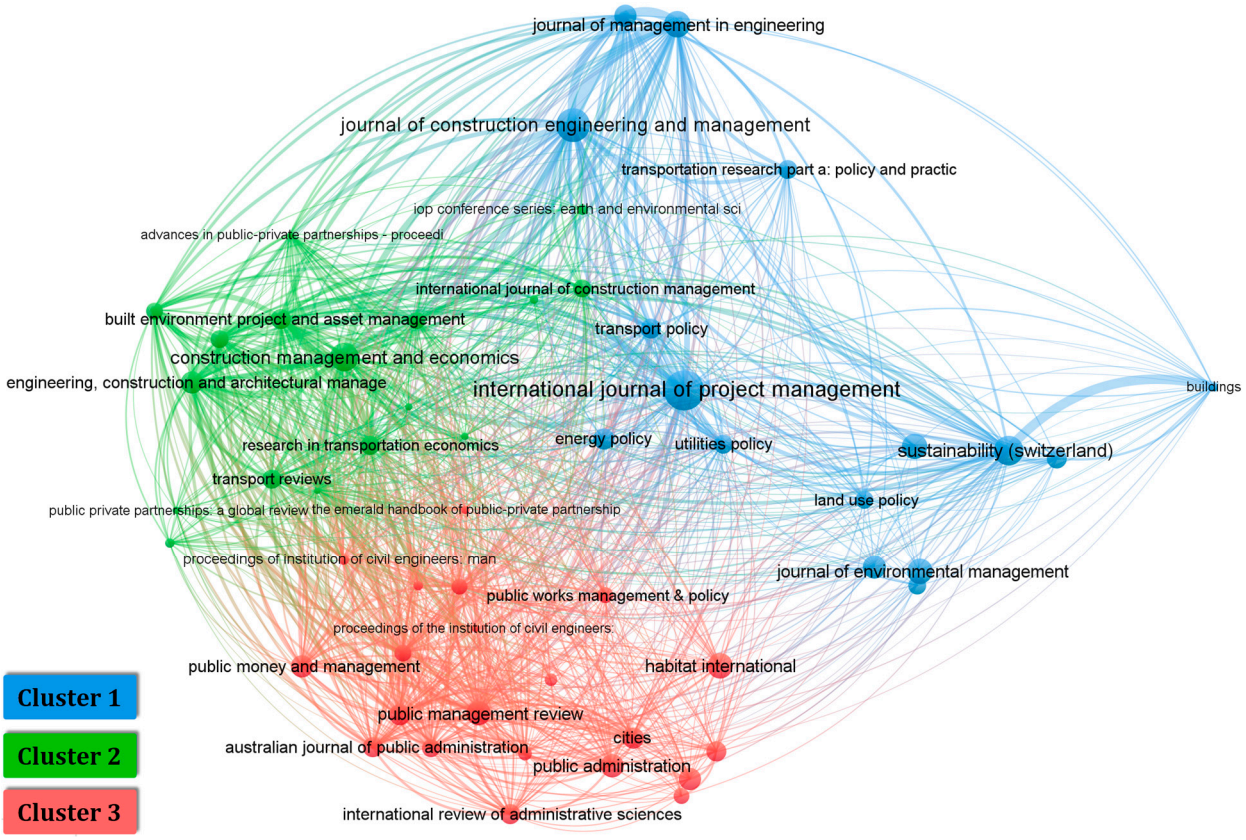

Figure 4. Network map of bibliographic coupling based on the sources (journals).

Table 4. Top five sources (journals) with the highest impact on each cluster, sorted by citation value.

Cluster	Source (Journal) Title	Nr. of Documents	Citation	TLS
Cluster 1	International Journal of Project Management	76	8412	3434
	Journal of Construction Engineering and Management	94	4669	5636
	Sustainability (Switzerland)	261	3108	2806
	Journal of Management in Engineering	71	2282	4465
	Journal of Cleaner Production	46	1935	338
Cluster 2	Construction Management and Economics	59	2857	4518
	Engineering, Construction and Architectural Management	54	1244	4870
	Built Environment Project and Asset management	63	945	4303
	Research in Transportation Economics	42	748	814
	Transport Reviews	21	720	1872
Cluster 3	Habitat International	27	1802	546
	Public Management Review	40	1728	3138
	Public Administration	30	1449	918
	International Journal of Urban and Regional Research	26	1185	440
	Public Money and Management	46	1176	1301

7. Further Discussion and Research Agenda

The expansion of urban areas, the rise of manufacturing and industrialization, and the reforms of government were among the prominent elements that shaped the ground for a novel paradigm of commercial partnerships between government and business owners, so-called PPP [1,36]. On the one hand, the public authorities had encountered societal challenges that required extra funding sources, e.g., demand for better public health, necessity of police and fire services, etc., and on the other hand, the private sector was suffering from weak infrastructure and public administration. Thus, a business partnership emerged

between the public and private sectors that was in favor of satisfying the objectives of both parties. In other words, the societal demands and commercial goals of the government and private sector were in a synergic and bilateral stream that led to the advent of a more efficient mobilization of resources in pursuit of better service delivery and infrastructure. These elements were the rudimentary drivers for establishing a partnership within the framework of PPP in the early 1800s. Although numerous studies, unions, and authorities have sought to provide an inclusive definition of PPP, they have merely presented a 'function-specific' explanation of this concept, as also emphasized by Brinkerhoff and Brinkerhoff [53]. The risk-transferring and sharing approach [54] and the long-term contract between the public and private sectors [55] are only a few instances in this context. Therefore, regardless of such functional definitions, the assessment of PPP evolution helped to recognize PPP as a business model that seeks to satisfy the mutual objectives of the public and private sectors, which are societal and commercial goals, respectively, and facilitates the atmosphere and conditions for optimal resource mobilization. This comprehension serves as an operational definition that presents PPP as a business chapeau and enables better mapping and approaching of the topics and elements that are attributed to this concept. Thus, this perception not only resonates the importance of these elements and drivers but also suggests approaching them within a commercial framework, including, but not limited to, risk sharing and private investment options [5], performance measurement, transparency concerns, and achieving higher V*f*M [56], contracting partiesand special purpose vehicles (SPVs) [57], and so forth.

The development of PPP revealed that the incorporation of private business and funding has extensively favored governments in addressing societal challenges. To reflect the major streams of focus within the research community in the realm of PPP, an extensive list of research items, including 11,700 references, was utilized in order to conduct a thorough bibliometric analysis. This assessment, first and foremost, demonstrated the advantages of PPP in response to universal crises such as the global recession, the health pandemic, and so forth. This emanates from the practice of PPP in absorbing grand business leaders and private investments, which satisfies mutual benefits through the mobilization of resources. Further examinations, and particularly evaluation of the keywords and the most contributing journals, enabled a thematic review of academic efforts pertaining to the last five decades—from 1979 to 2023—and the results are classified and concisely discussed as follows:

- Contributing nations and regions: Although PPP is not a new concept, it has not been practiced and developed evenly throughout the globe. The keyword analysis revealed that nations and regions with a more impactful and larger economy have made a higher contribution to the application and conceptual development of PPP, such as the U.S.A., U.K., China, Europe, Australia, and so forth. It is worth mentioning that this does not imply ranking the most contributing countries/regions, given the fact that this assessment was not based on enumerating the PPP projects associated with each individual geographical section. For instance, according to Pu et al. [58], the number of PPP projects in China had reached a record of 14,424 by 31 December 2017, which is not comparable to many regions and nations. As a matter of fact, the number of case studies associated with each country, along with its contribution to the conceptual development of PPP, are the primary factors for a nation/region to be highlighted in this assessment.
- Application areas and project sectors: The most eminent applications of PPP are urban development and the delivery of public infrastructure. As also discussed earlier, PPP was incited by the pale societal situation and civic needs, and thus, improvement of habitat areas and public services were the primary drivers in this regard. This objective goes hand in hand with the development of several project sectors, and the results of bibliometric analysis revealed the most important ones, including, but not limited to, transportation, water supply, waste management, healthcare, and education. In fact,

the economic capacities and versatile characteristics of PPP enable this business model to contribute to various sectors.

- Economic and organizational management: Due to the incorporation of private funding and the large scale of organizations involved in a PPP project, it is majorly advised for the accomplishment of complex projects [7]. From a commercial perspective, this implies that the economic and financial aspects of PPP must be justifiable for both parties. On the other hand, and from the operational perspective, this complexity necessitates significant attention to the organizational management of a PPP project, which in turn embraces a long array of concerns, e.g., procurement procedures, contractual arrangements, project ownership, etc. [6]. In this context, the bibliometric analysis shed light on some major aspects of academia's focus that are classified as the economic and organizational management of PPP: economic and financial assessment of PPP, risk sharing, improvement of policies surrounding the application of PPP, contracting, and so forth.
- Sustainable development: It is also vital to highlight the interplay between sustainability and other dimensions of PPP that were discussed in this regard. The results of the bibliometric analysis demonstrated that sustainability has influenced the studies associated with PPP in two major aspects, which are economic and environmental sustainability. In this regard, sustainability puts emphasis on strategic decisions and policies regarding PPP by covering a wide range of topics such as investment, budget control, climate change, and so forth. It is also worthwhile to highlight that within the framework of sustainable development goals (SDGs), UNECE has pushed the frontiers of sustainability in conjunction with PPP and articulated this concept by prioritizing sustainable economic recovery and reconstruction, sustainable PPP and infrastructure finance, and green PPP procurement, just to name a few [59].

Future Research Agenda

Although the bibliometric analysis favored highlighting the main streams of the research works, it is also helpful in revealing the aspects that have received limited attention, and this section sheds light on these themes as recommendations for future studies.

- *Value for Money (VfM):* According to the stimuli of PPP that are broadly discussed by researchers, achieving V*f*M is inevitably one of the major motivations for public authorities to select this model over the traditional project delivery alternatives, which was also emphasized within the frameworks of PFI [40,41]. However, a deeper evaluation of keywords reveals that this term has been used only 85 times, which is not comparable to the prior discussed domains. Further assessment in this regard depicts that the most considerable link between V*f*M and other keywords in the sample is limited to 'Public-Private Partnership'. Although this is an indicator of a logical conceptual link, it signifies a shortage of academic effort in this area. This implies that a substantial amount of research is demanded from researchers regarding V*f*M and other dimensions of PPP.
- *Technology and Innovation:* Technological advancements have contributed to the improvement of operations and administration in various industries and organizations throughout the last couple of decades. Although manufacturing, aerospace, and medical science, just to name a few, have extensively benefited from the advantages and opportunities delivered by the recent technological improvements [60], e.g., industrial robots, collaborative robots (Cobots), 3D printing, artificial intelligence (AI), etc., there are various digital technologies that have contributed to the construction industry [61], e.g., building information modeling (BIM), geographical information systems, virtual reality (VR), augmented reality (AR), etc. Despite significant potential lying in this area, the analysis of keywords shows that limited research has addressed this direction. 'Technology', Technological Innovation', Technological Development', 'Technology Adoption', and 'Technology Transfer' are the only keywords that exist within the sample, and their frequency of occurrence ranges from 28 to 68, except for the last one,

which is 122. In addition, they have zero connection with other keywords, and the only observable link is with 'Public-Private Partnership', which is still weak. Hence, it is of significant benefit to investigate the potential of incorporating digital technologies into PPP, which in turn could be accomplished in several directions, such as procurement management, digitalization of PPP phases, and so forth.

- *Smart Infrastructure (SI) and Smart City (SC):* Given the new era of urbanization developed under the impact of technological advancements, smart infrastructure (SI)—which is characterized as a bridge towards smart education, smart living, smart safety and security, smart economy, smart mobility, and smart communication—has been discussed as the prerequisite for developing smart cities (SCs) to address sustainability concerns [62]. This agenda requires particular expertise, financial mobilization, and concrete cooperation between governments and private sectors, which are potentially satisfied through PPP [63,64]. According to the importance of this topic towards meeting sustainable development goals (SDGs) as well as addressing urban life issues, there is limited research in this area in connection to PPP. In this regard, the assessment of keywords indicates limited research from academia, given only 65 occurrences for 'smart cities' as the only keyword appearing within the sample. Hence, it is deemed essential to put more efforts into this direction in order to explore and harness the potential of PPP with regards to developing a more sustainable society through SI and SCs.

It is noteworthy to mention that the proposed domains for future research works are not binding in terms of application given the generic scopes of this paper regarding PPP, nor are they limited to the enumerated above list according to the multidimensional structure of this business model. Moreover, and particularly given the role of technology, the provided discussion seeks to elucidate a holistic framework and trigger further elaboration on this dimension, aiming at better harnessing the potentials of digital solutions within the realm of PPP. It is also important to highlight that the outlined agenda does not neutralize the significance of current research areas, as pointed out in this study, but rather attempts to illuminate the promising directions that demand more attention from academia and are in favor of addressing several trending concerns of PPP and even society, which is one of the major beneficiaries of this approach.

8. Conclusions

The broad international application of PPP and decades of research in this regard have not only contributed to an extensive accumulation of knowledge and experience but, on the other hand, have imposed difficulties in deriving a unified comprehension of this concept. Variety in definitions provided by governments and international expert unions, different contractual arrangements, and diversity in conceptualization and classification of PPP are only a few of the additional factors that hinder conceiving a more solid perception of this model. While numerous review studies have been carried out focusing on different aspects of PPP, e.g., risk allocation, stakeholder management, contract management, project investment, etc., only a limited number of those have addressed this topic from a more holistic perspective. Hence, this study put forward to present a more transparent comprehension of PPP through the elaboration of its evolution throughout history and the analysis of the academic works surrounding this topic. To achieve that aim, we sought the answers to two research questions, which are concisely reflected below:

- Research Question 1: We conducted a narrative review to present a wide perspective of the structural development of PPP within the last couple of centuries, and particularly within the political economy environment. This assessment shaped the groundwork to recognize PPP as a business model and to illustrate a detailed timeline of PPP evolution, embracing the fundamental elements and milestones contributing to the structural development of this concept.
- Research Question 2: We employed the bibliometric analysis method and utilized the bibliometric data of studies pertaining to the last five decades, from 1979 to 2023. This

method favored in conducting profound assessments of the PPP extant literature by using three quantitative examinations, i.e., publication trend, keyword co-occurrence analysis, and bibliographic coupling, which are accompanied by the corresponding in-depth interpretations. We also proposed a research agenda, including three major directions, to provide insights on future research regarding PPP.

Reviewing the structural development of PPP throughout the last couple of centuries and particularly under the impact of the political economy environment, we elucidated four major phases for the evolution of this concept: patronage partnerships, booster partnerships, redevelopment partnerships, and growth partnerships. Studying the decisive regional and global milestones in this evolution path and identifying the financial capacities and economic impacts as the core aspects of PPP led to the recognition of this concept as a *business model* that emerged and developed in response to societal, economic, and even global urges. The publication trend—studies carried out between 1979 and 2023—primarily depicted that almost 80% of the papers were published after 2010, a trend that has been under the influence of various factors and phenomena, such as the financial advantages of PPP in response to the economic crises and the introduction of PF2 by the U.K. Further examinations of the bibliometric analysis initially demonstrated that the U.S.A., U.K., and China, just to name a few, have had the highest contribution to the conceptual development and application of PPP. Urban development and delivery of public infrastructure were identified as the most prominent applications of PPP, followed by other project sectors that have benefited from PPP, including, but not limited to, transportation, water supply, waste management, healthcare, and education. Apart from the application areas of PPP, the overall outlook of the keyword co-occurrence analysis and the bibliographic coupling illuminated two major streams within the research works: economic and organizational management and sustainable development. The former majorly emphasizes the strategic decisions and policies surrounding PPP projects and embraces a wide spectrum of concerns, which include, but are not limited to, risk allocation, economic and financial assessment of PPP, improvement of policies regarding the application of PPP, and contracting. The latter is an integration of economic and environmental sustainability. The interaction between sustainability concerns and other aspects of PPP elucidated that the research community has focused on the incorporation of sustainability into the strategic and administrative decisions pertaining to PPP. This highlights not only the significance of environmentally friendly projects but also the vital role of accomplishing a PPP project with sustainable financial decisions.

Although numerous studies have been carried out within the realm of PPP, the bibliometric analysis enabled the identification of areas that have received limited attention from academia. In this regard, this paper recommends three major directions for future research: (1) value for money (V*f*M); (2) technology and innovation; (3) smart infrastructure (SI) and smart city (SC). Despite the fact that the importance of V*f*M is well-justified as one of the major drivers and pillars of PPP, such as in PFI and PF2, the keyword analysis implicated the necessity of more research in this area. Moreover, according to the potential benefits of technology and digitalization, there is a particular essence to harnessing the advantages delivered by digital and technological solutions. In this regard, it is deemed necessary to conduct meticulous investigations on the challenges of PPP projects that can be addressed by technological and innovative solutions, which in turn lead to a more sustainable and efficient delivery of projects with PPP. Last but not least, and also following the sustainable development goals, SI and SC are two important areas that are in the early phases and demand more studies from both the organizational management of PPP and technical aspects.

This study put forward the idea of conducting a review of PPP at a high abstraction level and contributed to presenting a more transparent comprehension of this business model. Although the assessment of PPP evolution and quantitative evaluation of the extant literature surrounding this topic were fruitful in satisfying that objective, this research was under the influence of some limitations that are worth mentioning. According to the

scope of this study, assessment of the PPP's evolution was maintained at a general level and based on holistic elements. This implies that microfactors are not incorporated into this phase, and the presented timeline embraces only major milestones. The bibliometric analysis was conducted on the sole basis of the records retrieved from the Scopus online database; however, it is of significance to use other well-recognized online databases, such as WoS, and merge the results of these databases to benefit from a more extensive list of records. Moreover, limiting the list of articles with an English language filter automatically eliminates research works carried out in other languages. While this is an inevitable consideration, it implies disregarding potentially influential research that is published in other languages. Thereby, we recommend addressing the outlined limitations throughout future research in this context.

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Why Are PPP Projects Stagnating in China? An Evolutionary Analysis of China's PPP Policies

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Abstract: The Public–Private Partnership (PPP) model has significantly contributed to global infrastructure and public service provision. The evolution of the PPP model closely aligns with policy directives. China's PPP policy evolution has included five stages: budding (1986–2000), fluctuating (2001–2008), steady (2009–2012), expanding (2013–2018), and stagnating (2019–present). This study employs bibliometric analysis and co-word analysis to examine 407 policies enacted by the Chinese government from 1986 to 2018. By extracting policy text keywords at various stages and constructing a co-word network matrix, this study delineates the distinctive characteristics of Chinese PPP policies across different epochs. It can be found that critical areas such as "government credit", "contract spirit", and "power supervision" are still underappreciated. The challenges confronting China's PPP model are multifaceted, stemming from policy gaps that have led to substantial project difficulties. Although the government proposed a new mechanism for franchising in 2023, the new mechanism is only for new PPP projects, and the difficulties of existing PPP projects have not been solved. This study advocates for enhancements in project bankability, regulatory clarity, institutional environment improvement, contract spirit defense, and the development of the PPP-REITs model to address these issues.

Keywords: public–private partnership (PPP); franchise; policy; China; bibliometric analysis

1. Introduction

The Public–Private Partnership (PPP) model has played a pivotal role in the development of global infrastructure, utilities, and other sectors in recent decades. Through enduring collaborations between public institutions and the private sector [1] PPP has emerged as a crucial mechanism for delivering high-quality services and public goods while alleviating fiscal pressures [2]. Since the 1980s, the Chinese government has progressively liberalized its policies, enabling social capital to engage in various domains in partnership with the government. This period witnessed the emergence of significant projects, such as the Laibin B Power Project in Guangxi [3], the Chengdu Water Plant, and the Shenzhen Shajiao B Power Plan13t [4]. The evolution of Chinese PPP policy has traversed phases of intermittent relaxation, low density, and high density, reflecting a transition from a "passive response" to "active promotion" and, ultimately, to "comprehensive leadership". Notably, the policy document 'Decision of the Central Committee of the Communist Party of China on Several Important Issues Concerning Comprehensively Deepening' [5] advocated for the participation of social capital in urban infrastructure investment and operations through franchising, among other methods. Furthermore, the 'Notice of the Ministry of Finance on Promoting the Use of the Cooperative Model of Government and Social Capital (No. 76 [6])' explicitly encouraged the adoption of the government and social capital cooperation model in infrastructure and public services, marking a continuous deepening of the

PPP system and policy reform by the Chinese government. The PPP industry ushered in a peak period from 2015 to 2017. Then, in 2019, the Ministry of Finance required that regions where PPP investment accounts for more than 5% of fiscal expenditure in the current year do not have new PPP projects. In 2022, the National Audit Office conducted a special audit of 18 provinces. In 2023, the PPP sector encountered a cessation phase, leading to the suspension of the PPP Center project library, for instance, by the Ministry of Finance.

Within less than ten years, China's PPP projects witnessed a trajectory from rapid growth to decline. This shift has prompted widespread inquiry and introspection regarding the stagnation of PPP projects in China.

However, most studies into China's PPP policy employ qualitative or theoretical model analysis [7]. Existing studies often summarize development laws from a qualitative standpoint or conduct phased policy analyses from a quantitative perspective, which does not fully address the policy texts' development direction and political intentions [8]. This paper seeks to bridge this gap by integrating qualitative and quantitative methods, identifying policy development focuses or keywords and employing co-word analysis to examine the co-occurrence of keywords at different stages.

To this end, this study has compiled a Chinese PPP policy database from 1986 to 2019, employing systematic retrieval and meticulous screening based on the quantitative research paradigm of the policy literature [9]. Utilizing statistical analysis, cluster analysis, and co-word network analysis, this paper explores the mining of China's PPP policies from the perspective of policy changes over time. It delineates the changing patterns of policy content, governance methods, and policy emphasis across different policy periods and highlights the policy's characteristics and trends.

2. Prior Research into PPP Project Policy

The core of Public–Private Partnerships (PPP) is a distinct procurement activity undertaken by the government [10]. The execution of PPP projects encompasses a more extensive contractual relationship between the public and private sectors and is different from traditional procurement (design and construction) and other procurement methods [11,12]. Typically, the PPP lifecycle encompasses three principal phases: the development stage, the implementation stage, and the operation stage [13].

Currently, research into Public–Private Partnerships (PPP) primarily concentrates on risk management, critical success factors, financing, investment climate, procurement processes, economic viability, concession durations, etc. [1], alongside the contribution of PPPs to sustainable development [14,15]. Nonetheless, the evolution of PPPs is intricately linked to national policies and frameworks. While each region possesses unique conditions, cross-regional policy comparisons are instrumental for fostering the standardized progression of PPPs. Qi et al. [16] analyzed the discrepancies within the PPP decision-making processes between China and Singapore, aiming to enhance the legal framework, policy and regulatory system, and institutional arrangements. Verhoest et al. [17] assessed the policy's support across 20 European countries from a systemic perspective, creating the PPP government support index. Willems and Van Dooren [18] evaluated the PPP policies of the UK and Flanders, not by conducting a detailed policy comparison but by identifying notable trends in PPP policies through the examination of key documents and media coverage. Gurgun and Touran [19] conducted a comparative analysis of PPP development status in Europe, the United Kingdom, the United States, China, and Turkey through policy descriptions.

Previous studies have predominantly concentrated on facets of PPP policies, such as risk allocation and diffusion [20,21], post-implementation assessment [22], financing challenges [23,24], and preliminary evaluation and value verification [25,26], among others. Notably, countries that have extensively investigated and identified the success factors of policy implementation have significantly benefited from this procurement approach. In contrast, those with limited insights have not fully capitalized on implementing the PPP policy [27]. For instance, through its Ministry of Private Sector Development and the Presi-

dential Special Initiative, the Government of Ghana formally embraced the PPP concept as a national policy and introduced policy guidelines until 2004 [28]. Wang et al. [29] emphasized the importance of a robust system for PPP success, advocating that China foster an institutional environment conducive to PPP. Zhang et al. [30] argued that the essence of PPP governance resides at the institutional and organizational levels, ensuring proper "order and rules". Zhang [30] elucidated key success factors for PPP projects and offered policy recommendations, including legal frameworks, financial subsidies, and government compensation policies. In their study of PPP model policy support, Verhoest et al. [15] conducted an empirical analysis and developed the PPP government support index, highlighting government support as a critical component of a country's PPP endeavors. Ke et al. [31] demonstrated through case studies that social capital regards "tax incentives" as an efficacious means of financing PPP projects. Shi and He et al. [32] explored the influence of performance guarantee policies and government subsidies in preventing the inefficient dissolution of PPP infrastructure projects when external benefits are significant and assured. Despite these insights offering valuable recommendations for PPP policies, a comprehensive understanding of PPP policies remains elusive [33]. To effectively leverage legal policies for guiding PPP development, it is imperative to review and comprehend the trajectory and directives of previously issued policies within a temporal context and to forecast and advise on future PPP development. Zhang et al. [13] devised a theoretical framework for PPP evolution, suggesting that the PPP system has undergone excessive developmental phases, evolving and maturing with systemic changes. Chen et al. [33] performed a bibliometric analysis of 299 policy documents issued by the Chinese central government from 1980 to 2017, categorizing the evolution of PPP policies into three historical stages and demonstrating the ongoing enhancement of the sustainability of PPP's role in China's development.

While much of the existing literature has focused on identifying the deficiencies of the current PPP legal framework, with some scholars highlighting key shortcomings from a sustainability viewpoint [34], none have satisfactorily explained the current predicaments faced by China's PPP projects, indicating a gap in systematic institutional analysis, particularly from a dynamic evolutionary perspective [13].

Building on previous studies, this paper refines the developmental stages of PPP and enhances the methodology for policy text screening. Subsequently, a database of PPP policy texts was created, with policy themes extracted at each stage. This paper concludes by analyzing the trajectory and prospective direction of PPP development.

3. Research Methods

The bibliometric method is a research approach that involves collecting, identifying, and organizing the relevant literature on a specific research topic. It then systematically, objectively, and quantitatively analyzes the content of this literature to extract information, culminating in a scientific comprehension of the facts [35–37]. The co-word analysis method is particularly adept at examining research subjects characterized by voluminous texts and complex, elusive patterns, such as policies, government reports, and other documents necessitating thorough interpretation [38,39].

Leveraging the established PPP policy database, this study employed a dual approach combining bibliometric methods with policy content analysis techniques. This integrated method facilitated both quantitative and qualitative examinations of the evolution of PPP policy analysis in China (Figure 1).

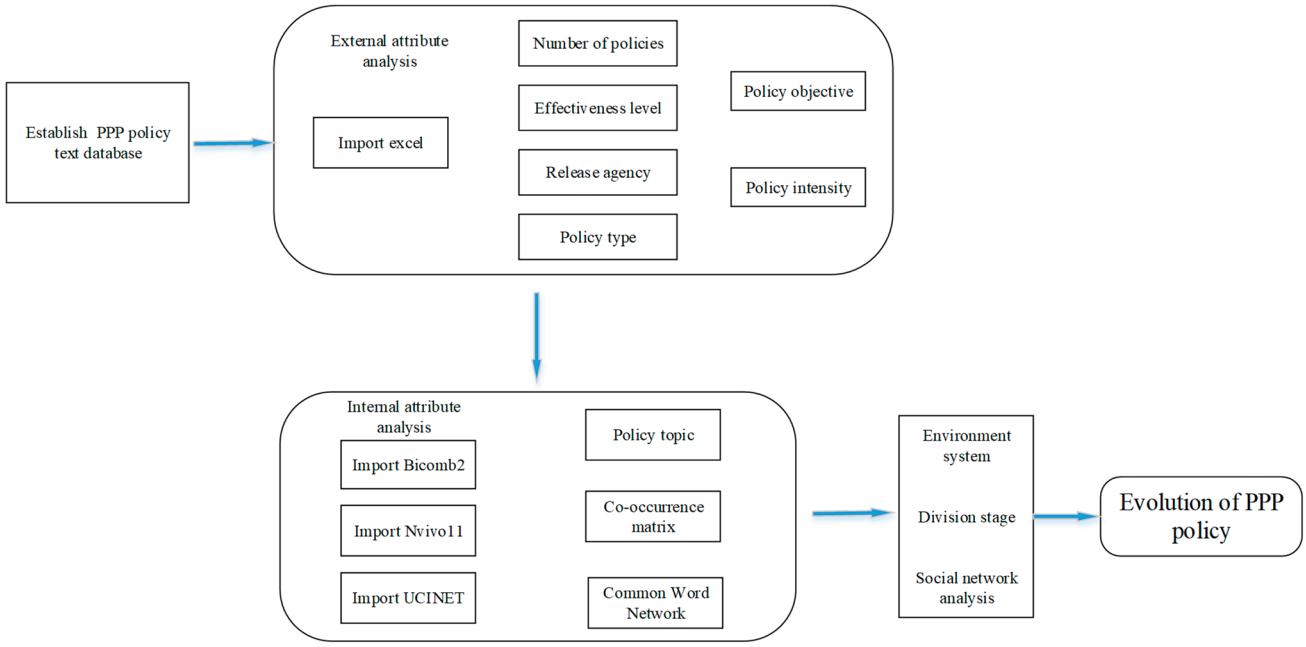

Figure 1. Research framework.

3.1. Data Acquisition

A comprehensive search was performed for policy texts issued by government departments regarding social capital access in infrastructure and public sector investment construction, with 1986 to May 2019 used as the focal point of the search. The search was conducted by utilizing the government's official website, and "PKULAW" was the primary policy retrieval database (http://www.pkulaw.cn/ accessed on 7 April 2024), as it is a renowned repository of laws and regulations frequently used by researchers to gather Chinese policy information [40]. Keywords such as "cooperation between government and social capital", "PPP", "build-operate-transfer (BOT)", "private capital", "social capital", "foreign capital", "private investment", and "franchise" were employed to search and export data. Consequently, 4454 central judicial interpretations were identified, encompassing 83 laws, 691 administrative regulations, and 3196 departmental regulations. To ensure the accuracy and representativeness of the data, a pre-analysis screening was conducted based on specific criteria:

1. Documents with binding authority, including administrative regulations, regulatory documents, departmental regulations, working documents, and others issued by the central government, the State Council, the Ministry of Finance, the Ministry of Housing and Urban–Rural Development, and other relevant ministries and commissions, were present;
2. Policy documents pertinent to the establishment of the PPP model, featuring terms such as "franchise", "marketization", "foreign capital", "private capital", "BOT", "TOT", and similar were present;
3. The policies significantly influence the development of the PPP model.

After removing duplicates and irrelevant entries according to these criteria, this study ultimately identified 407 national-level policies related to the PPP theme. The publication date, title, number, issuing organization, level of effectiveness, and content link of each policy text were meticulously recorded to construct the PPP policy evolution database (as detailed in Table 1).

Table 1. List of PPP-related policies.

Numbering	Posting Time	Policy File Name	Document Number	Organization	Effective Level
1	11 October 1986	State Council's regulations on encouraging foreign investment	State Council Issue (1986) No. 95	State Council	Administrative regulations
2	15 December 1987	Circular of the General Office of the State Council on Forwarding the Interim Provisions of the State Planning Commission on Guiding the Direction of Absorbing Foreign Investment	Office of the State Council Issue (1987) No. 76	Office of the State Council	State Council regulatory documents
3	16 July 1988	Notice of the State Council on Printing and Distributing the Recent Reform Plan of the Investment Management System	State Council Issue (1988) No. 45	State Council	State Council regulatory documents
...	...	...	...		
278	28 May 2017	Notice of the Ministry of Finance on Resolutely Stopping Locally the Infringement of Financing in the Name of Government Purchase Service	Ministry of Finance Budget Division (2017) No. 87	Ministry of Finance	Departmental regulatory documents
...	...	...	...		
406	7 March 2019	Implementation Opinions of the Ministry of Finance on Promoting the Development of Government and Social Capital Cooperation	Finance (2019) No. 10	Ministry of Finance	Departmental regulatory documents
407	26 March 2019	Notice of the General Office of the Ministry of Culture and Tourism on the Collection of 2019 "Belt and Road" Cultural Industry and Tourism Industry International Cooperation Key Projects	Office of the Ministry of Culture and Tourism Issue (2019) No. 50	Ministry of Culture and Tourism	Departmental working paper

3.2. Calculating Policy Intensity

To observe the evolution path of China's PPP policy more intuitively, the relevant policy documents issued by China from 1980 to 2019 were used according to time (as shown in Table 2).

Table 2. Quantitative Scoring Indicators Table.

Index	Score	Judging Criteria
Policy level	5	Legal documents such as laws, decisions, resolutions, reports, etc., promulgated by the National People's Congress and its Standing Committee [Law]
	4	Administrative regulations such as regulations, regulations, decisions, and measures promulgated by the State Council [Administrative regulations]
	3	Provisional Regulations, Interim Provisions, Interim Measures, Notices, and Opinions Promulgated by the State Council, State Council Regulatory Documents, etc. [Administrative Regulations] The Ministry of Finance, the Ministry of Housing and Urban–Rural Development, the Ministry of Transport, the National Development and Reform Commission, and other ministries [Department Regulations]
	2	Regulations, methods, opinions, implementation rules, etc., of ministries and commissions such as the Ministry of Finance, the Ministry of Housing and Urban–Rural Development, the Ministry of Transport, and the National Development and Reform Commission [Regular Regulatory Documents]
	1	Interim regulations, interim measures, notices, and notices of various ministries;
Policy goal	5	"Highly valued", "must", "forbidden", "resolutely stop", "strictly control", "legislation", "all-round opening", "as soon as possible", "maximum", "strongly promoted", and the other strongest and most detailed descriptions
	4	"Further encouragement" "emphasis/priority" "increase... support" "widely attract", "deep promotion", "accelerate promotion", "strongly promote", "sloping support", "should", "perfect", "not allowed", etc., [Detailed Description]
	3	"Actively guide", "cultivate and develop", "pilot", "fully mobilize", "expanding... scope", "actively introducing", "normative", "creating conditions", and other strong tone descriptions
	2	General description of conditions such as "encourage", "absorption", "attraction", "Introduction", "discussion", and "support"
	1	General descriptions such as "allow", "may" and "relax";

Table 2. *Cont.*

Index	Score	Judging Criteria
Policy measures	5	Give detailed implementation standards and control indicators for PPP-related aspects and give specific explanations or demonstrations
	4	Give specific implementation content and control standards for PPP-related aspects;
	3	List more specific measures for PPP-related aspects and classify the implementation content based on multiple aspects
	2	From a macro perspective, the introduction of foreign capital and social funds in a certain field, market-oriented operations, and other relevant content or related aspects to outline brief measures
	1	Only from a macro perspective, the introduction of foreign capital and social funds in a certain field; for market-oriented operations and other related content, there is no specific operational plan

The frequency of policy promulgation can reflect the government's policy orientation and attention to a certain field to a certain extent, but due to the different attributes of various policy documents, the number of documents alone cannot fully reflect the government's support in this field. Policy intensity can be determined by corresponding quantitative standards and quantitative statistics based on required indicators to obtain a more objective and accurate expression of policy support.

The calculation method of the policy intensity was divided into three steps. Firstly, quantitative indicators were established from three dimensions: policy level, policy measures, and policy objectives. Then, the policy documents were scored according to the established quantitative scoring criteria. Finally, the policy intensity quantitative value of the newly issued policy for that year was summarized via policy intensity calculation (1) [41].

$$PMG_i = \sum_{j=1}^{n} (m_j + g_j) p_j \quad (1)$$

where "i" is the year of publication of the scoring policy, "n" is the number of items of the policy issued in year "i", "j" is the j_{th} policy issued in year "i", $(m_j + g_j)$ is the score of each policy objective "g" (goal) and policy measure "m" of the j_{th} policy, "p_j" is the power score of the j_{th} policy, and PMG_i is the overall status of the level, objectives, and measures of the PPP-related policy content issued in the year "i".

Considering the continuity of the policy, the newly issued policy reflects the change in the government's support towards a certain area, which is the main part of policy attention. Therefore, the policy intensity of the current year can be characterized by the cumulative value of the quantified policy intensity from the initial year to the current year, and the value of the policy intensity of the current year can be obtained by using the cumulative Formula (2).

$$NPMG_i = \sum_{k=c}^{i} PMG_k \quad (2)$$

where "k" is the year and "c" is the initial year of the policy under study. Based on the PPP's burgeoning policy in China in 1986, in this study, "c" = 1986, $NPMG_i$ represents the quantified value of policy intensity in the i_{th} year. Due to the timeliness of the policy, the intensity of the policy in the year "k" needs to be deducted from the cumulative amount of the initial year of the policy to quantify the strength of the policy documents that have expired to ensure the accuracy of the data and the rigor of the research.

3.3. Coding Analysis Based on Nvivo

Nvivo11 represents the forefront of computer-assisted qualitative data analysis software, being the first of its kind in the world [42]. This software is a crucial tool for qualitative researchers to efficiently manage substantial volumes of qualitative data. Advances in computer technology have now enabled the integration of qualitative and quantitative data into a unified dataset [43]. Through ongoing development and updates, Nvivo11 has achieved capabilities for coding, indexing, and theorizing non-quantitative and unstructured materials.

Coding is a fundamental step in analyzing qualitative research data, helping us to organize and impart meaning to text. It facilitates material organization by segmenting observed or collected data into memos by sentence and line. Consequently, a coding system is devised to structure the data, unveil patterns and themes, and identify the topics or types of words or phrases encompassed by the data. Coding serves as a unit of meaning that labels or tags the descriptive or inferential data collected during the research process. It serves as a mechanism for data reduction and expansion, generating new inquiries, and interpreting concepts [44]. In essence, coding is the transformation of data into concepts, where researchers dissect collected data, assign new concepts, reorganize data into various units of analysis, categorize them into distinct types, and investigate operations particularly pertinent to the research topic.

In this study, the coding and cluster analysis functionalities of Nvivo11 were employed to conduct a cluster analysis of policy topics, thereby extracting the focal points of policy attention. By utilizing BICOMB version 2.0 bibliographic analysis software, keywords from policy texts were statistically extracted. The resulting similarity matrix of common words for each stage was processed using UCINET version 6.766 and its accompanying visualization software NETDRAW version 2.158, which led to the generation of co-word networks for PPP policy text keywords at different stages.

3.4. Co-Word Analysis

Social network analysis employs network structure diagrams to depict the social relationship structures and attribute relationships between individuals, groups, or social units. It serves as a specialized instrument of Social Network Theory for examining relationships, information, or knowledge primarily shared between entities such as people, groups, and organizations, and evaluating their significance [45]. In this study, UCINET social network analysis software, along with its integrated visualization module NETDRAW, was utilized to analyze and create a knowledge map of research related to policy texts. In the generated graph, the nodes represent keywords, with larger nodes indicating a greater focus on the research content denoted by those keywords. The degree of centrality measured the number of direct connections to a node. A higher value signified a node's greater importance within the network graph. Consequently, the co-word matrix of PPP policy text keywords corresponding to the four stages was derived. These keywords were considered significant, with values greater than or equal to 1.

4. Result Analysis

4.1. Policy Intensity Distribution Analysis

Using the index system and policy intensity quantification method established above, the quantitative distribution of Chinese PPP policy from 1986 to 2018 was summarized to obtain the annual distribution figure of policy intensity (Figures 2 and 3).

Source: The PPP policy quantity data were compiled by the authors from PKULAW; the project quantity data came from the World Bank PPIAF database, and for 2014, 2015, 2016, 2017, and 2018, the annual project quantity was obtained according to the China PPP quarterly report.

From the time axis, the enactment of China's PPP-related policies has transitioned through various phases, from periods of low-frequency discontinuity, through phases of fluctuating growth, to stages of continuous high-density issuance.

The general trend in policy distribution is upward, signifying that the Chinese government's policy guidance on PPPs has progressively intensified. However, policy distribution does not exhibit stable linear growth; it is marked by certain fluctuations and is characterized by distinct phases. From 1986 to 2000, policy issuance was sporadic and infrequent, with these periods scoring low in terms of policy objectives and measures, reflecting weak policy intensity and slow growth. Continuous policy releases occurred from 2001 to 2008, with a notable peak in 2006. Despite this, the quantitative assessment of policy intensity reveals that policy measures remain relatively low. From 2009 to 2012, policies were pub-

lished continuously, with an increasing frequency of issuance. The quantitative analysis of policy intensity indicates that the scores for policy measures and objectives improved somewhat, leading to a steady increase in policy intensity. Between 2013 and 2018, policy publications maintained a high density, reaching a peak in 2016. The quantitative results for policy intensity show that the overall scores for policy objectives and measures have achieved a high level, indicating a significant leap in policy intensity.

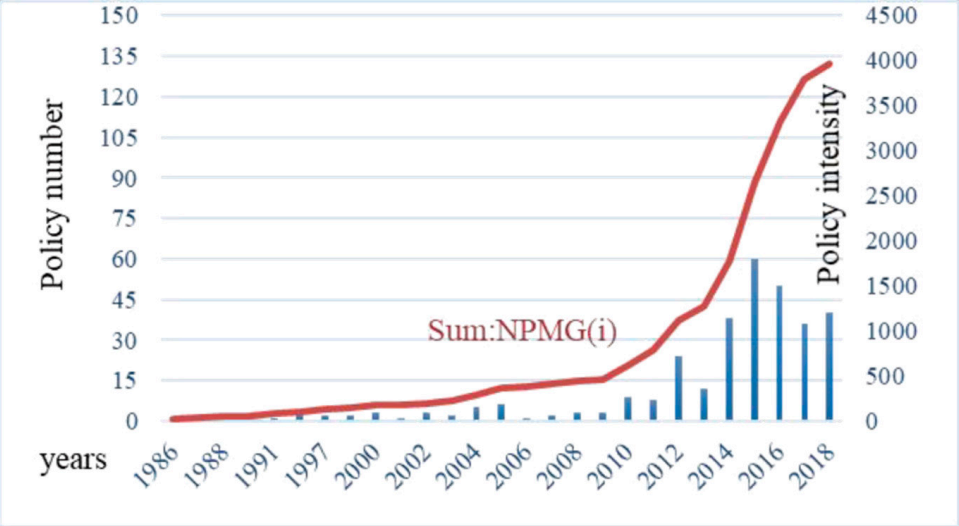

Figure 2. Distribution of the number and intensity of Chinese PPP policies from 1986 to 2018.

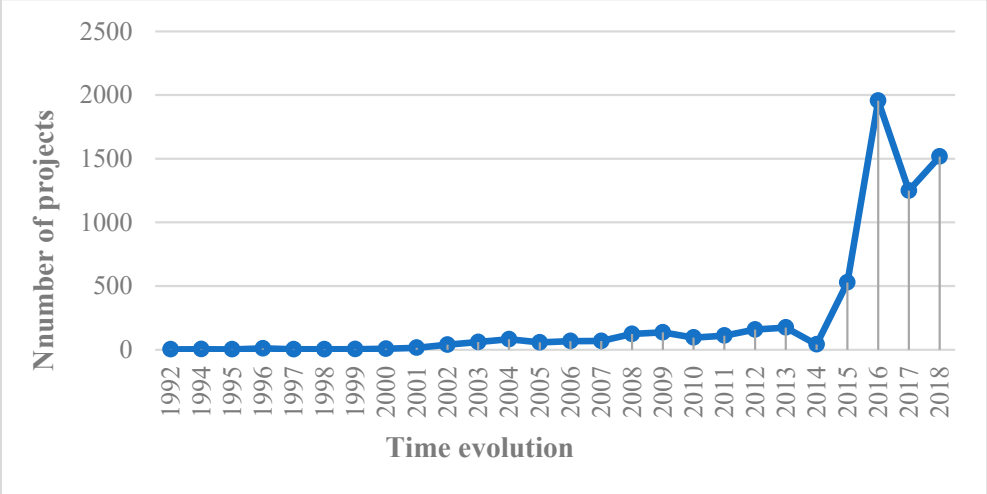

Figure 3. Quantitative distribution of Chinese PPP projects from 1986 to 2019.

The above analysis shows that the periodic features characterizing the Chinese government's policy support for the PPP model are characterized by periodic features. For further analysis of policy shifts, this article categorizes the evolution of policy into four stages: the budding period (1986–2000), the fluctuation period (2001–2008), the steady development period (2009–2012), and the expansion period (2013–2018).

4.2. Policy Topic Analysis

This article employed Nvivo11 coding to identify several policy subject terms for each stage, subsequently performing statistical analysis and clustering. Analogous to the academic literature, the subject terms of policy documents serve as the core vocabulary that encapsulates the content and dictates the literature types. The objective is to streamline the classification, storage, and retrieval of the policy literature. Typically, the number of

subject terms in a document ranges from 4 to 6, which should encapsulate not only words that convey policy direction, such as "support" and "tax", but also terms that articulate the core content of the policy text, like "facilities" and "investment".

4.2.1. Budding Period (1986–2000)

During this period, 15 key policies were extracted and analyzed using Nvivo11 to code and statistically identify policy subject terms. Eighteen keywords were extracted (as detailed in Table 3), representing the policy focus on investment subjects, industry access, and investment methods.

Table 3. PPP policy keywords during 1986–2000.

Subject	Frequency	Subject	Frequency	Subject	Frequency
Foreign investment	13	Infrastructure	2	Introduction of technology	1
Traffic	8	BOT	2	Fixed asset	1
Energy	7	Franchise	2	Land policy	2
Tax exemption	4	City municipal	2	Post telecommunications	1
Marketization	2	Social funds	2	Overseas financing	1
Bidding system	2	Water affairs	2	Garbage disposal	2

Using BICOMB 2.0, the high-frequency words in the literature were compiled into a common word matrix (18 × 18) (partial matrix, as shown in Table 4).

Table 4. High-frequency keyword co-occurrence matrix (partial).

	Foreign Investment	Traffic	Energy	Tax Exemption	Bidding	Marketization	Infrastructure	BOT	Franchise
Foreign investment	1	0.615	0.538	0.308	0.077	0	0.154	0.154	0.154
Traffic	0.615	1	0.462	0.154	0	0	0.077	0.077	0.154
Energy	0.538	0.462	1	0.154	0	0	0	0.077	0.077
Tax exemption	0.308	0.154	0.154	1	0	0	0	0	0
Bidding	0.077	0	0	0	1	0.077	0	0	0
Marketization	0	0	0	0	0.077	1	0	0	0
Infrastructure	0.154	0.077	0	0	0	0	1	0.077	0
BOT	0.154	0.077	0.077	0	0	0	0.077	1	0.077
Franchise	0.154	0.154	0.077	0	0	0	0	0.077	1

The keyword co-occurrence matrix can be used to mine the implicit association information between high-frequency keywords, as shown in Table 4. In the co-occurrence matrix, the closer the value is to 1, the more similar the two keywords are; on the contrary, the similarity is lower. As can be seen from Table 4, bidding (0.769), traffic (0.615), energy (0.0.538), and other topics are the focus of attention, while franchise (0.154) receives relatively little attention.

It is evident from the analysis that the keywords used during this period were predominantly concentrated in infrastructure sectors such as foreign investment and transportation (Figure 4). Following China's reform and opening-up policy initiation in 1978, a significant influx of advanced technology and foreign capital investment from developed countries occurred. To encourage and attract foreign investment during this process, the BOT (Build–Operate–Transfer) model became increasingly prominent. Frequently adopted by developing countries for infrastructure development, the BOT model has achieved notable success. It balances maintaining market mechanism operations and providing an effective avenue for government intervention. Thus, the embryonic form of government–social capital cooperation emerged, undergoing continuous exploration in policies and practices. The policy texts issued during this stage primarily aimed to encourage and permit social capital's participation in some public projects, with a significant focus on attracting foreign

capital for domestic projects. At that time, the potency of private capital was limited, and due to the pressing need for marketization, foreign capital, with its mature market and risk assessments and ability to introduce advanced technology, was particularly encouraged.

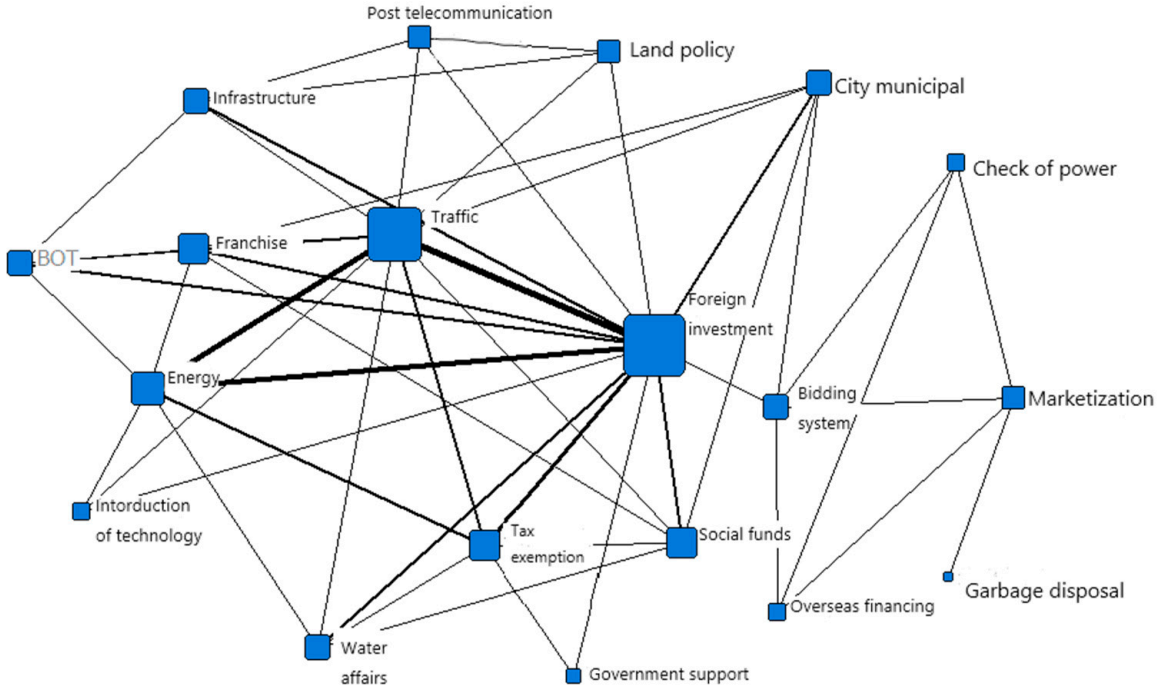

Figure 4. Social network diagram of subject terms from 1986 to 2000.

However, this period lacked effective policy guidance for attracting social capital investment and implementing public projects. In BOT projects, issues such as the government's unprincipled guarantees or commitments gradually arose. Generally, the project applications at this stage were mainly in transportation, infrastructure, and water services, with the primary policy orientation being towards encouraging foreign investment.

4.2.2. Fluctuation Period (2001–2008)

A high-frequency keyword was obtained from the policy texts at this stage using Nvivo 11 software; then, the high-frequency words in the literature were compiled into a common word matrix by using BICOMB 2.0 (partial matrix as illustrated in Table 5).

Table 5. High-frequency keyword co-occurrence matrix (partial).

	Legal Policy	Investment and Financing	Traffic	Sewage Treatment	Supervision Mechanism	Franchise	Private Capital	Garbage Disposal
Legal Policy	1	0.222	0.222	0.222	0.556	0.222	0.111	0.111
Investment and Financing	0.222	1	0.333	0.111	0.333	0.111	0.222	0.111
Traffic	0.222	0.333	1	0.333	0.111	0.333	0.111	0.333
Sewage Treatment	0.222	0.111	0.333	1	0.222	0.444	0.333	0.444
Supervision Mechanism	0.556	0.333	0.111	0.222	1	0.222	0.222	0
Franchise	0.222	0.111	0.333	0.444	0.222	1	0.222	0.444
Private Capital	0.111	0.222	0.111	0.333	0.222	0.222	1	0.222
Garbage Disposal	0.111	0.111	0.333	0.444	0	0.444	0.222	1

From this analysis, it is evident that keywords such as "private capital", "investment and financing", "legal policy", "supervision mechanism", and "franchise" hold significant importance. In the 21st century, the rapid development of urbanization in China has led to a conflict between the limited funding available through government finances and the pressing need for urban infrastructure construction. To address this, the central government has enacted a series of laws and policies to actively promote the development of the PPP model, as manifested in two primary aspects: the vigorous promotion of marketization within urban infrastructure utilities and the encouragement of private investment. Investment and financing channels have been progressively expanded, the approval procedures for private capital investment have been simplified, and more industries and sectors have been opened to private capital. Concurrently, China has begun to enhance policy support to foster the growth of the non-public-ownership economy, despite traditionally restricting entry to non-public ownership. Policies regarding franchises in the infrastructure and utilities sectors have seen rapid development. In response to demand, the Chinese government has recognized the benefits of the PPP model and further integrated social capital to address developmental challenges.

Contrary to the earlier period's encouraging and supportive investment policies, the policy goals of this phase have shifted towards the application in specific urban facilities, such as sewage treatment, waste management, rail transit, and water supply (as shown in Figure 5). Moreover, due to the absence of policy constraints and guidance at the end of the last century, local PPP development revealed numerous issues. During this phase, the central government emphasized market access and project operation via the supervision mechanism. Overall, the proportion of foreign companies declined during this period, with domestic private and state-owned enterprises becoming more predominant. The extensive selection of investors through public bidding has effectively reduced costs and established a relatively mature PPP project implementation process.

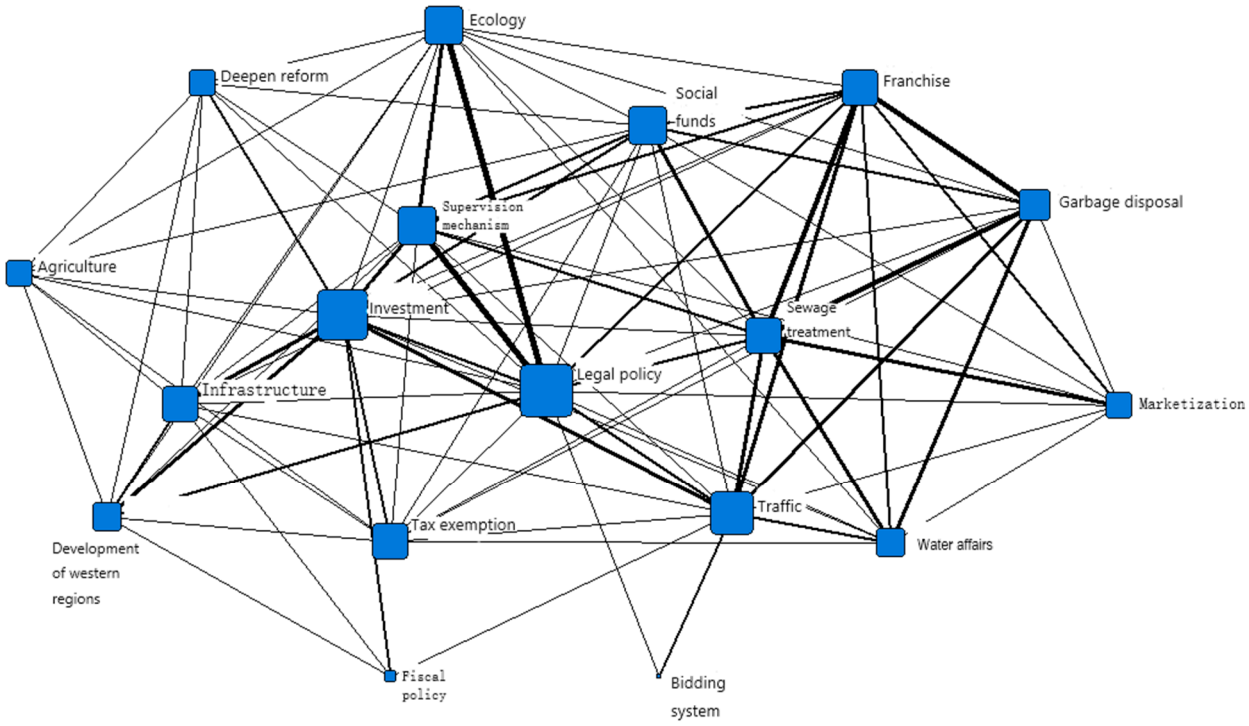

Figure 5. Policy topic gatherings from 2001 to 2008.

4.2.3. Steady Period (2009–2012)

The high-frequency keyword co-occurrence matrix can be obtained by extracting keywords from the policy text extracted at this stage using Nvivo11 software (as shown in Table 6).

Table 6. High frequency keyword co-occurrence matrix (partial).

	Private Capital	Governmental Support	Financial	Technological Innovation	People's Livelihoods	Investment and Financing	Medical	Energy Conservation
Private Capital	1	0.45	0.15	0.05	0.15	0.10	0.15	0.10
Governmental Support	0.45	1	0.35	0.25	0.25	0.25	0.20	0.05
Financial	0.15	0.35	1	0.30	0.30	0.25	0.15	0.15
Technological Innovation	0.05	0.25	0.30	1	0.20	0	0.10	0.10
People's Livelihoods	0.15	0.25	0.30	0.20	1	0.05	0.10	0.05
Investment and Financing	0.10	0.25	0.25	0	0.05	1	0	0
Medical	0.15	0.20	0.15	0.10	0.10	0	0.05	0.05
Energy Conservation	0.10	0.05	0.15	0.10	0.05	0	0.05	1

As illustrated in Figure 6, keywords such as "private capital", "energy saving and emission reduction", "people's livelihood", "energy", "technological innovation", "finance", and "fiscal policy" hold significant prominence. Following the 2008 Asian financial crisis, the development of PPPs experienced a downturn. In response, the central government enacted a series of proactive fiscal policies to stimulate economic recovery, which led to the exacerbation of local government debt issues. This positive policy environment prompted many local governments to pursue project construction through establishing local investment and financing platforms to fulfill their performance objectives. Addressing local government debt and standardizing the management of financing platforms, thus, emerged as pressing concerns. The central and local governments initiated specific policy research efforts, such as encouraging private capital to invest in basic public welfare projects and regulating local government financing platforms. Despite volatile development phases, these conditions provided opportunities for the advancement of PPPs. PPPs began to be applied across various sectors, with preliminary efforts in specific areas.

At this stage, public projects involving social capital started to exhibit diverse characteristics, and issues such as healthcare, pensions, affordable housing, and people's livelihoods were placed on the policy agenda, creating new pathways for the integration of social capital. The collaboration between government and state-owned enterprises emerged as a defining feature of PPPs with distinct Chinese characteristics during this period. With the surge in capital requirements and the maturation of the financial market, a variety of new financing channels for PPP projects, including public offerings, corporate bonds, and trusts, gradually began to emerge.

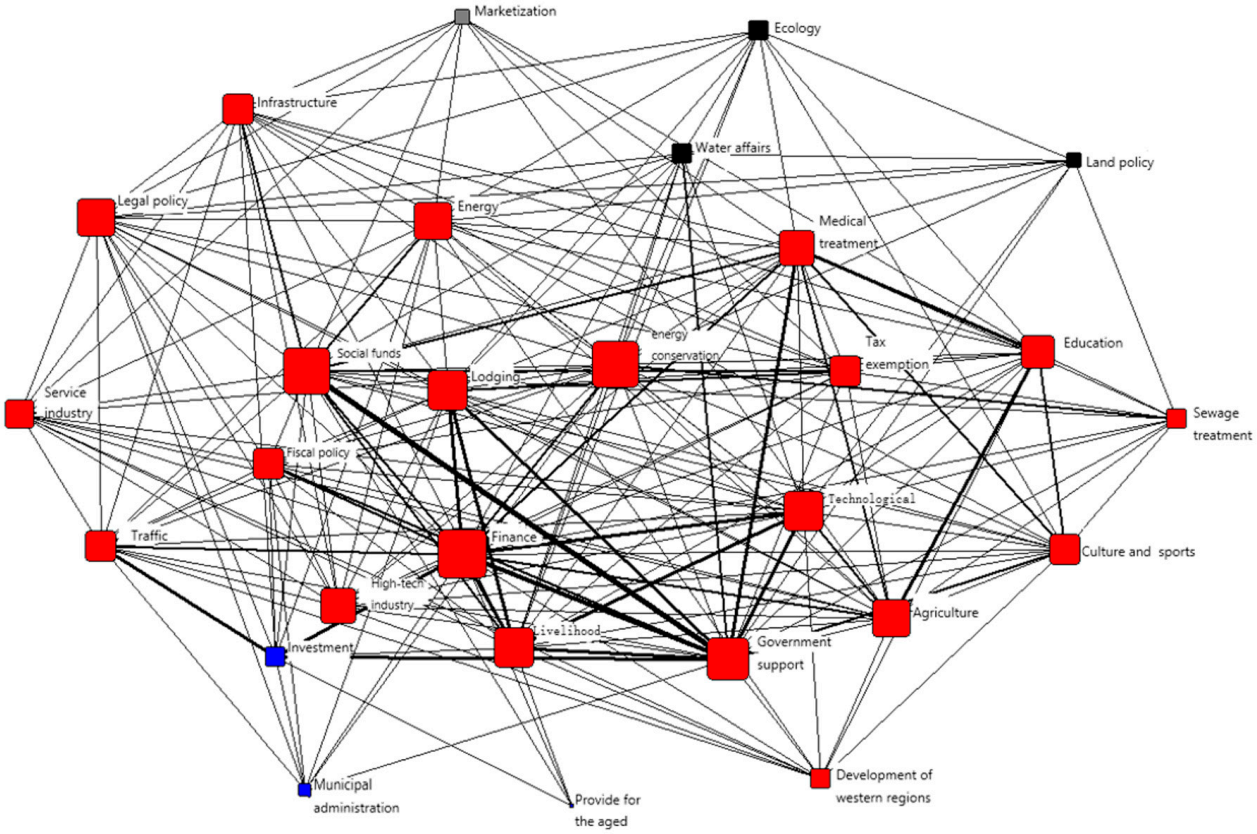

Figure 6. Policy topic gatherings from 2009 to 2012.

4.2.4. Expansion Period (2013–2018)

The high-frequency keyword co-occurrence matrix can be obtained by extracting keywords from the policy text extracted at this stage using Nvivo11 software (as shown in Table 7).

Table 7. High-frequency keyword co-occurrence matrix (partial).

	PPP	Investment and Financing	Infrastructure	Fiscal Policy	Private Capital	Governmental Support	Traffic	Agriculture	Financial
PPP	1	0.298	0.170	0.191	0.149	0.117	0.106	0.074	0.128
Investment and Financing	0.298	1	0.170	0.057	0.160	0.138	0.053	0.043	0.074
Infrastructure	0.170	0.170	1	0.043	0.096	0.096	0.064	0.064	0.032
Fiscal Policy	0.191	0.057	0.043	1	0.064	0.011	0.053	0.064	0.096
Private Capital	0.149	0.160	0.096	0.064	1	0.128	0.064	0.021	0.032
Governmental Support	0.117	0.138	0.096	0.011	0.128	1	0.021	0.011	0.032
Traffic	0.106	0.053	0.064	0.053	0.064	0.021	1	0.085	0.021
Agriculture	0.074	0.043	0.064	0.064	0.021	0.011	0.085	0.011	0.043
Financial	0.128	0.074	0.032	0.096	0.032	0.032	0.021	0.043	1

The analysis reveals that "PPP" has emerged as the most significant keyword node within the network diagram (Figure 7). Beyond infrastructure, the co-occurrence of keywords such as "ecology", "urbanization", "government support", "deepening reforms", "private capital", and "scientific and technological innovations" is notably pronounced. Additional keywords, including "energy saving and emission reduction", "energy", "healthcare", and "tax reduction and exemption", as well as their co-occurrence relationships with

"agriculture", "rural areas", and "ecology", are also strengthening. Sectors like "tourism", "development of the West", "high-tech industries", and "environmental governance" continue to expand investment channels for social capital. Through franchising, the central government has facilitated social capital's participation in urban infrastructure investment and operations and encouraged investments in rural areas, public cultural service systems, and ecological environmental protection. Consequently, the application of the PPP model has flourished extensively.

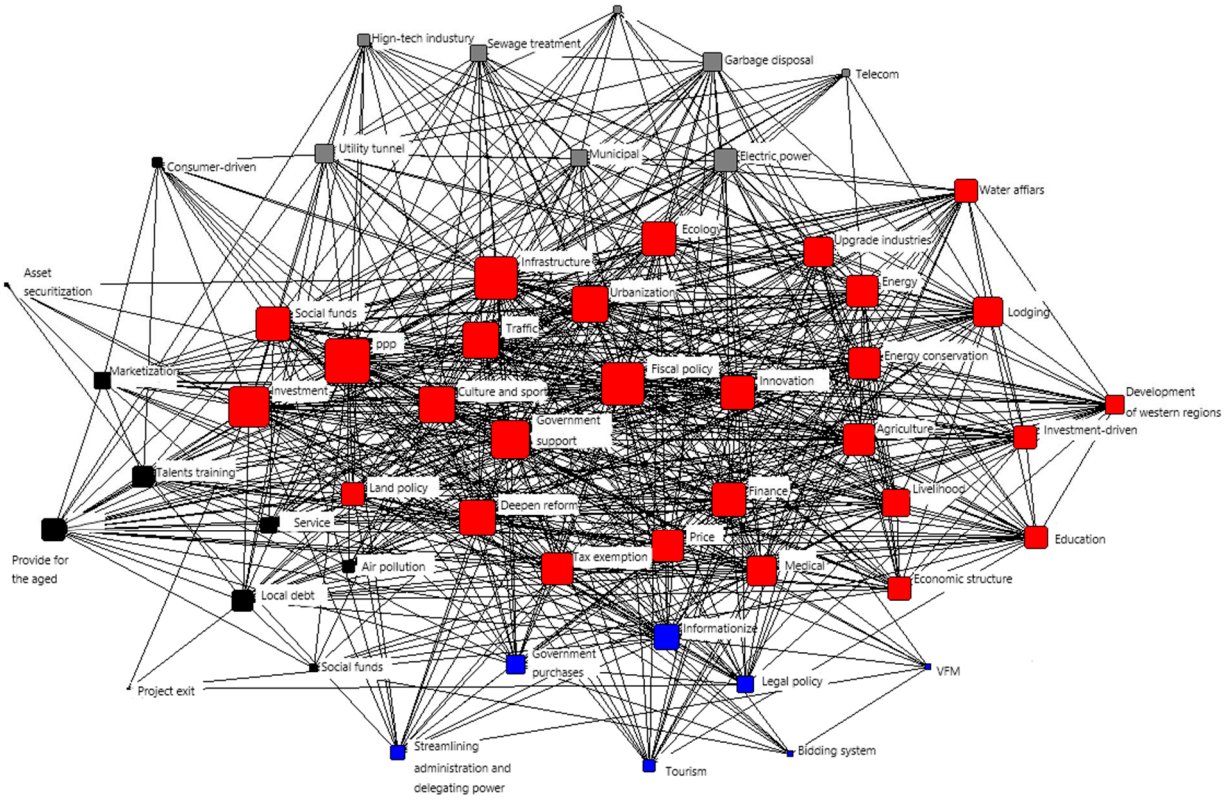

Figure 7. Policy topic gatherings from 2013 to 2018.

The years 2014 and 2015 marked the most intensive period in the history of PPP policy development. The evolution of the central government's approach towards PPP policies and strategies transitioned from initially encouraging broad policies to departments adopting specific policy tools for distinct industries, culminating in a clear stance that PPPs would serve as a platform to address local government debt issues and a critical means for managing local government financing.

During this time, the central government delineated the direction for local government investment and financing, advocating for reforming investment and financing mechanisms through the PPP model to establish a competitive foundation for social capital. The government assured investors long-term and stable returns through pre-agreed revenue rules, franchise rights, reasonable pricing, and financial subsidies. However, 2017 marked the beginning of a rationalization and deepening phase for PPP projects. The General Office of the Ministry of Finance systematically reviewed inbound PPP projects nationwide. It introduced a negative list for government service purchases, strictly prohibiting the misuse or fabrication of government service contracts for illegal financing. Subsequently, the State-Owned Assets Supervision and Administration Commission issued directives to curb the overheated investment of state-owned enterprises in PPPs and encourage private capital participation in infrastructure construction within cultural, tourism, sports, health, pension, and education sectors. As of 2013, the PPP policy landscape has transitioned into a stable and rational development phase.

4.2.5. Stagnant Period (2019–Present)

In 2019, the Ministry of Finance released "The Implementation Opinions on Promoting the Standardized Development of Government and Social Capital Cooperation" (Finance (2014) No. 76), stipulating that regions where PPP projects account for more than 5% of fiscal expenditure should not initiate new PPP projects. This directive aimed to address the issue of PPP projects exacerbating the debt burdens of local governments, leading to a massive cleanup of irregular PPP projects. By 2023, the PPP initiative reached a standstill, with the PPP Center's official website under the Ministry of Finance ceasing the provision of updates.

In November 2023, the General Office of the State Council of China disseminated a document titled "Guiding Opinions on Standardizing the Implementation of a New Mechanism for Cooperation between Government and Social Capital", which delineates a refined approach towards the Public–Private Partnership (PPP) model, transitioning it towards a user-pays franchise scheme. This adjustment restricts the PPP framework, emphasizing the recoupment of investments predominantly through user charges. The revised PPP paradigm advocates for governmental subsidies to exclusively support operational expenditures, excluding construction costs. This evolution signifies a strategic shift from a conventional Public–Private Partnership towards a franchising model that predominantly involves social capital. Although the government proposed a new mechanism for franchising in 2023, the new mechanism is only for new PPP projects, and the difficulties of existing PPP projects have not been resolved.

5. Discussion

The Public–Private Partnership (PPP) model represents a significant advancement in the mechanism of public service provision, whereby the government engages social capital—entities with capabilities in investment, operation, and management. Within this framework, the roles, responsibilities, and rights of both parties are explicitly delineated, allowing social capital to deliver public services while the government compensates these entities based on the outcomes of performance evaluations, ensuring a reasonable return on investment for social capital. This model is posited to effectively harness market mechanisms, thereby enhancing the quality and efficiency of public service delivery and optimizing public interest. Following its endorsement by the Ministry of Finance and the National Development and Reform Commission in 2014, the PPP model garnered substantial interest from local governments and state-owned and private enterprises, resulting in an exponential increase in both the quantity of PPP projects and the level of investment. This period of rapid expansion, however, was not without its challenges; the PPP model has been critiqued for deviating towards local financing tools and giving rise to new forms of concealed debt risk. Additionally, there is a discernible imbalance favoring construction over operational management, alongside deficiencies in the framework for performance evaluation.

The current development of China's Public–Private Partnership (PPP) model faces numerous challenges. The analysis of policy trends reveals a decline in PPP projects since 2019, attributable to the absence of key policy elements such as "government credit", "contract spirit", and "power supervision". This deficiency has precipitated significant issues across various aspects of China's PPP projects, rendering their continuation problematic.

1. *Lack of project bankability.* Globally, PPP projects grapple with securing affordable financing, a challenge also prevalent in China. High capital costs and stringent lending criteria complicate private investors' ability to fund infrastructure projects under the PPP model. The lack of financial viability and bankability, attributed to inadequate risk allocation, unclear revenue streams, and insufficient government support, deters private investment.
2. *Regulatory issues.* Successful PPP development necessitates a clear, unified policy environment with standardized supervision. China's evolving regulatory framework for PPP projects suffers from a lack of clear guidelines and standardized procedures, intro-

ducing uncertainty for private investors and impeding the development of successful PPP projects. The approval process involving multiple government stakeholders often results in delays or cancellations due to political considerations or shifts in government priorities.

3. *Institutional environment*. Countries with effective PPP models have established management and service systems tailored to their development needs. While China has introduced various systems to encourage and manage PPPs, no specific laws governing government and social capital cooperation have been enacted. Divergences in PPP development perspectives and legislation between the Ministry of Finance and the Development and Reform Commission complicate decision-making related to local governments and social capital for promoting PPP projects.
4. *Contract Spirit*. Emphasizing the full integration of PPP-related laws and policies, the market concept and contract spirit of PPP should be upheld. The Chinese government must balance all participants' interests, adhering to interest measurement principles.
5. *PPP-REITs model*. Real Estate Investment Trusts (REITs) offer a mechanism to revitalize asset stocks for reinvestment. The structural design and logic of REITs differ fundamentally from those of PPPs, which are debt-financed, whereas REITs are equity-financed. PPP affects the construction period of a project, while REITs have an impact from the operational phase onwards. Utilizing REITs to rejuvenate PPP infrastructure assets could provide a way out of the current dilemmas, contingent on resolving legal issues and ensuring that PPP projects generate stable cash flows.

6. Conclusions

A chronological analysis of China's PPP policy documents from 1986 to 2018 reveals a maturation in policy focus and intensity, especially post-2009. However, critical areas such as "government credit", "contract spirit", and "power supervision" remain under-addressed. The policy's evolution has gone through five stages: budding (1986–2000), fluctuating (2001–2008), steady (2009–2012), expanding (2013–2018), and stagnating (2019–present). Initially focused on public utilities, the participation dynamics have shifted, with foreign enterprises receding and private and state-owned entities predominating.

The challenges confronting China's PPP model are multifaceted, stemming from policy gaps that have led to substantial project difficulties. This study advocates for enhancements in project bankability, regulatory clarity, institutional environment improvement, contract spirit defense, and the development of the PPP-REITs model to address these issues.

This analysis of the evolution of China's PPP policy provides suggestions for the healthy operation of China's PPP projects and provides references for PPP projects in other countries and regions.

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Towards an Enhanced Business Case Development for Public–Private Partnership (PPP) Projects: A Comparative Study of China and New Zealand

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Abstract: Public–Private Partnerships (PPPs) are widely used for delivering public assets and associated services. A well-developed business case is crucial for the successful execution of PPP projects. This research conducts a comparative study of the critical factors influencing PPP business case development and proposes practical policies and management interventions to enhance this process. Using a systematic literature review and semi-structured interviews with 46 PPP stakeholders from China and New Zealand, the study identifies four key areas essential for an improved business case development: (1) contextual factors, including political support and enabling legal and regulatory frameworks; (2) procedural factors, such as comprehensive service need analysis, robust procurement option assessment, and clear affordability analysis; (3) capability-related factors, including strong public sector capability and credibility; and (4) organizational factors, such as streamlined institutional arrangements and effective governance structures. By adopting the proposed strategies, policymakers can make more informed decisions on PPP-related policies, while public procuring authorities will be better equipped to plan, structure, and manage the business case process effectively. The research focused on PPP practices in two countries, China and New Zealand, with findings derived from a limited number of interviews. This raises questions about the generalizability of the results. Additionally, the recommendations may need to be adapted to account for varying economic, social, and policy contexts when applied in different settings.

Keywords: Public–Private Partnerships (PPPs); business case development; China; New Zealand

1. Introduction

Public–Private Partnerships (PPPs) are increasingly used for delivering public assets and associated services. In a PPP arrangement, a private sector entity enters a long-term contract (typically 20–30 years) with the public sector to provide a service that requires the construction or enhancement of a facility. The private sector is responsible for financing, constructing, operating, and maintaining the facility, with control transferred to the public sector at the end of the contract [1,2].

A typical PPP procurement process consists of three main stages: business case development, tendering, and contract management. Decisions made in the early stages of a project significantly impact later stages in its life cycle [3]. Business case development is an

initial stage that consolidates and summarizes the findings of all necessary research and evaluations of a proposed investment, ensuring that the optimal solution is selected for the given circumstances [4]. In PPP projects, an effective and efficient business case stage enables informed and timely decision-making while facilitating smooth implementation [5]. Conversely, a business case process lacking rigor and robustness limits the availability of accurate and sufficient information, often leading to suboptimal decisions [5]. For example, in the Hangzhou Bay Cross-Sea Bridge Project, private sector investors experienced significant financial losses because traffic volume did not meet the initial forecast. Without a well-defined economic assessment at the business case stage, toll revenues could not offset capital and operating costs, resulting in substantial financial losses for private investors [6]. Therefore, preparing an effective business case is crucial in PPP projects [7].

The management of the business case process is a crucial aspect of PPP project management [8]. Rockart defined critical success factors (CSFs) as the "few key areas of activity where favorable results are absolutely necessary for a manager to reach his/her goals" [9]. Since the 1990s, numerous studies have focused on CSFs within the context of PPPs [10–12]. Researchers have also applied the CSF concept to various stages of PPP procurement by identifying factors affecting specific processes, such as the feasibility stage [13], PPP briefings [14], the initial design stage [15], the tendering stage [16], contract administration [17], and ex-post evaluation [18]. Therefore, to enhance business case development, it is essential to identify the CSFs that contribute to the success of the process. This study aims to identify the critical factors that contribute to a successful PPP business case and develop policy and management recommendations for improving PPP business case development. To achieve this, a comparative analysis of the key factors influencing the successful development of PPP business case practices in China and New Zealand is conducted. The research seeks to answer the following questions:

- What are the factors that are critical to the success of the PPP business case?
- Based on the critical factors identified, what are the useful and workable policies and management interventions for enhanced business case development processes?

China and New Zealand were selected for this comparative analysis due to their similarities and differences in PPP development. Over the past two decades, both countries have gradually developed active PPP markets, drawing on mature international PPP models such as the Private Finance Initiative (PFI) and Build–Operate–Transfer (BOT). As the dynamics of PPP projects have evolved, so too have PPP practices in both nations. The development of PPP schemes occurs within diverse social, economic, and policy contexts. China, as the world's second-largest economy, has a substantial pipeline of infrastructure projects, attracting international investors to its PPP market. In contrast, New Zealand has a relatively small economy with lower infrastructure demands, making its PPP market less attractive to private sector players. China operates a centrally planned economy, where the government directs and controls economic activities, including the promotion and implementation of PPP programs. Due to its unique administrative system and construction industry practices, international PPP experiences may not be directly applicable to China's PPP market. Conversely, New Zealand represents a typical free-market economy and shares significant similarities with mature PPP markets such as the UK and Australia. Its PPP model is largely based on well-established international frameworks. Given the fundamentally different environments, comparing PPP practices in China and New Zealand significantly enhances our understanding of how various contextual factors shape the formation, development, organization, and management of PPPs at the business case stage. Although such fundamental contextual differences present methodological challenges, it is precisely these contrasts that amplify the significance of this comparative study. By examining both similarities and differences in PPP business case processes and

analyzing the underlying reasons for these variations, the research uncovers deeper insights into how distinct institutional, economic, regulatory, and cultural environments influence PPP business case development. Cross-national comparative studies inherently aim to highlight how contextual dynamics affect the applicability and adaptability of theoretical models and practical frameworks. Consequently, this comparative analysis uniquely contributes to PPP scholarship by identifying context-sensitive nuances and adaptable best practices that can enhance business case robustness, flexibility, and cross-contextual learning. Thus, rather than undermining validity, these contextual distinctions enrich our findings and offer more broadly generalizable recommendations with meaningful implications, not only for China and New Zealand but also for other jurisdictions seeking to adopt and adapt best practices within their distinctive institutional contexts.

In this research, a comprehensive literature review was first conducted to identify the critical factors affecting the execution of PPP projects. Semi-structured interviews were then carried out to gather insights and perspectives from industry practitioners on key issues related to PPP business case development. Drawing on interviewees' opinions, this study proposes recommendations to enhance business case processes for PPPs. The findings contribute to the international PPP best practice framework by highlighting core issues specific to the business case development stage. By implementing the strategies and measures proposed in this research, public procuring authorities will be better positioned to initiate, plan, and execute PPP projects effectively.

2. Literature Review

2.1. PPP Business Case Development Stage

According to the Association for Project Management (2017), a business case "provides justification for undertaking a project or program. It evaluates the benefit, cost, and risk of alternative options and provides a rationale for the preferred solution" [19]. Recognized as a best practice in business and organizational management, the business case approach has been adopted in public sector procurement and is now widely used across jurisdictions to support capital project investment decisions [20]. It is a crucial component of the planning, approval, procurement, and delivery of investments. The business case ultimately takes the form of a proposal document outlining the objectives and key aspects of implementation management [21]. The depth and detail of a business case vary depending on the nature and complexity of the proposal. A well-developed business case not only provides the procuring authority with evidence to support decision-making but also assures other stakeholders that the process has been conducted responsibly and transparently.

A typical PPP process broadly consists of project identification, feasibility and structuring (business case stage), tendering, construction, operation and maintenance, and the handover process [5]. HM Treasury outlines that a business case consists of five interconnected but distinct components: strategic, economic, financial, commercial, and management [3]. The development of a business case is an iterative process that unfolds over time in a sequential manner. As the proposal progresses, previous assumptions and analyses are revisited to ensure the continued effectiveness of the work undertaken [22]. The New Zealand Treasury recommends a multi-stage business case development process, which includes the Program Business Case (PBC), Indicative Business Case (IBC), and Detailed Business Case (DBC) [23–25]. The multi-stage process and the primary tasks involved in each stage are illustrated in Figure 1.

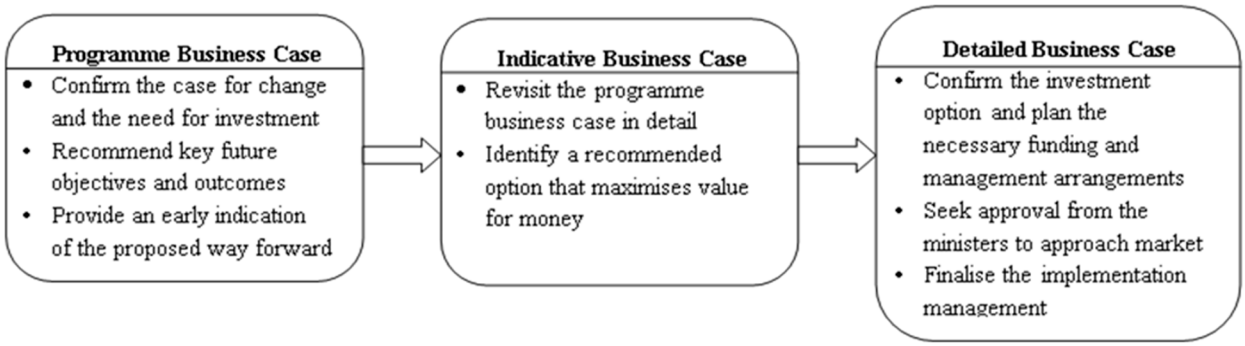

Figure 1. The multi-stage business case process in New Zealand.

Like other procurement methods, the PPP procurement process should be integrated with the business case development framework. Procuring authorities planning significant investments are typically required to evaluate all procurement options, including PPPs. In New Zealand, formal consideration of PPPs is required during the development of an Indicative Business Case (IBC), which also impacts the development of the IBC and Detailed Business Case (DBC). For example, if a PPP is included in the shortlist of options, the procuring authority must consult with joint ministers and engage with potential private sector participants during the IBC stage. Additional analyses at the subsequent DBC stage include a second round of market sounding, the development of a performance regime, and both qualitative and quantitative assessments, including the compilation of a Public Sector Comparator (PSC) [26].

PPP business case development faces several potential obstacles. The business case process is iterative and time-consuming, and the adoption of PPPs is highly susceptible to political environments. Procurement option selection is sometimes driven by ideological considerations rather than thorough analysis [27]. Public procuring authorities are often under significant pressure to accelerate project timelines rather than develop a well-articulated and compelling business case [28].

The value-for-money analysis, typically conducted at the business case stage, aims to determine the most cost-effective procurement method by comparing a PPP approach with traditional procurement. This assessment primarily relies on financial analysis and cost accounting principles to evaluate PPPs. However, it often fails to incorporate sustainability goals, which involve contingent and fair value accounting [29,30]. Fully integrating value-for-money calculations with sustainability criteria—such as environmental impact, resource consumption, health and well-being, and social equity—remains a significant challenge due to the complexity of measuring and enforcing sustainability considerations [30].

Additionally, business case development is inherently multifaceted and requires multidisciplinary knowledge, skills, and expertise [20]. Public sector project teams, particularly those within organizations with limited experience in capital projects, often lack the necessary expertise to engage in such complex endeavors [31,32]. Insufficient public sector capacity can significantly hinder the progression of business case development.

2.2. Critical Factors Affecting the Successful Development of PPP Business Case

Critical Success Factors (CSFs) are key elements whose presence at each stage of the project life cycle is essential for successful project management. Identifying CSFs helps improve project management practices by drawing on best practices learned from previous projects [31]. In the context of PPP projects, CSFs highlight key managerial activities that must be effectively executed for successful PPP project management [8]. Over the past few decades, research on CSFs for PPP projects has become a major focus in PPP studies [12,32]. The CSF concept has also been applied to PPP project process management to identify

optimal approaches for executing specific PPP processes [13–18]. A review of the existing literature on PPP critical factors identifies six key factors influencing the execution of PPP projects, which are particularly relevant to business case development [33]. These factors, derived from the literature review, establish the conceptual foundation for the subsequent empirical investigation.

Prior studies have shown that the presence of a political champion and social support determines whether PPP deals can move forward [15,16]. PPPs are often misunderstood by the public as a form of privatization, which can create challenges in gaining stakeholder agreement. Political and public support are, therefore, crucial for ensuring a fair and transparent procurement option analysis, a core component of business case development [34].

Legal and regulatory frameworks define the boundaries within which public entities operate. The adoption and implementation of PPPs involve various legal and regulatory considerations, including project ownership regulations, authorization of specific PPP models, and restrictions on the private sector's ability to set service fees. The availability of these frameworks significantly influences decisions on whether to adopt PPP models, as well as the commercial, financial, and contractual arrangements involved [10,11].

Ensuring the existence of a service need is crucial for securing a sustainable PPP project [35]. This requires a thorough service need analysis, which is a key task in the business case development phase of a PPP. Central to this issue is the long-term demand for the proposed project [13,14].

Prior studies have highlighted the importance of value-for-money assessment in evaluating PPP procurement options [36]. Value for money is widely used to justify the adoption of PPPs. This assessment typically follows a Public Sector Comparator (PSC) approach, where private bids are compared against the PSC—a risk-adjusted, life-cycle cost estimate of delivering the project through traditional procurement [37].

PPPs are a relatively novel procurement method and involve inherently complex contractual and commercial arrangements [31,32]. The preparation and management of a PPP business case requires extensive cross-disciplinary knowledge and expertise. Therefore, public sector capacity is crucial to the successful development of a PPP business case [34]. The capability, experience, and commitment of the project team are essential to ensuring that the PPP transaction is well planned and structured.

Researchers have identified good governance as a prerequisite for the smooth progression of PPPs [16]. Establishing clear governance structures at the business case stage is critical to ensure that informed and timely decisions are made at key decision-making points.

2.3. PPP Practices and Policies

2.3.1. PPPs in China

China has extensive experience in the application of PPPs. The development of PPPs in China can be categorized into four stages: pioneer (1990–2003), modern (2003–2013), expansion (2013–2018), and stagnation (2019–present) [38,39]. In the first phase, PPPs were predominantly implemented in the form of Build–Operate–Transfer (BOT) projects. The primary driver was to alleviate the government's budgetary burden of providing public assets by utilizing private sector financing [40]. The concept of PPPs was officially introduced in China around 2003, when the government began experimenting with PPPs under a new policy objective: achieving value for money by leveraging private sector expertise and innovation in public service delivery [38,41]. The Beijing Metro Line 4 Project is regarded as the first successful modern PPP project in China [16]. Over time, the focus shifted from asset-based to service-based PPPs. Since late 2013, another wave of PPPs has emerged as the new generation of leadership has demonstrated a strong interest in

increasing private sector involvement in public services. The government has since outlined an ambitious plan to expand PPP programs. The development of PPPs has entered an expansion phase [42]. However, since 2019, China's PPP sector has reportedly experienced stagnation [39]. Many projects underperformed, and as of February 2023, a significant number of PPP projects were suspended until an updated guideline for PPP mechanisms was issued in November 2023. The new mechanism now requires local governments to prioritize user-paid franchise schemes, with government subsidies limited to supporting operational expenditures while excluding construction costs. This marks a strategic shift toward a franchising PPP model [39].

Institutional, legal, and policy frameworks have evolved to encourage the application of PPPs. A central PPP unit, the China Public–Private Partnerships Center (CPPPC), was established within the Ministry of Finance to coordinate PPP activities at the national level, provide expert advice to assist procuring authorities in planning and executing PPP projects, and serve as a platform for knowledge sharing [38,43]. China's National Development and Reform Commission (NDRC) has created a database for PPP projects, offering the market clear information about project pipelines. In 2015, a PPP regulation, Measures for the Administration of Concessions for Infrastructure and Public Utilities, was introduced and enforced, defining PPP concessions in the Chinese context and establishing a common legal foundation for PPP implementation [44]. Various central government departments, along with provincial and municipal governments, have issued policies and guidelines—such as the Note on Standardizing Contract Management in Public–Private Partnership Projects and the Guidelines on Standardized PPP Contracts—to clarify the government's approach to PPP procurement and its role in transactions [45]. These guideline documents provide practical support to procuring authorities in structuring and managing PPPs, significantly contributing to their widespread and effective application [42].

2.3.2. PPPs in New Zealand

In New Zealand, the private sector has been involved in delivering public infrastructure, related services, or a combination of both for many years [46]. This involvement has taken various forms, including outsourcing, franchising, and privatization. Although several quasi-PPP projects, such as Wellington's Clear Water Project, were undertaken by local governments, the central government remained skeptical about adopting PPPs [43]. However, since 2009, the New Zealand government has emphasized the effective and efficient provision of public services, as well as improvements in capital asset management and procurement. PPPs have been recognized as a key mechanism for achieving these objectives, leading to the establishment of the New Zealand PPP program. Two pilot PPP projects—the Wiri Prison and Hobsonville Schools—were initiated using the Design–Build–Finance–Operate (DBFO) and Design–Build–Finance–Maintain (DBFM) models, respectively [28]. To date, eight PPP projects have been implemented across the education, corrections, and transportation sectors.

To support PPP development, a dedicated PPP team was established within the New Zealand Treasury, serving as a center of excellence for PPP programs. This team formulates PPP policies and processes, assists public agencies with PPP procurement, and monitors project implementation [47]. Additionally, a database was created to provide basic information on existing PPP projects, as well as those under procurement and consideration. Drawing on precedents from other established PPP markets and insights from New Zealand's pilot projects, a Standard Form PPP Project Agreement was developed, offering credible and tested contractual positions for future projects. Furthermore, the PPP Procurement Process guidance was issued to outline New Zealand's PPP procurement framework,

serving as a key reference for public sector entities considering or implementing PPPs for major infrastructure projects [26].

3. Research Methods

The choice of research methodology is largely determined by the research problem and purpose [48]. This study aims to conduct a comparative analysis of the critical factors influencing the successful development of PPP business cases in China and New Zealand. Based on these findings, it proposes practical and effective policies and management interventions to enhance business case development processes in PPP projects. A qualitative approach was adopted as it provides an in-depth means of soliciting experts' insights into PPP practices at the business case stage, and subject matter experts' perspectives offer detailed elaboration on concepts and best practices [49]. Additionally, qualitative data provide well-grounded, rich, and insightful descriptions and explanations of processes and organizational structures embedded within specific social and economic contexts [50]. This approach was well suited to the study's objective of exploring the organization and management of PPPs at the business case stage and examining how they are influenced by various contextual factors.

The research began with a systematic review of the relevant literature, including journal articles, conference papers, research reports, and online sources, to establish foundational knowledge on PPP business case development and provide an overview of PPP practices and policies in China and New Zealand. Studies on critical success factors for PPP projects were extensively analyzed to identify those most relevant to the business case stage. The literature review aimed to develop the overall research framework, establish the theoretical foundation for the subsequent empirical investigation, and create a template for interviews [51].

Semi-structured interviews were conducted as the primary research method to provide empirical evidence supporting theoretical explanations by eliciting insights and perspectives on PPP implementation, with a particular focus on the business case stage. Participants were selected through a purposeful sampling process, which enables the identification of information-rich individuals for in-depth investigation [50]. The selection criteria included (1) experience in PPP projects, (2) familiarity with PPP procurement and the country's policy direction regarding PPPs, and (3) position within their organizations. Detailed information on the interview participants is provided in Table 1.

Table 1. Background information of interview participants.

Characteristic	Category	China			New Zealand		
		N	%	Interviewee Code	*N*	%	Interviewee Code
Role of organisation in PPPs	National coordinating authority	1	4%	CN1	2	9%	NN1-NN2
	Central government department/agency	2	8%	CG1-CG2	8	36%	NG1-NG8
	Local government	4	17%	CL1-CL4	3	14%	NL1-NL3
	Construction contractor	4	17%	CC1-CC4	2	9%	NC1-NC2
	Operator/facility manager	2	8%	CO1-CO2	1	5%	NO1
	Financier	4	17%	CF1-CF2	2	9%	NF1-NF2
	Advisors (commercial/legal)	3	12%	CA1-CA5	4	18%	NA1-NA4
	Researchers	4	17%	CR1-CR4			
Designation	Upper management	6	25%		8	36%	
	Middle management	8	33%		10	46%	
	Professionals	10	42%		4	18%	

Table 1. *Cont.*

Characteristic	Category	China			New Zealand		
		N	**%**	**Interviewee Code**	***N***	**%**	**Interviewee Code**
Years of experience with PPPs	More than 15 years	3	12%		4	18%	
	10–15 years	8	33%		6	27%	
	5–10 years	4	17%		2	9%	
	Less than 5 years	9	38%		10	46%	

The interviewees were initially contacted via email and telephone. A face-to-face interview technique was adopted, as it facilitates deeper discussions on the issues and topics raised during the interviews. Based on a series of potential critical factors identified through the literature review, a semi-structured questionnaire was developed and used in the interviews. The interview questions and subsequent discussion areas are presented in Table 2.

Table 2. Interview questions and discussion areas.

Interview Questions	Discussion Areas or Probes	Purpose
Based on your work/research experience in relation to PPPs, how do you perceive the performance of business case development in PPP projects? [4,22]	A robust case for change that represents strategic synergy Optimised value for money Commercial viability Financial affordability Management achievability Costs and durations of business case development	To gain an understanding of the current practices of business case development in PPP projects
What are the key issues/concerns encountered in the business case development of PPP projects? What are the initiatives taken to address the issues/concerns emerged? How would you evaluate their effectiveness? [18,32,52–56]	Political and social support Legal and regulatory frameworks Service need Value for money assessment Public sector capacity and commitment Governance Structures	To identify critical factors influencing the successful development of business cases in PPP projects
Given the nature of your profession, could you identify additional strategies	Open-ended questions	To recommend policies and management interventions for an enhanced business case development process

Forty-six participants—24 from China and 22 from New Zealand—were interviewed. The number of interview participants was considered sufficient for generating and elaborating on key themes and sub-themes, as information saturation was reached and the collected data began to exhibit iterative patterns [50]. The interviews lasted between one and one and a half hours. All interviews were audio-recorded and subsequently transcribed by the researchers. The data were coded and analyzed using the qualitative data analysis software NVivo 10. This software facilitated the identification of emerging trends and themes from the interviews and enabled a comparative analysis of text codes within the same category to ensure consistency in coding and interpretation [16]. In this study, the interview data were initially coded into predetermined categories of critical factors derived from the literature review. The researchers then continued to gather and group interview content with shared characteristics, allowing new categories to emerge. The coding process was conducted iteratively to ensure that key concepts and themes were generated from a comprehensive dataset rather than a single round of analysis. Through this process, the critical factors influencing the successful development of PPP business cases were identified

and subsequently grouped into four categories. These critical factors are presented and discussed in the following section.

4. Results and Discussion

Interviews with 46 PPP stakeholders from China and New Zealand identified nine factors influencing the successful development of business cases in PPP projects. These factors are categorized into four groups: contextual factors, procedural factors, capability-related factors, and organizational factors. The interview results are presented and discussed in the following sections under these four headings.

4.1. Contextual Factors

4.1.1. Political Champion

Interviewees from both countries (16 from China and 18 from New Zealand) consistently emphasized the critical role of political leadership in advancing the PPP business case process. The direction set by government policies significantly influences the integration and prioritization of PPP options within public sector delivery models. In China, PPP development has been notably driven by overarching governmental policy objectives. During China's expansive PPP growth phase (2013–2019), the central government positioned PPPs not merely as an alternative procurement mechanism but also as an essential instrument for deeper economic reforms and improvements in public service delivery. This policy stance resulted in the substantial growth of project pipelines and increased capital investment in PPP projects. However, China's PPP development entered a period of stagnation after the government shifted toward a more restrictive regulatory framework, emphasizing greater reliance on user-pay models. Reflecting on this transition, participants CR1 and CR2 remarked:

> The government tends to use strong administrative power, rather than a rigorous business case framework to push PPP forward. Lacking a systematic thinking, the sustainability of China's PPPs remains a question mark.

The New Zealand government tends to adopt a cautious approach toward PPPs, primarily due to community concerns that such partnerships represent another form of privatization. Public skepticism often stems from a perceived loss of control and accountability. For example, participant NG2 highlighted concerns within the education sector, stating: "Under a PPP, the responsibilities traditionally held by the school board would shift to the private sector, directly impacting relevant community stakeholders such as parents and teachers". Such apprehensions, driven by insufficient public understanding and transparency, generate substantial community resistance, placing political pressure on decision-makers who advocate for PPP initiatives. Furthermore, New Zealand's relatively short electoral cycle introduces additional uncertainty and complexity, causing political leaders to proceed cautiously with PPP commitments. Participants NA1 and NA4 elaborated on these challenges as follows:

> Decisions in infrastructure take long time to make. You can have change of politicians during the decision-Making process. That creates some problems. The market did reflect a level of nervousness that due to change of political power, contracting arrangements changed as a result.

This research aligns with previous studies highlighting the importance of political champions as crucial for the successful implementation of PPP projects [32]. Compared to traditional procurement methods, PPPs frequently generate greater controversy and are highly sensitive to shifts within social and political contexts. Consequently, the business case development phase is exposed to considerable uncertainties stemming from polit-

ical instability or changes in leadership. A primary driver of political opposition is the concern that PPPs could undermine social justice objectives and restrict opportunities for meaningful community participation in decision-making processes. Therefore, ensuring that PPPs are selected through a systematic and transparent procurement options analysis rather than driven by ideological motivations is essential. Without consistent and robust political and administrative support, even well-suited PPP projects risk abandonment or failure. Moreover, the premature or rapid expansion of PPP programs without rigorous evaluation can result in suboptimal outcomes, including contract renegotiations, early project termination, financial inefficiencies, and diminished user satisfaction and public trust.

4.1.2. Enabling Legal and Regulatory Frameworks

All participants from China emphasized that enabling legal and regulatory frameworks are central to initiating and structuring PPP projects. More than 100 regulations and policies have been issued by various government departments at different administrative levels, which, to some extent, have facilitated the development of PPP programs. However, these regulatory and policy documents are formulated and implemented in a fragmented manner, lacking coherence and consistency. Participants CC3, CO1, and CA3 pointed out:

> The provisions are sometimes contradictory to each other. Different sectors have varied approaches and procedures. Local governments even have their own requirements. This brings about lots of confusions to the market. When inconsistencies occur, how to interpret the priorities of relevant provisions?

A broad suite of existing laws and regulations applies to the execution of PPP projects, including the Government Procurement Law, Bidding Law, Contract Law, and Corporation Law. However, discrepancies exist between these legal provisions and PPP practices, which must be addressed to establish a consistent and enabling legal environment. Additionally, guidelines and policy documents have been developed to provide practical guidance for PPP participants. Participants CL1 and CL2 noted that such guidelines—such as the Guidance on Value for Money Assessment, the Guidance on Affordability Analysis for PPP Projects, and the Guidelines for the Implementation of PPP Projects—serve as important references for practitioners in developing a business case for PPP projects.

Compared to China's PPP practitioners, interviewees from New Zealand expressed fewer concerns regarding legal and regulatory issues. The country's common law tradition, respect for contracts, and transparency instill confidence in the market. Participants NA3 and NA4 mentioned that New Zealand has an established legislative and regulatory framework to support the PPP program. A Standard Contract was developed, incorporating precedents from other well-established PPP markets. The financier (NF2) acknowledged that while the Standard Contract may require significant project-specific amendments, legal precedents demonstrate that commercial principles, risk allocation, and contractual structures are generally enforceable. Moreover, a more robust business case toolkit was developed, integrating the PPP process into the broader business case framework, thereby facilitating informed decision-making.

This research reinforces previous findings that China's evolving regulatory framework lacks consistency and standardization, creating significant uncertainty for private investors. Prior studies emphasize that a robust and enabling legal and regulatory framework forms the cornerstone of successful PPP program development [57,58]. The findings from this study further confirm that regulatory clarity and stability directly influence practices at the business case development stage. Legislative provisions establish the overarching framework within which PPPs are implemented, significantly affecting their governance and operational viability. For instance, in civil law jurisdictions such

as Japan, France, and China—where PPP implementation is guided explicitly by legal codes or statutes—high-level legislation clearly delineates government approval authorities, defines PPP development and management processes, outlines exit strategies, and sets dispute resolution mechanisms. Such regulatory clarity, combined with well-defined commercial structures and standardized contractual terms, provides essential foundations for PPP transactions, enhancing the quality, transparency, and effectiveness of the PPP business case.

4.2. Procedural Factors

4.2.1. Sound Service Need Analysis

Eleven interviewees (seven from China and four from New Zealand) emphasized that the adequacy of service need analysis is a prerequisite for ensuring a robust business case. Participant NA3 reflected on previous unsuccessful PPP experiences in Australia and advised, "Focusing on confirming the need first, making sure you've got your service need absolutely known before you start going to your solution". In China's public procurement, there is a tradition where project decisions are not always based on rigorous evaluation. Participants CA2 and CR1 argued:

> It is common to see the construction of a project has commenced whilst the service need not being adequately confirmed. It also happens to PPP projects. Some local governments just want to get a PPP built without asking: "Do we really need it? Whether the option is cost effective".

The slowdown in China's PPP development since 2019 has been partly attributed to a strategic reassessment of service requirements for proposed PPP projects. Authorities implemented a more rigorous evaluation process designed to ensure the long-term viability and relevance of service needs. Similarly, interviewees from New Zealand strongly emphasized the importance of assessing whether services provided by PPPs remain meaningful and sustainable over the project's entire lifecycle. Participant NG8 highlighted international experiences, noting that many unsuccessful PPPs globally were not necessarily failures of the PPP model itself but rather due to inadequately justified or poorly defined service needs from the outset. He posed critical sustainability-focused questions to guide this assessment, including: "Will the infrastructure and associated services still be necessary in 20 years? Who will the users be at that time? Could the land and resources allocated for these projects be effectively repurposed if required?" Participants NN1, NG4, and NA3 further stressed the value of adopting a programmatic, systematic approach when conducting the service-need analysis, ensuring robust and comprehensive decision-making at the planning stage. During the business case for the Wiri Prison Project, significant doubts were raised about the necessity of building a new prison, given the projected decline in offender numbers. However, the project was expedited as part of the Department of Corrections' broader strategy to modernize the country's prison network, particularly as some aging prisons were nearing the end of their operational lifespan.

Conducting a well-developed service-need analysis is crucial for ensuring a viable PPP [34,37]. This research reinforces that such analysis is also a vital component of a successful business case. PPPs involve long-term contractual agreements and partnerships, making it essential to address sustainability concerns before finalizing decisions in the service need analysis [30]. Factors such as shifting economic and social conditions, technological obsolescence, and stakeholder and community satisfaction are closely tied to the long-term demand for the infrastructure or service. It is widely accepted that a well-articulated service need analysis is a fundamental practice in capital project procurement [13], and this research confirms that PPPs are no exception.

4.2.2. Robust Procurement Option Analysis

Most interviewees (18 from China and 15 from New Zealand) emphasized that conducting a robust procurement option analysis—characterized by a systematic and comprehensive evaluation of the merits, risks, and implications associated with PPPs—is essential to developing a strong business case. In China, the Ministry of Finance (MoF) explicitly encourages public procurement authorities to conduct a rigorous value-for-money assessment when preparing PPP proposals. When reliable preliminary project estimates are available, the Chinese government further recommends performing a quantitative analysis using the Public Sector Comparator (PSC) method. Interviewees acknowledged ongoing criticisms regarding the quantitative PSC method, particularly relating to its complexity and assumptions. However, they strongly maintained that applying such a structured, transparent, and evidence-based approach significantly enhances the robustness and credibility of procurement decisions, ultimately strengthening stakeholder confidence in PPP projects.

Beyond quantitative value-for-money analysis, the interviewees reiterated the importance of considering qualitative criteria, particularly sustainability factors. Although these factors are challenging to measure and enforce, they should be seriously considered in the procurement option analysis. Key questions to address include: What are the environmental impacts of PPP options, such as energy conservation effects, efficient use of natural resources, and optimal land utilization? Do PPPs contribute to improving public service quality, as well as citizens' health and well-being? Do PPPs encourage community engagement and stakeholder participation, which are fundamental to social justice?

Participant CO2 commented:

> The "surname" of Public-Private Partnerships is "Public". The goal of PPPs is to achieve benefits for general public. You build a characteristic town PPP project. Will the local community gain better access to facilities? Will they have more job opportunities? Will their well-beings improve due to the town's development?

Two senior managers from local government authorities (CL3 and CL4) stressed:

> At the current stage, we shall at least have a comparison so that our decisions-making can be grounded in reasons. We can mainly adopt a qualitative method, assisted with the PSC. It is a progressive process from a general appraisal to a systematic and comprehensive evaluation. It is a balance we are seeking.

New Zealand utilizes the PSC as a primary analytical tool to assess whether a PPP is the most suitable procurement approach for a given project. Although participants acknowledged certain limitations inherent in the PSC, the New Zealand interviewees emphasized that it provides a rigorous, systematic, and structured framework for objectively evaluating PPP proposals. Compared to China, New Zealand benefits from its ability to incorporate established best practices from international experiences—particularly those of countries with mature PPP markets such as the United Kingdom and Australia. However, participants also stressed the importance of including qualitative factors—such as stakeholder satisfaction, social outcomes, and broader community benefits—in the PPP decision-making process. Illustrating this perspective, Participant NG1 argued that significant community benefits could be achieved by leveraging private sector innovation:

> The long-term nature of the contract means that they (the private sector) have an opportunity to earn revenues that can be used to offset project costs. Say you have a school PPP. They might build a recreational center open to the public to generate more revenue, and at the same time, the facilities will be fully utilized, and the adjacent communities also benefit.

Participant NA1, who provided advisory services for the Hobsonville Schools project, believed that a higher level of stakeholder satisfaction could result from improved service quality. He commented, "With someone else (the private sector partner) looking after the maintenance services, the board can focus on achieving better educational outcomes. Everyone is happy".

Proponents of PPPs frequently emphasize value-for-money outcomes as evidence of superior PPP performance [37]. Internationally, the PSC method is widely adopted as a quantitative tool for comparing life-cycle costs between PPPs and traditional procurement approaches [16]. However, the recent literature indicates growing skepticism towards the PSC approach, criticizing its limited accuracy in forecasting long-term costs over concession periods and highlighting its sensitivity to assumptions regarding the selected discount rate [36]. These methodological constraints of the PSC approach were also acknowledged in this research. Specifically, Chinese interviewees emphasized significant challenges due to inadequate historical data, complicating accurate risk-adjusted forecasts and informed discount rate selection. This finding underscores the necessity for more robust and context-sensitive evaluation methods when assessing PPP viability and performance.

Beyond the challenges associated with the PSC, the value-for-money analysis has also been criticized for focusing primarily on financial considerations while overlooking other important criteria [29]. Kweun et al. (2017) found that value-for-money studies fail to quantify social benefits and costs beyond the specific project examined [59]. Vining and Boardman (2008) advocated for a "comprehensive social accounting" approach to PPPs, arguing that the effectiveness and desirability of PPPs depend on their ability to generate social benefits [60]. Hueskes et al. (2017) introduced a sustainability-based (fair value) perspective in evaluating PPP performance, incorporating social, ecological, and economic considerations into PPP procurement [30]. The interviewees in this research agreed that qualitative factors, particularly those related to achieving sustainability objectives—especially the social dimensions of sustainability—should be considered when conducting procurement option analyses.

4.2.3. Articulated Affordability Analysis

Fourteen interviewees (eight from China and six from New Zealand) emphasized the importance of conducting a comprehensive affordability analysis—carefully assessing the government's fiscal position throughout the concession period—to ensure the sustainability of PPP business cases. Historically, before the current period of stagnation, availability-based payment mechanisms were frequently adopted in PPP arrangements, with governments committed to providing periodic unitary payments to private sector entities. However, following the rapid expansion phase of PPP development, the Chinese government has increasingly recognized the long-term fiscal implications for local governments, as prolonged payment obligations significantly strain their financial stability. Consequently, China's PPP model has evolved towards a user-pay system, where private partners recoup their investments predominantly through third-party user charges. Furthermore, government subsidies for PPP projects have been restricted, only permitting support for specific operational costs rather than covering initial capital investments [39]. This strategic shift reflects a deliberate effort to manage fiscal risks and reinforce financial sustainability in PPP development.

Recognizing the significant implications of PPP projects on public-sector affordability, China's Ministry of Finance mandates that government bodies at various administrative levels undertake a thorough affordability analysis prior to adopting a PPP model. If the proposed PPP project successfully meets affordability criteria, the responsible government entities must explicitly incorporate the corresponding financial obligations into their annual

budgets and long-term fiscal planning. Chinese interviewees broadly concurred that such proactive measures emphasizing affordability greatly benefit the development and sustainability of PPP projects, enhancing financial transparency and promoting fiscal discipline across governmental agencies.

In New Zealand, most PPP projects are concentrated within the social infrastructure sector. However, transport projects have also increasingly employed PPP models. Notably, the Transmission Gully motorway was delivered through a PPP using an availability-based payment mechanism. This approach shifts focus toward long-term affordability and budget predictability rather than short-term capital investment alone. Consequently, New Zealand interviewees highlighted the significance of affordability implications, stressing that careful financial planning is essential to sustain public support and fiscal responsibility. Participants NG5 and NG6 further elaborated on these affordability concerns:

> Compared to traditional procurement, the affordability of PPPs is about cost of finance and efficiency differentials. The current capital asset management guidance and practices require care for affordability. If analysis shows PPPs are unaffordable, possible remedies like adopting a different design can help to close the gap.

Affordability plays a critical role in determining the long-term performance and success of PPP projects [5,8]. Closely tied to affordability is the issue of fiscal sustainability, which underpins the concept of intergenerational equity [30]. If affordability is inadequately assessed, PPP procurement may lead to intergenerational inequity, wherein future generations inherit unsustainable levels of public debt or taxation required to finance today's infrastructure investments. The findings of this study highlight governments' increasing awareness of the significant financial implications PPPs have on their long-term budgetary practices. Specifically, China's shift toward a user-pay PPP model illustrates the government's prudent stance in thoroughly evaluating affordability risks associated with PPP arrangements. To safeguard the long-term viability and fiscal sustainability of PPP projects, it is imperative for the public sector to carry out a rigorous and accurate affordability assessment at the business case stage. Moreover, PPP structures should remain flexible enough to allow adjustments or reconfigurations that address any identified affordability gaps, thus securing equitable outcomes for both current and future generations.

4.3. Capability-Related Factors

4.3.1. Strong Public Sector Capability

The interview findings strongly suggest that public-sector capability is instrumental in developing robust and defensible PPP business cases, as indicated by the interviewees (18 from China and 20 from New Zealand). Given that both China and New Zealand are still developing their PPP markets, public procurement authorities often lack sufficient knowledge, expertise, and practical experience to effectively manage the complexities involved in PPP business case development. While participants from both countries demonstrated a general awareness of PPP principles, misconceptions and misunderstandings remain widespread.

For instance, participant CF2 highlighted persistent misconceptions within China's public sector: "There are some people in public sector entities supporting PPPs for the wrong reasons. They think it is about free private sector money". Similarly, participant NA3 from New Zealand noted that some public-sector officials mistakenly equate PPPs exclusively with Australia's toll road concession model, failing to appreciate the broader spectrum of available PPP frameworks—particularly the availability-based payment model, which offers distinct advantages in terms of risk allocation and public accountability. These misconceptions underscore the critical need for enhancing public-sector capabil-

ity through targeted education, training, and knowledge-sharing initiatives to support informed decision-making and ensure successful PPP implementation. Participant NN2 further emphasized:

> In terms of providing output specification, it is very difficult with [the public sector] have been used to. They are happy with the concept of it but find it very hard to do in practice. How to specify the outcomes through setting up a series of KPIs?

The interview findings indicated that the novelty of PPP procurement and the absence of widely shared practices are not the sole factors contributing to the capability gap within the public sector. More critically, prevailing cultural attitudes and procurement approaches in the public sector act as significant barriers to developing necessary capacities. Effective PPP implementation requires proactive collaboration among public-sector entities, builders, operators, facility managers, and financiers, enabling comprehensive discussions and the co-creation of solutions prior to the procurement phase. However, as highlighted by Participant NA2, the public sector often exhibits discomfort with these collaborative practices: "(The public sector) is not comfortable with the level of detail required. It is problematic for them to adapt to the discipline required for long-term asset management and operational solution development". Consequently, participants emphasized that a fundamental cultural shift within public institutions is essential to establish a robust and sustainable PPP framework. Furthermore, the initiation and planning stages of PPP projects were recognized not only as opportunities for delivering infrastructure but also as catalysts for broader public-sector reform, driving systemic improvements in capability, accountability, and operational efficiency.

Participants NG3, NG7, and NF1 opined that expert advice from external legal and financial advisors effectively supplements public sector experience and skills. This is largely because New Zealand's PPP framework is modeled after those of the UK and Australia, allowing international advisors to enter the market with minimal barriers. Once involved in a particular PPP, these advisors can leverage overseas experience to address challenges. In contrast, while Chinese interviewees acknowledged the benefits of engaging advisors, they expressed concerns about the capability and business ethics of the profession. For example, Participant CC2 reported:

> Some consultancy firms' areas of expertise are not in PPPs. They know PPPs are very popular and decide to transform their business. Some of them learn the basics about PPPs and go ahead working on projects. I highly doubt the quality of their professional services.

A highly skilled and experienced public procuring authority is essential for effective PPP implementation throughout the procurement process [16,28]. This research aligns with previous findings and underscores its particular significance in business case development. Unlike traditional procurement, which is often limited to a design-and-construct brief, PPPs integrate design, service delivery, and the asset's operational functionality. The whole-of-life focus—achieved through the full integration of upfront design, construction, and ongoing service delivery—necessitates a more rigorous analysis at the business case stage.

The public sector project team must mobilize the necessary resources to establish the fundamentals of PPP agreements. Guidance and support from the central PPP unit, along with external advisors, are crucial for addressing capacity gaps. This research also recommends fostering a cultural shift across the public sector to enhance the adoption of PPPs, which could improve overall procurement decision-making—even in cases where a PPP model is ultimately not implemented.

4.3.2. Public Sector Commitment and Credibility

During the business case stage, market-sounding exercises are conducted with potential market players. Incorporating market feedback to refine key aspects of PPP transactions (e.g., contractual and financing structures) helps ensure a well-founded business case. New Zealand participants reported that, due to the country's high standards of public sector governance, they had confidence in the government's commitment to projects. The credit quality of public authorities is sufficient to support their commitments. Despite this, Participants NG5 and NN2 reiterated:

> When we initiate a PPP program, it is crucial that we adhere consistently to our stated intentions. Any commitments made during the market sounding process must be rigorously upheld. If we deviate from these promises or demonstrate uncertainty, it creates anxiety within the market and undermines stakeholder confidence.

> We indicate to people at the time we are going to detailed business case. That is prior to being approved as a PPP. The market knows that we are undertaking a serious investigation as opposed to a preliminary one. We are careful with what we publicize so people don't have to run around.

The Chinese interviewees highlighted significant concerns regarding the credibility and trustworthiness of public sector entities, citing a historical pattern of government bodies neglecting contractual obligations and reputation when interacting with market participants. Participant CC1 articulated these frustrations from the perspective of a construction contractor:

> As a construction contractor, we frequently experience frustrations in our dealings with public sector clients. They often lack what we refer to as the 'contract spirit', meaning commitments outlined in contracts are not consistently respected. When disputes arise, we encounter considerable obstacles; we cannot even pursue legal action effectively, since, under current Civil Law, these public sector bodies are often not recognized as fully accountable legal entities.

This sentiment underscores deeper institutional challenges in China's PPP environment, particularly the need for strengthened legal frameworks and improved governmental accountability mechanisms to support successful PPP implementation.

In addition to the credibility issue, private sector participants further emphasized that having a committed public sector procurement team is instrumental in leading the business case process. Participant CF4 elaborated: "You have many challenges throughout the process. If the project team doesn't commit to overcoming the challenges, PPP proposals can be easily called off". Involving high-level government officials provides a useful means of addressing various challenges, such as coordinating with different government departments and enhancing the level of public sector commitment.

The research results align with conclusions that a dedicated, committed public sector procurement team with a high level of credibility is desirable in PPP projects [61]. Compared to the contract management stage, where public sector commitment and credibility are primarily reflected in fulfilling contractual obligations and maintaining partnerships, the development of the business case requires the procurement team to be proactive in driving the process forward and consistent in the messages they deliver to the market. PPPs represent complex contractual structures and unique commercial principles, which place considerable pressure on the public sector to prepare the business case. Only with a committed and credible team can an optimized PPP profile be achieved, ensuring that market appetite is accommodated.

4.4. Organisational Factors

4.4.1. Streamlined Institutional Arrangements

Institutional arrangements, specifically defined roles and authorities in relation to capital asset procurement, attracted significant attention from fifteen interview participants (nine from China and six from New Zealand). They emphasized the need for streamlined arrangements to facilitate informed and efficient decision-making. Participant CA1 believed that lacking a coherent and consistent approach toward PPPs would create considerable confusion for line agencies and local governments. Streamlined institutional arrangements are strongly needed.

Compared to China, New Zealand's central coordinating authority has a clearly defined role in PPPs. However, interview participants expressed significant doubts regarding the decentralized institutional arrangements for capital asset procurement. Participant NL1 stated: "The Treasury may be there telling the Department what to do. But lots of expenditures are not placed by the Treasury". The independence of decision-making at various levels of public sector bodies is not conducive to advancing a PPP. Participants NC2 and NA1 argued:

> PPPs would be difficult where there are many local boards involved in the decision making, such as the current practices with the education sector. The Ministry of Education is responsible for the provision of school assets. But the school boards take charge of the maintenance based on its annual maintenance fund. The fragmentation of procuring power makes it difficult to take a whole of life perspective towards capital asset delivery.

> In the health sector, we've got multiple DHBs (District Health Boards). When it comes to PPPs, we need centralized power to make decisions, rather than many DHBs as we've got.

This research identifies institutional arrangements, which have not been mentioned in the existing literature, as an important factor affecting the business case stage of PPP projects. Business case development falls under the responsibility of government departments, public agencies, or local governments. Typically, multiple organizations have direct or indirect influence on public service provision, such as the central coordinating authority, the public procuring authority, and the Board of Trustees. The involvement of multiple entities is likely to result in role duplication, overlapping responsibilities, and decentralized decision-making power. This research, therefore, recommends the establishment of streamlined institutional arrangements for capital asset procurement.

4.4.2. Effective Governance Structures

Thirteen Chinese and eight New Zealand interviewees stated that effective governance structures should be established to ensure a smooth business case process. The progression of PPP proposals requires approvals from various government departments. Project development involves coordination with a wide range of departments, including finance, development and reform, construction, and taxation. Therefore, it is crucial to establish a steering committee comprising the public procurement team, officials from different departments, representatives from various government levels (e.g., municipal, provincial, and/or central), and external expert advisors. The steering committee oversees the process, coordinates with relevant parties to obtain necessary approvals, and addresses issues that arise at different stages.

The New Zealand participants agreed with their Chinese counterparts that clear and responsive governance structures are essential to ensuring appropriate actions are taken in a timely manner. Participant NG7 elaborated on the four-level governance structure

adopted in existing PPP projects, as shown in Table 3. A procuring authority establishes a dedicated project team to manage the process, led by a qualified Project Director and a Project Governance Group. This team consists of in-house personnel and external advisors, covering technical, service, commercial/legal, and project management aspects.

Table 3. Recommendations based on the identified critical factors.

Category	Critical Factor	Recommendations
Contextual factors	Political champion	• Governments should take a reasonable and fair view towards the adoption of PPPs. • Governments must fully understand the nature of PPP projects and the country's social, economic and legal environments to set out policy directions of PPPs. • Following clear policy directions, governments must develop PPP model and policy suited to the country's specific contextual elements.
	Enabling legal and regulatory framework	• For countries with civil law system, a systematic legal framework should be established with a national, high level PPP law providing the basic features of the country's PPP model. • Guidance and standardized documents should be established to provide practical guide to undertake PPP procurement.
Procedural factors	Sound service need analysis	• Public procuring authorities must endeavor to conduct a well-elaborated service need analysis to make sure the service is viable in the long run. • Sustainability requirements that must be answered during the service need analysis. • A program-level view is preferred when evaluating the service need to ensure the proposed project is in line with the government's wider capital asset procurement framework and overall policy objectives.
	Robust procurement option analysis	• A robust value for money assessment is required to be undertaken for procurement option analysis. • A quantitative analysis method, the PSC, is recommended to be adopted. • Qualitative factors, especially the sustainability considerations should be considered in evaluating PPPs.
	Articulated affordability analysis	• Public procuring authorities need to rigorously examine the financial implications of a PPP proposal on the government's long-term budgetary position. • When proposal exceeding the affordability threshold, PPPs will be excluded from the option list, or alternatively, supporting measures such as reconfiguring the service scope and change of outcome specifications may be adopted to close the affordability gap.
	Public sector commitment and credibility	• The public project team should be committed to the business case process and value their reputation and credibility during market sounding.
Organisational factors	Streamlined institutional arrangements	• Streamlined institutional arrangements, with clearly defined roles and responsibilities in capital asset procurement are desirable to achieve an efficient business case process.
	Effective governance structures	• Effective governance structures and clear lines of reporting should be established with different levels of government officials positioned at right levels of the governance structure.

The Treasury PPP advisors work closely with the project team to provide an understanding of the New Zealand PPP model and policy and to assist with developing the economic, financial, and commercial cases of a project's business case, such as risk analysis and the development of a PSC. At key milestones, approvals are required from Joint Minis-

ters (the Minister of Finance and the Minister responsible for the procuring authority). A subcommittee within the Cabinet is established once the business case is submitted to the Cabinet agenda. Participant NN2 commented:

> The project steering committee was formulated at the outset. They meet monthly. The core project team meet every week. Any existing or potential barriers can be addressed in time. The Treasury PPP team holds their [the project team] hands to make sure they are on the right track.

The research results align with prior studies, confirming that good governance is essential for managing the procurement process in PPPs [12,32]. Compared to traditional procurement, the whole-of-life focus of PPPs inherently requires a greater upfront investment of time and resources. Therefore, it is crucial for the public procuring authority to adequately resource its project team and establish effective governance structures. In contrast to the service delivery stage, where governance structures typically involve establishing clear reporting lines for contract administration and service performance monitoring, the business stage focuses on setting up responsive governance structures. This involves resourcing different levels of governance with the right individuals (e.g., PPP specialists, ministers) to facilitate informed and efficient decision-making.

4.5. Comparative Analysis and Recommendations

A comparative analysis of PPP practices in China and New Zealand, drawing on insights from experienced industry practitioners, reveals both notable similarities and distinct differences in the implementation approaches adopted by the two countries.

Both nations have actively pursued PPP programs in recent years, with their respective practices significantly shaped by domestic legal, regulatory, and policy frameworks. In China, PPP implementation initially experienced rapid growth marked by varied regulatory practices and shifting policy directives. However, recent refinements in policy objectives, especially the clear transition towards the user-pay PPP model, have resulted in a more disciplined and stringent project-selection process. Consequently, there has been a marked reduction in the volume of PPP projects progressing to the procurement phase.

In contrast, New Zealand's approach to PPPs has evolved more incrementally. The government has continuously adapted and enhanced the PPP model based on lessons learned from completed projects. Recent modifications in risk allocation, affordability thresholds, and collaborative tendering practices have collectively contributed to significant improvements in the government's approach to planning, procuring, and delivering future PPP initiatives.

Practitioners from both countries emphasized the critical importance of clearly defining the service need prior to embarking on PPP projects. China's expansive economy and substantial infrastructure development demands led initially to a significant pipeline of PPP projects. Nevertheless, participants noted that during the rapid expansion phase, local governments occasionally expedited service-needs analysis prematurely, pushing projects into the national PPP database without thorough vetting. Many of these projects were later abandoned during the stagnation stage, creating problematic PPP arrangements. In comparison, New Zealand has pursued a notably more selective approach, successfully completing only eight PPP projects since 2011. Given the relatively limited project pipeline, New Zealand has prioritized a streamlined procurement process and attractive project packages (such as bundling several smaller-scale projects together) to reduce transaction costs and maintain the interest of private-sector investors.

Both countries have recognized the significant long-term financial implications of PPPs on government fiscal positions. China has explicitly shifted toward a user-pay model to mitigate government fiscal liabilities. New Zealand, on the other hand, has increased the

affordability threshold within the Public Sector Comparator (PSC) analysis to ensure the economic sustainability and fiscal prudence of PPP arrangements.

Finally, interviewees from both contexts strongly agreed that successful PPP implementation fundamentally depends on the capability, commitment, and credibility of public sector entities. Besides leveraging advice and support from central PPP units or external legal and commercial consultants, public procuring authorities need continuous investment in enhancing internal procurement capability. Additionally, they must foster a culture receptive to innovation, collaboration, and flexibility within public-sector procurement systems to ensure successful, sustainable PPP outcomes.

5. Conclusions

PPPs have gained increasing popularity worldwide for the provision of public assets and associated services. The success of PPP execution largely depends on the effectiveness and efficiency of business case development. Therefore, this research aims to conduct a comparative analysis of the critical factors influencing the successful development of PPP business cases in China and New Zealand. Based on this analysis, useful and practical policies and management interventions are proposed to enhance business case development processes.

Through a systematic literature review and semi-structured interviews with forty-six PPP stakeholders from China and New Zealand, this study identifies nine key factors, categorized into four groups, that are crucial for business case development in PPP projects: (1) contextual factors, including political champions and enabling legal and regulatory frameworks; (2) procedural factors, comprising sound service needs analysis, robust procurement option analysis, and well-articulated affordability analysis; (3) capability-related factors, consisting of strong public sector capability, as well as public sector commitment and credibility; and (4) organizational factors, such as streamlined institutional arrangements and effective governance structures.

5.1. Implications

This research extends the growing literature on critical success factors (CSFs) for public–private partnerships (PPPs) by identifying the key factors that affect the successful development of a business case. These identified factors serve as a foundation for determining the essential policy and management activities that must perform well during the business case stage. This study contributes to PPP project management practices by highlighting the "good practices" specific to the business case process. By adopting the recommended strategies, governments can make more informed decisions regarding the introduction and updating of PPP policies. Additionally, public procuring authorities will be better positioned to plan, structure, and implement business case development, thereby enhancing current practices.

It is important to note that PPPs are one of the procurement options available to governments. Therefore, the strategies and measures proposed in this research not only serve as indicative guidelines for business case development in PPP projects but also apply to broader public-sector capital asset and service provision, with appropriate adjustments based on specific contexts. It is hoped that the insights gained from PPP business case development will benefit wider public-sector procurement practices.

5.2. Limitations and Future Research

This research has limitations that future studies can address and expand upon. Based on semi-structured interviews, a list of critical factors for the successful development of a PPP business case was derived. However, the relative importance of each factor

remains unknown. Additionally, the forty-six interviewees do not fully represent the population from which they were drawn, raising concerns about the generalizability of the research findings.

Future research could employ a large-scale questionnaire survey to collect quantitative data and statistically assess the importance of these factors. Furthermore, this study conducts a comparative analysis of PPP business case development practices in China and New Zealand based on the perceptions and insights of PPP stakeholders from both countries. It remains uncertain whether the identified critical factors and proposed recommendations are applicable to other economic, social, and policy contexts. Future research could explore PPP business case practices in other jurisdictions to facilitate meaningful comparisons with the present study, thereby enhancing the generalizability of the findings.

Moreover, this paper does not focus on specific industry sectors. Future studies may adopt case study approaches to identify critical factors for PPP business cases that are specific to sectors.

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Exploring Briefing Processes across Mature Markets of Public–Private Partnership (PPP) Projects: Comparative Insights and Important Considerations

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Abstract: The primary objective of this research paper is to conduct a comprehensive investigation into the process of developing briefs for Public–Private Partnership (PPP) projects. The study aims to outline the fundamental stages, standard processes, and critical decision points involved in this process. This is achieved through a comparative analysis of briefing frameworks used in three countries that are among the top in the PPP Market Maturity chart: The United Kingdom, Australia, and Canada. The paper discusses the stages and decision points within these countries' briefing processes, highlighting their challenges, similarities, and differences. It emphasizes the fundamental role of effective communication and coordination in PPP projects, which involve multiple stakeholders. By examining these interconnected activities and analyzing the phases, stages, and key processes constituting the briefing process, the study provides valuable insights into the PPP briefing processes in these nations. The paper concludes by proposing a conceptual process framework for brief development in PPP projects, which will be further tailored for adaptation in the PPP market in the United Arab Emirates.

Keywords: briefing process; decision points; public–private partnership (PPP); comparative analysis

1. Introduction

The project briefing is the process by which the client's needs are investigated, developed, crystallized, and communicated to the supply side of the construction industry [1]. The briefing process, known in North America as Architectural Programming, is considered the initial step toward establishing an effective client–architect/designer relationship. It is a vital stage of every project and must be planned and responsive to the client's needs. The project brief should be clear and workable, providing a sound basis for the project's needs and design [2]. A clear project brief aids in reducing brief changes, design changes, and construction changes throughout project delivery. According to [3], a clear and comprehensive project brief is crucial for project success, particularly in the construction industry, as it can reduce changes and errors, ultimately improving cost and time performance.

The briefing process is considered the keystone for achieving client satisfaction due to its crucial role in eliciting and communicating the client's requirements to the design and construction teams [4]. Most of the significant decisions made during the briefing stage of any project will have a far-reaching impact throughout the project's life cycle. Clients are at the core of all project processes; satisfying them is considered the main measure of project success; this is why the briefing must be well planned to respond to the client's needs. Research work by [5] emphasized that clients' satisfaction can be achieved by meeting two requirements: first, translating their needs into a design that specifies the criteria and

quality standards for the technical characteristics and functional performance of the work and second, completing the project on time and in the most cost-effective manner.

The client's requirements are normally captured in briefing documents, which record them in a documentary form known as the "brief". This is a means of communication and interaction between the client and the architect. For architects and others involved in a construction project, the brief should provide a clear overview and understanding of the needs and ambitions of the client in accommodating the work of his/her organization. In addition, the brief document functions as a "touchstone" for testing the design proposals, where alternatives can be compared. It helps to structure the debate between the client and architect about the quality and value of the design proposals. Hence, the importance of this document comes from its serving as the basis of the facility's planning, design, and technical work at different stages [6,7].

In the context of the PPP procurement method, project delivery is a highly complex process involving multiple stakeholders and multidisciplinary inputs from numerous participants. This contributes to the complexity of communication and coordination, making the briefing process one of the most important stages.

2. Research Methodology

The research presented in this paper is the first part of a comprehensive research project. The main aim is to develop and validate a process framework for PPP briefing, with a specific focus on the PPP market in the United Arab Emirates (UAE). The development of this framework aims to enhance the efficiency and effectiveness of the brief development of PPP projects in the UAE. The framework's development is divided into two main stages:

- The first stage is aimed at reviewing PPP briefing, stages, and processes in general, and briefing practices in the mature PPP markets in particular through conducting a comparative analysis of the briefing frameworks of three countries that rank highly on the PPP Market Maturity level. This step led to the development of a "Generic Conceptual Process Framework for the Development of Briefs in PPP Projects".
- The second stage has two main methods. First, case studies and document analysis are proposed to localize the above conceptual framework for the UAE PPP market. This is followed by structured interview sessions with experts from the UAE PPP market to finalize and validate the above preliminary framework. The output of this process will be the final Process Framework for PPP brief development with special reference to the UAE construction industry. See Figure 1 for more details.

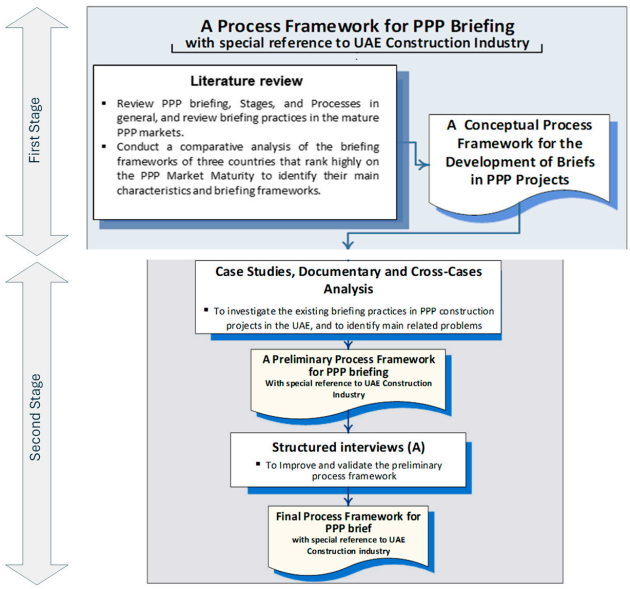

Figure 1. The research methodology to develop a systematic process framework for PPP brief development with special reference to UAE construction projects.

Figure 1 illustrates the research methodology stages and main processes and outcomes. This paper details the first stage and outlines the creation of a Generic Conceptual Process Framework to guide the development of briefs in PPP projects.

3. The Brief Development: Stages and Processes

The briefing process is the preliminary stage in the design process. It is considered the initial step toward establishing an effective client-architect/designer relationship. Successful briefing can ensure project delivery, on target time, cost, and quality [8]. Several studies highlighted the critical role of construction project briefing in achieving successful project delivery. Both [3,8] emphasize the importance of a clear and comprehensive client brief in reducing change orders and improving project performance.

The briefing process is often referred to and developed through a stage or a series of stages in the design or construction process, representing a part of the overall life cycle of the construction project. It is usually developed through a systematic approach of inquiry by which the client's requirements are made explicit and understandable. In their review of the brief development process, research by [9] claimed that there are two main schools of thought on construction project briefing: one views the brief as a static entity that is finalized after a critical period, while the other sees it as a dynamic document that evolves iteratively through a series of stages from an initial global brief, thus being an ongoing activity during the early project life cycle.

Fundamentally, the briefing process can be divided into two main stages: strategic briefing and project briefing [10–12]. The strategic stage aims to review the stated requirements in light of the objectives by identifying the organization's needs to determine if a building of a specific type and in a particular location is the most effective solution [13]. According to [14], a strategic briefing study should describe the mission of the business project and its strategic fit with the corporate objectives of the client organization. It is suggested that corporate objectives should be explicit in terms of commercial goals and implicit in terms of cultural values, with the client's value system being formed by a combination of these objectives and values. One advantage at this stage is the opportunity to discuss a range of options for delivering the business project, helping strategic management make informed decisions by providing unambiguous information before advancing to the next stage.

The second stage, project briefing, involves making tactical decisions. The project brief translates the strategic brief into physical terms according to the design specification [15], specifying the performance requirements for each project element. Ref. [14] argued that the project brief is the "construction industry's response to the client requirements expressed in the strategic brief". Project requirements encompass several sets of criteria, including those related to the client, user, site, environment, regulations, design, construction, and life cycle [16]. It is worth noting that researchers generally agree on this separation of the briefing process [11,14,15,17–20].

The RIBA Plan of Work is the most common document used in the UK to describe the different stages of construction projects. The evolution from the RIBA Plan of Work 2007 to the 2020 version reflects advancements in the process of brief development of projects.

In the 2007 Plan, brief development starts with Stage A: Appraisal and Stage B: Design Brief. The Appraisal stage identifies client needs and objectives, laying the groundwork for the project. The Design Brief stage then develops these initial requirements into a detailed project brief, outlining specific needs, goals, and design parameters, where the Project Brief is completed through the design development stage. The 2013 Plan introduces Stage 0: Strategic Definition and Stage 1: Preparation and Brief. Strategic Definition focuses on high-level project goals, resulting in a Strategic Brief that addresses site selection and project scope. The Preparation and Brief stage builds on this by developing a detailed project brief through feasibility studies and early design considerations, ensuring alignment with strategic goals and a finalized design program.

Finally, the 2020 Plan refines the 2013 approach, with refined outcomes for each stage, and maintaining Stage 0: Strategic Definition and Stage 1: Preparation and Brief. Strategic Definition involves strategic appraisal, resulting in a Strategic Brief that outlines key project outcomes and considerations. The Preparation and Brief stage further develops the project brief, incorporating feasibility studies and stakeholder engagement to ensure clear alignment with strategic objectives, agree on project brief derogations, and finalize the design program. Figure 2 compares the RIBA Plan of Work 2020 with the RIBA Outline Plan of Work 2007.

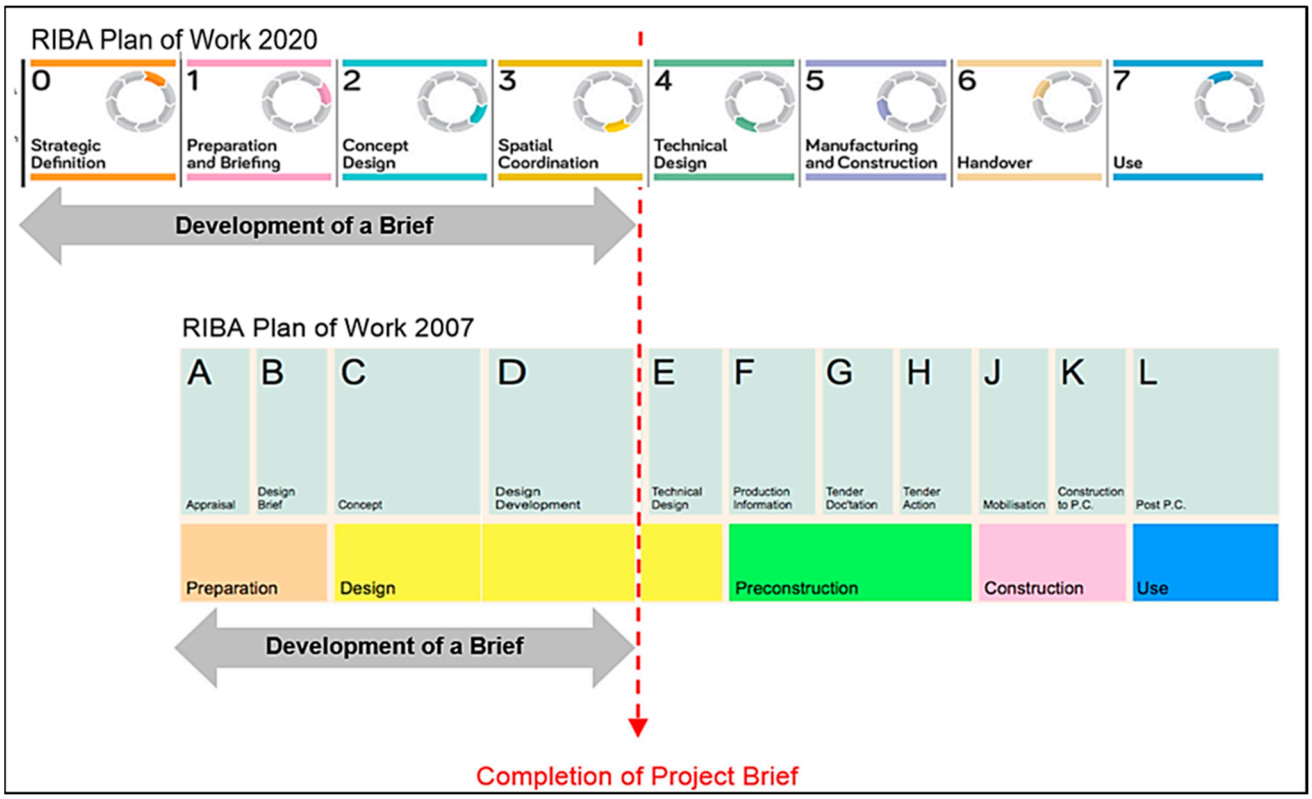

Figure 2. RIBA Plan of Work 2020 compared with RIBA Outline Plan of Work 2007—developed based on [21,22].

The briefing process usually involves actively archiving data to enhance the documentation of lessons learned by collecting, organizing, analyzing, identifying, interpreting, compiling, and presenting all essential information required for a construction project [23]. However, the briefing process frequently encounters execution problems that can ultimately impact its effectiveness. Despite being crucial for successful project delivery and client satisfaction, the process is widely acknowledged as needing improvement [24]. Many issues in construction projects can often be traced back to deficiencies in the briefing stage [9,25].

Briefing in PPP Projects

PPP projects can be executed through various modes, each tailored to the specific needs and circumstances of the project. Research by [26] has investigated and identified the various execution modes of PPP infrastructure projects. The BOT type is commonly used worldwide, especially in tolled roads and highways PPP projects, followed by BLT, BOOT, and O&M PPP contracts.

As explained in the previous section, the briefing process takes place during the early stages of a project's development. In PPP projects, a briefing session typically occurs about halfway through the bid preparation period [17]. Appropriate PPP briefing is crucial for large-scale infrastructure projects like transportation, public utilities, and healthcare facilities. Transportation projects (highways, bridges, railways, airports) require detailed

planning for logistical, financial, and operational demands. Research [22–24] discusses the legal, financial, and operational challenges of PPPs in transportation projects. Identified challenges include complex concession agreements, risk sharing, and the need for new evaluation tools and risk transfer mechanisms.

For public utilities (water supply, waste management, energy), important issues that should be well investigated in brief development include technology integration and regulatory compliance. According to [22], the challenges in PPP public utilities are multifaceted, including the need to balance political control with managerial autonomy.

In the case of healthcare, facilities require precise briefs for construction and operational efficiency, including patient care standards. According to [27,28], the challenges of PPPs in healthcare facilities include inadequate risk management models, difficulty in reaching agreements, project complexity, a lack of bankable project agreements, institutional capacity, risk allocation, and environmental and social impact assessments.

4. Briefing Practices in the Mature PPP Markets

Different countries around the world follow unique paths in developing PPP infrastructure, influenced by local geography, political climate, capital market sophistication, and the driving forces and factors favoring partnerships. Various stages of understanding and sophistication in using innovative partnership models are required to bring a country's PPP program or market to maturity.

The "maturity" analysis of PPP programs worldwide was investigated by [29]. The research compared the maturity of PPP markets in several countries, using typical success factors based on their levels of sophistication and activity. Following that [30], in 2011, reviewed and updated this maturity analysis. Furthermore, [30] explained that PPP maturity worldwide can be categorized into three distinct stages: stage one, the developing PPP market; stage two, the active PPP market; and stage three, the well-functioning and mature PPP market. The curve analysis of the compared PPP mature market curves generates the following findings:

- The overall ranking of countries in PPP maturity levels changed due to the global financial crisis in 2008 and its aftermath, which is shown in arrows.
- The UK and Australia are the most mature adopters of the PPP model, outdoing many industrial countries in reaching Stage Three. In contrast, the Canadian market has moved towards Stage three in giant steps.
- Many European countries are either improving their position to the advanced stages or starting their journey to maturity.

PPP processes, including the detailed briefing stage, are investigated and analyzed in three of the most mature countries. This analysis breaks the process down into major stages, which are further subdivided into phases. The main processes within these phases, along with their inputs, expected outputs, and main implementation challenges, are identified in the following sections.

4.1. Briefing Practices in the UK PPP Projects

PPPs in the UK have developed mainly through the Private Finance Initiative (PFI) model; various studies by UK researchers have indicated the high success rate of this procurement model in the UK [11]. According to [31], the UK's "Private Finance Initiative" was launched in 1992. It is a specific type of PPP contract which bundles construction, operations, and maintenance into a single contract. PFI projects generally have a life span of approximately 25 years; numerous PFI projects are ongoing.

PFI traditionally involves establishing a Special Purpose Vehicle (SPV) to raise capital and undertake the project. This SPV is then run throughout the life of the infrastructure to receive payment over the life of the agreement with the public body [13]. PFI has traditionally been associated with social infrastructure such as health, education, and housing—although the model has been used for other infrastructure such as transporta-

tion [31]. Various studies by UK researchers have indicated the high success rate of this procurement model in the UK [14].

The PFI development process sequence appeared in the RIBA Outline Plan of Work 2007 [21]. This plan organizes the process of designing and managing building projects, as well as administering building contracts, into a number of key Work Stages. It illustrates the Work Stage sequences for different procurement methods. According to the RIBA Outline Plan of Work 2007 [21], the PFI Work Stage sequences are grouped into four main stages as illustrated in the RIBA Plan: (i) Preparation stage, (ii) Tender/Negotiations stage, (iii) Construction stage, and (iv) Use. Based on the PFI model of the Office of Government Commerce (OGC), this Plan of Work was issued in 2008 by the Royal Institute of British Architects. Furthermore, the briefing stage is located within the preparation and tender/negotiations stages. Those two stages examine such technical and financial issues as preparing the business case for the project, the invitation and pre-qualification of potential bidders, design, finding solutions, evaluation of bids to determine value for money and affordability, selection and negotiation of a contract with the preferred bidder, financial close and development of the full business case for the PFI project.

The UK segments the various phases of PPP projects through gateways (OGC) from 1 to 5, the first three gateways constituting the briefing stage. In the initial phase of Gateway 1, a strategic assessment is made to ensure the project meets the business needs. In Gateway 2, the business justification is evaluated, and recommendations for improvements are offered. Gateway 3 is the procurement strategic phase, which gauges the project's potential and ability to succeed.

It is worth mentioning that the RIBA Outline Plan of Work 2013, which was further refined in the 2020 version, does not specifically include diagrams or detailed guidance exclusively for PPP/PFI projects as seen in the 2007 version. These versions focus on a broader approach to project planning and management that can be adapted to various procurement routes but without dedicated diagrams for these specific methods.

In December 2012, the PFI procurement methods were replaced by a similar but updated approach called Private Finance 2 (PF2). According to [31], new improvement elements of PF2 include centralized procurement units for specific sectors, an 18-month cap for competitive tendering, the government acting as a minority equity investor, private sector equity competitions, a shift in risk allocation towards the public sector, increased standardization of contract documents, and the removal of soft facilities management from contracts.

Research by [32] investigated the challenges of the PFI model in the UK and identified issues such as inaccurate use of public sector comparators, skill strengths and deficits in the public sector, misallocation of risks, higher risk premiums charged to the public sector, complex and rigid PFI contracts, and lack of transparency. In a detailed case study by [33], the possible failure of a major transportation project in the UK was investigated. The study found several challenges and reasons for failure, including poor infrastructure conditions, lack of financial and risk management systems, poor corporate governance of the private sector company, the inability of the public sector to manage the contract, and a tied supply chain. A recent study identified the need for effective governance and stakeholder management as important challenges to PPP implementation in the UK [34]. Research by [33] also highlighted potential negative consequences, such as limited transparency and reduced government flexibility.

Successful implementation of PPPs requires a clear legal framework, risk allocation, and value-for-money objectives [35]. Analyzing the variety of risks and factors is essential before implementing the project [33].

4.2. Briefing Practices in the Australian PPP Projects

The practice of using the public–private partnership (PPP) model for the delivery of large-scale projects in Australia has been well established and has played a crucial role in the country's infrastructure development. According to [36], Australia is a world leader in PPP infrastructure delivery, with over two decades of experience in providing civil

and social infrastructure services through PPP concessions. Along the way, public and private participants in these projects have developed the practices and a mature institutional framework necessary for managing long-term, high-risk public–private commercial partnerships. Most PPP projects are undertaken in New South Wales (NSW), Victoria, and Queensland [37]. Moreover, New South Wales and Victoria have taken quick action to profit from their accumulated experiences in PPP infrastructure projects, compared with Western Australia, which preferred to use more PPPs with an alliance agreement [38,39].

According to [40–42], the PPP project development cycle generally comprises three main stages: (i) the project strategy stage, (ii) the project options stage, and (iii) the project delivery stage. The PPP process content of the activities of Partnerships Victoria [40] and the NSW [42] are the same. See Figures 3 and 4.

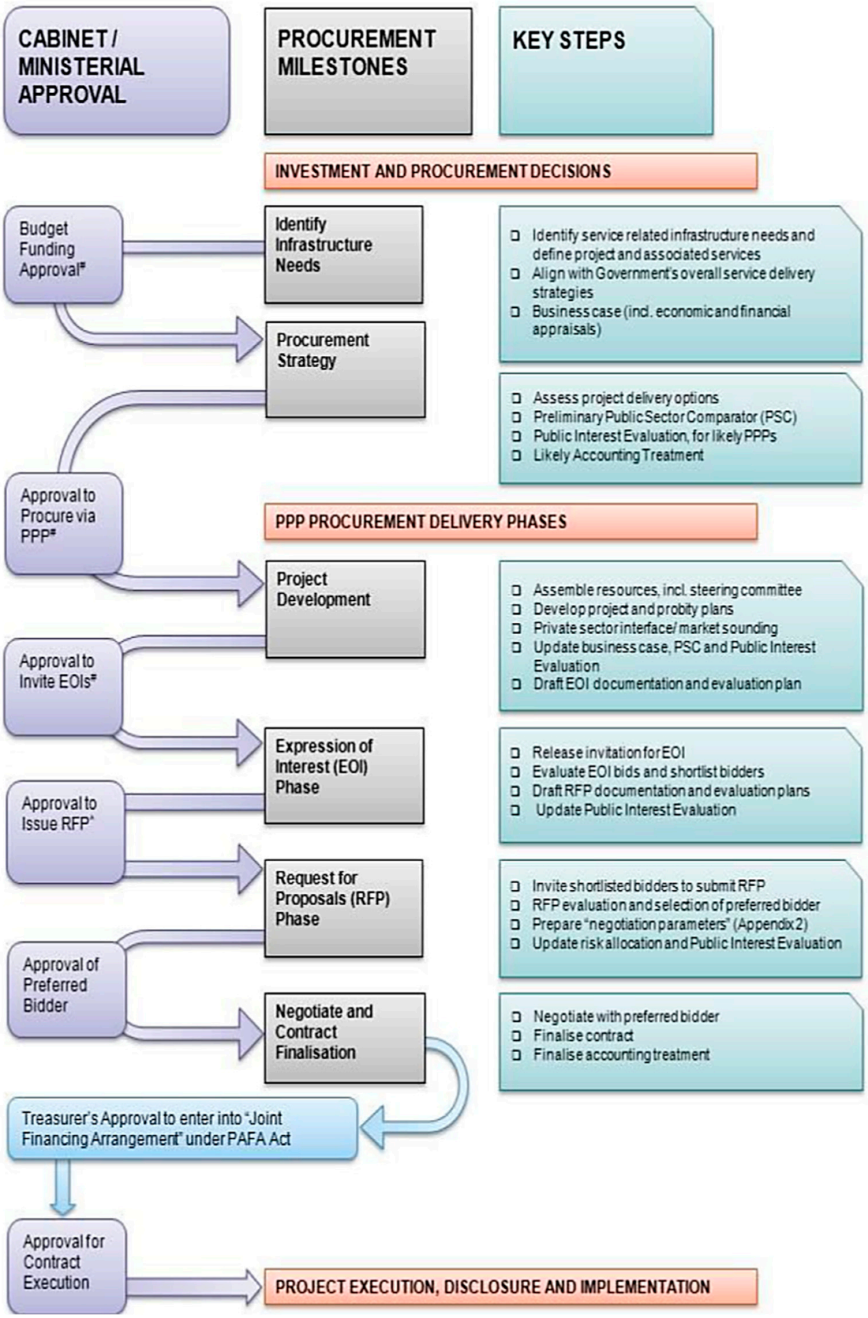

Figure 3. Phases and activities of the PPP delivery process in Australia—Phases of government approval in NSW—source: [42].

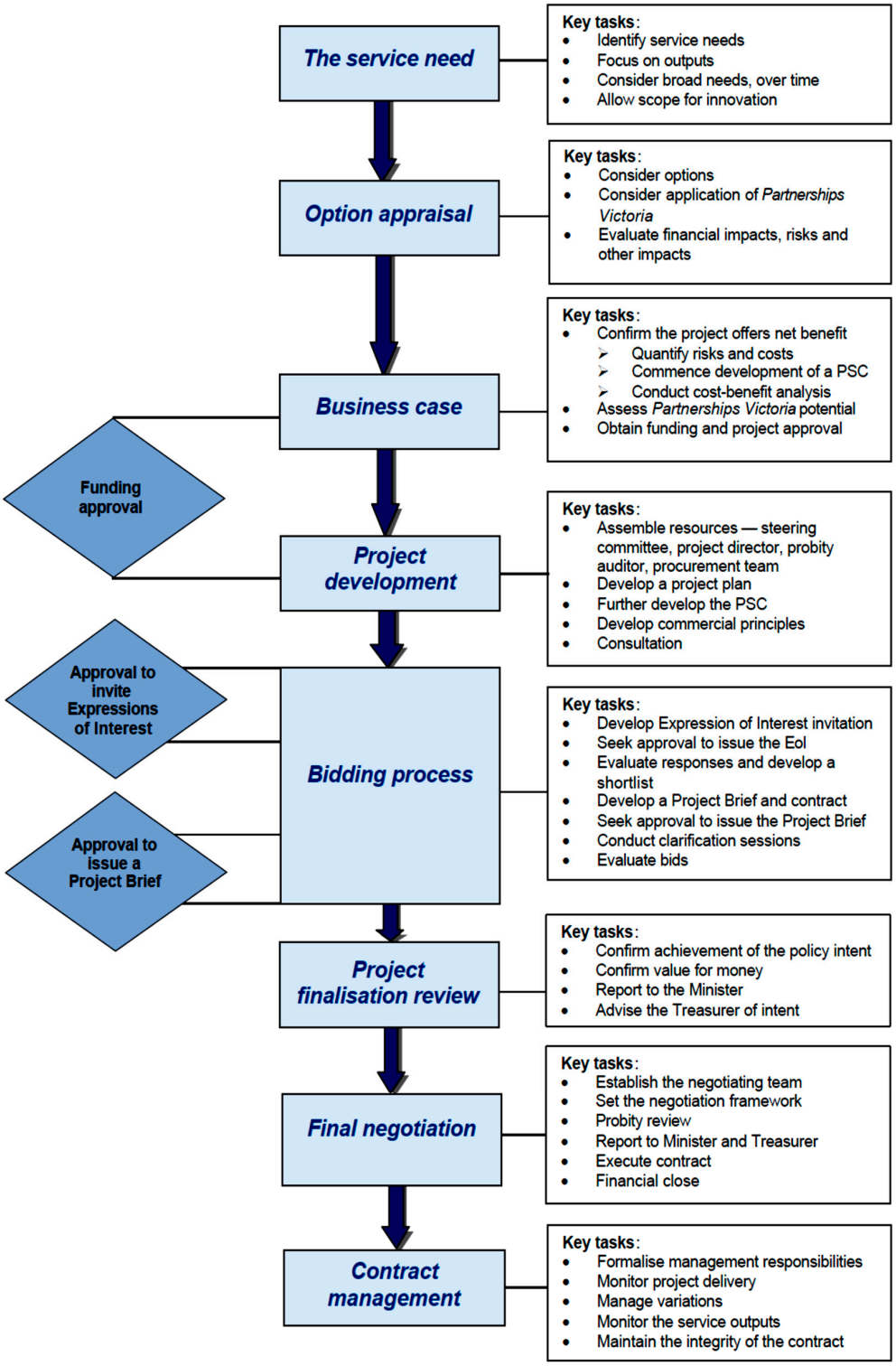

Figure 4. Phases and activities of the PPP delivery process in Australia—Major stages in developing a Partnerships Victoria project—source: [40].

Government approval will be required at various project milestones throughout the PPP procurement process. Figure 3 illustrates the government approval process and required documentation in NSW. The figure depicts two main stages: on a strategic level, the investment and procurement decision, where project needs and requirements are identified, followed by identifying options for the procurement strategy. After this, the project moves to the "procurement delivery phases", where the project brief is developed

further by identifying project parameters and resources, moving through the Expression of Interest phase (EOI), and then the Request for Proposal phase (RFP). Following that, the project will go through negotiations and contract finalization with bidders and receive final approval before moving to the execution stage.

According to the definition and timing of the process, the development of a brief in Australia should be in operation from the time of identifying a set of service needs up to the end of the bidding process. For example, according to [40], the PPP briefing process should encompass five major phases: identifying the services needed, options appraisal, business case preparation, project development, and reaching the bidding process. During the briefing process, a "gateway" approval of the PPP (by a special committee) is required for three major decisions: (i) project selection to proceed with the development of the business case; (ii) before issuing requests for expressions of interest; and (iii) before issuing project briefs and a contract. In analyzing this process, it is evident that high priority is given to clear communication with all stakeholders, particularly the bidders, to ensure that all variations are well understood in good time.

The challenges facing PPP implementation in infrastructure projects in Australia were investigated by [43]. Failure factors and lessons learned in two major PPP projects (road and light rail) were examined. The main challenges reported are inadequacy of business cases, independence of transport agencies, political interest, and limited objectivity in the Treasury office. The authors recommended several important points, including acknowledging the skills of key stakeholders and properly managing their involvement and interests in PPP mega projects, and accommodating political interest as part of the risk area in policies and National PPP Guidelines, as it improves public accountability in decisions taken during the development of the PPP project.

4.3. Briefing Practices in the Canadian PPP Projects

Public–private partnerships (PPPs) have been increasingly utilized in Canada for large-scale public infrastructure projects, with the government playing a significant role in funding and governance. Across Canada, governments at all levels have increasingly embraced PPPs as their preferred approach to delivering large-scale public infrastructure [44]. Since the mid-1990s, Canadian governments, like those in Europe and Australia, have been heavily involved in PPPs in capital-intensive infrastructure sectors, such as transportation (roads, airports, and bridges), water and wastewater, hospitals, recreation facilities, power and energy, and other facilities. Moreover, PPPs have been used to provide many other smaller projects [45,46].

Like Australia, Canada has a worldwide reputation for its procurement process in terms of efficiency and its track record of taking transactions through the procurement process to the financial close. Figure 5 describes the entire Canadian Public–Private Partnership process, as extracted from the Canadian Council for Public–Private Partnerships [47]. The delivery of a PPP project goes through three main phases: (i) planning (the pre-procurement stage), (ii) procurement, and (iii) contract management (operation). The detailed key tasks and major deliverables in each stage are shown in the same figure.

As can be noticed from Figure 5, the development of a project brief goes through two main phases: the planning and procurement phases. In planning, the project scope in terms of its requirements will be developed, screening different options as well as assessing the risk and cost of different project options. A project scope and feasibility study are the main deliverables of this stage. Following that, during the procurement phase, the project brief will develop in terms of its parameters and resources, moving through the request for qualifications, request for proposals (RFP), and then negotiation with bidders to finalize the project agreement. The project then moves to the execution phase.

Like Australia and the UK, the implementation of Public–Private Partnerships (PPPs) in Canada faces several challenges. Research by [44] investigated possible challenges and highlighted high upfront costs, limited community consultations, and a procurement process that hinders design excellence. Similarly, [48] argued that the presence of key

stakeholders as drivers of P3 policy was critical to the trust that industry participants placed in the process. They stressed the extreme importance of the internal capacity of the public sector. In many provinces, it is mandatory for P3s to employ the public sector comparator (PSC) to demonstrate value for money (VfM). However, there are suggestions that VfM is prone to manipulation to skew decisions in favor of the P3 model [49].

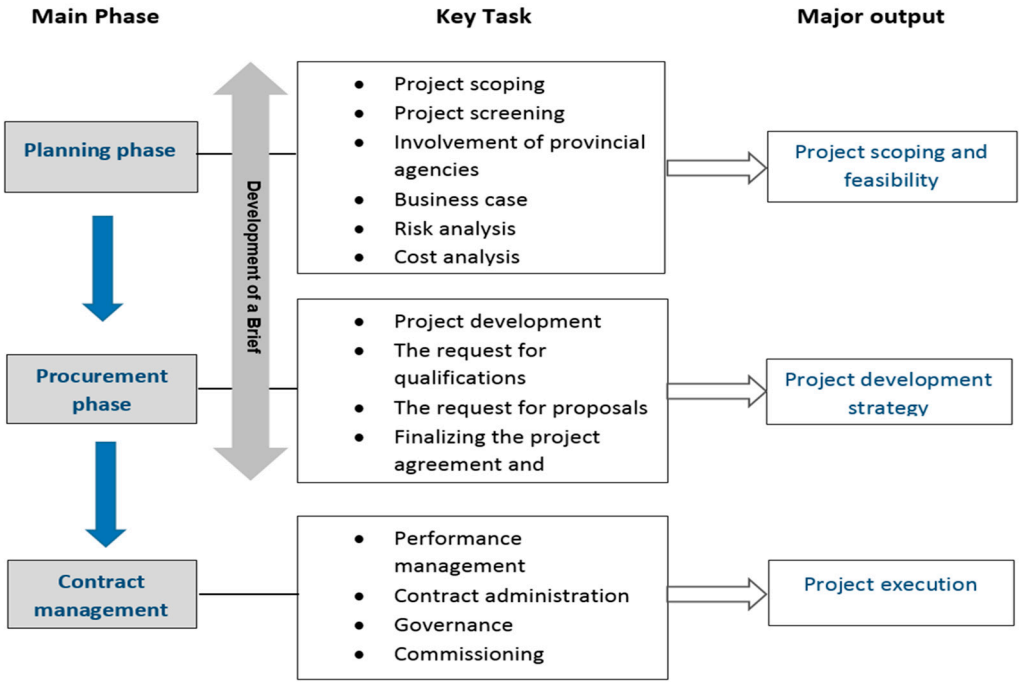

Figure 5. Overall, the Canadian PPP delivery process—developed based on [47].

5. Comparative Analysis of the Briefing Processes of the Mature PPP Markets in Light of Briefing Considerations

According to [11], briefing is a process that consists of a set of linked activities, taking an input (information) and transforming it to produce an output (brief). Therefore, the discussion of the PPP briefing processes in mature countries will compare these interrelated activities of translating inputs into outputs. For the purpose of comparison, it is necessary to map the briefing stages in the three countries discussed above to define the various phases, stages, main processes, and activities that constitute the briefing process. To this end, inputs and outputs should also be identified because if the inputs or the information are inconsistent, inadequate, or incorrect, then it is very likely that the activity/process and its outputs will also be deficient. Furthermore, the process content, decision gates, and identity of those who take control within the briefing processes of the three countries are also compared.

The procedure used in the three most mature countries to conduct the entire PPP process, including the briefing stage, was studied and analyzed to discern the main stages, which were subdivided into phases. Then, the main relevant processes within these phases, their inputs, expected outputs, decision gates, and control points were identified and analyzed. The comparison of briefing processes in the three countries is shown in Figure 6. The review of the processes applied during the PPP briefing process in these countries reveals that:

- The management and control of PPP briefing in the above countries are entirely under the public sector client (the public sector client body).
- Despite differences in the titles of the main phases in the three countries, the phases have almost the same content in their processes and share the same decision gates.
- The content of activities in the reviewed processes is almost identical, and the main differences between the processes relate to the timing of the briefing activities.

- Generally, there are three vital decision gates recognized through the briefing processes of the three countries: (i) the decision on the need for physical assets/infrastructure to meet the identified business and organization needs; (ii) the decision on the PPP's suitability; and (iii) the decision on whether to issue the final project brief.
- In the UK process, the task of negotiation precedes the evaluation of bids, whereas in Australia and Canada, the RFP process allows for negotiation after the preferred proponent is selected.
- Generally, the UK, Canada, and Australia use the same multi-stage procurement process: an Expression of Interest (EOI) stage, an RFP stage involving interaction with bidders, the selection of a preferred bidder, and pre-award contract negotiation.

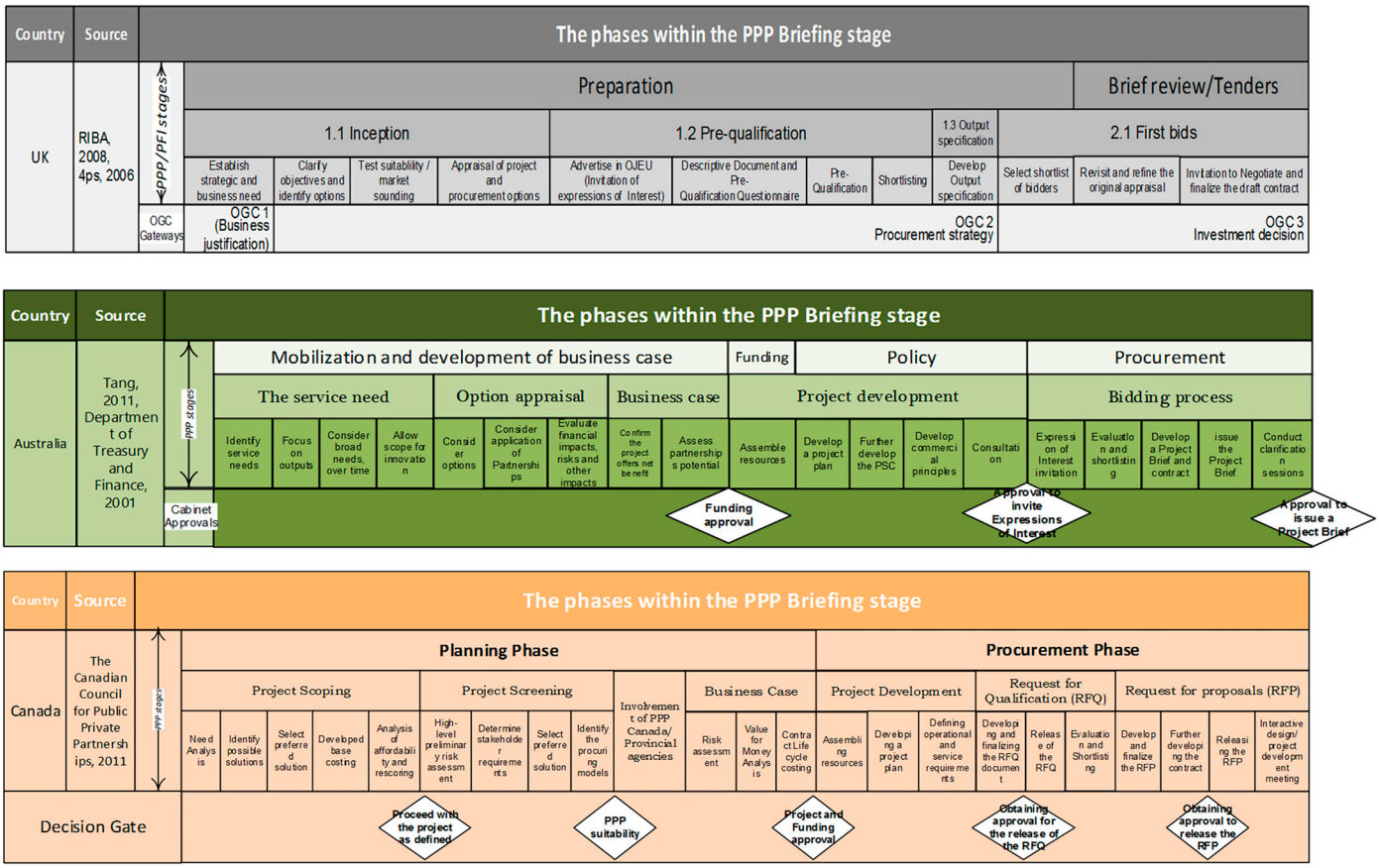

Figure 6. The overall briefing stages in detail for the three countries [17,21,22,40,47].

Figure 7 illustrates the main phases and decision gates within the PPP briefing stages in the three most mature countries.

The above analysis of interconnected activities and a detailed review of the phases, stages, and essential processes that comprise the briefing process provide valuable insights into the complexities of PPP briefings in the UK, Canada, and Australia. In all three countries, the public sector client plays a pivotal role in maintaining centralized control over the PPP briefing process, ensuring consistency across projects. Despite differences in the naming of phases, our analysis reveals significant similarities in the processes and decision-making gates, which are crucial for aligning project objectives and ensuring reliability. The uniformity in the content of activities, albeit with some timing differences, further contributes to the reliability of PPP projects. Three critical decision gates across these countries are identified: the necessity of the infrastructure, the assessment of PPP suitability, and the issuance of the final project brief. These gates serve as essential milestones in the project lifecycle.

Country	Source	The phases within the PPP Briefing stage				
UK	RIBA, 2008	Inception		Pre-qualification	Output specification	First bids
Australia	Tang, 2011; Victorian Government, 2001	Mobilization and development of business case	Funding	Policy		Procurement
Canada	The Canadian Council for Public Private Partnerships, 2011	Planning Phase		Procurement Phase		
Decision Gate		Asset-based solution	PPP suitability	Project and Funding approval	Obtaining approval for the release of the RFQ	Obtaining approval to release the RFP

Figure 7. Main phases and decision gates within the PPP briefing stages in the three most mature countries [17,21,40,47].

6. The Development of a Conceptual Process Framework for PPP Briefing

A conceptual process framework for PPP briefing is developed and presented in Figure 8. Reflecting on the comparative analysis described earlier for the three countries within the mature PPP markets, the proposed conceptual process framework includes nine processes covering the most common aspects within the PPP briefing stage. These nine processes are needs analysis, output and scope, options appraisal, risk assessment, value assessment (which includes affordability, value for money, and bankability), market testing, funding, project development, Expression of Interest (EOI), and Request for Proposal (RFP).

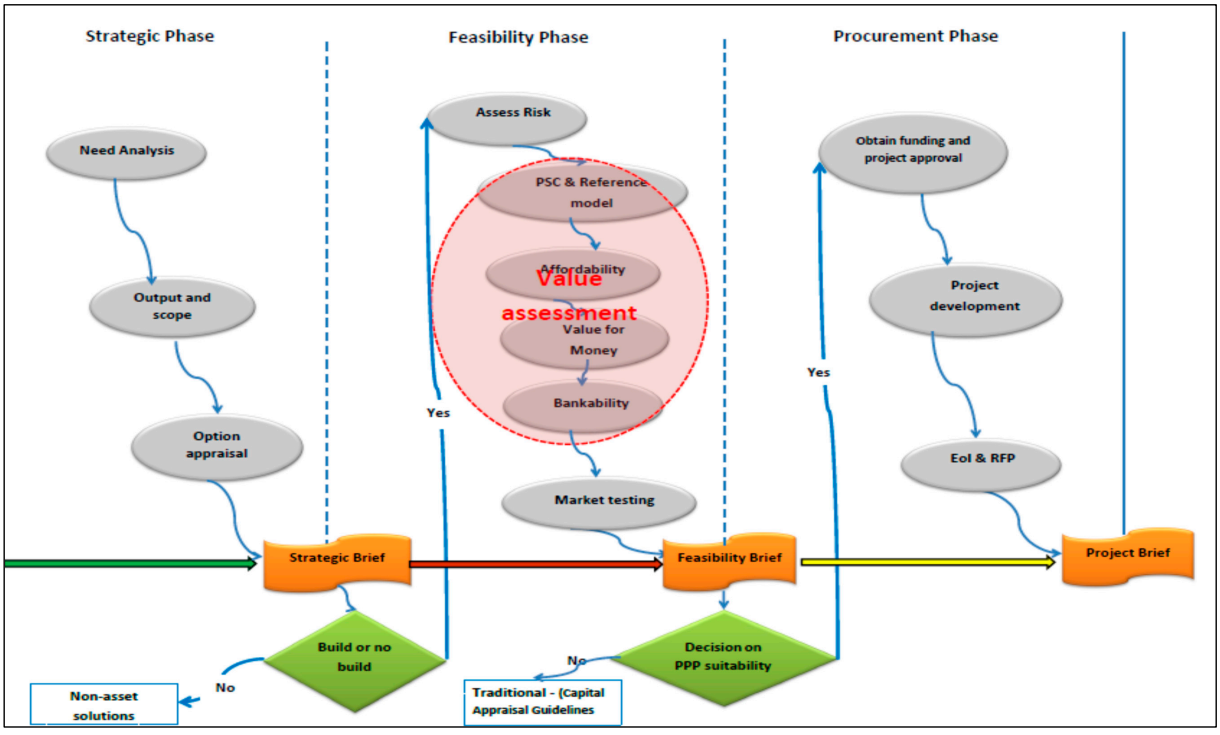

Figure 8. The proposed conceptual process framework for PPP briefing.

The proposed framework consists of three main phases: the strategic phase, the feasibility phase, and the procurement phase. It has 12 main processes through which the final PPP brief is iteratively developed. A key decision is required at each main phase of the PPP briefing development process. These three phases are described in detail below.

- The Strategic phase: During this phase, a list of reasonable alternative options is investigated based on analyzing the actual strategic and business needs before deciding

to proceed with the asset-based solution. This phase consists of three main processes: Needs Analysis, Outputs and Scope, and Option Appraisal. In the Needs Analysis process, the long-term business/service need is identified, project alignment with institutional strategic objectives is demonstrated, and institutional commitment and capacity are ensured. In the second process, the project parameters and scope are investigated through user group analysis and their input, the project parameters and specifications are analyzed, and the project statement of requirements is drafted. Finally, in the Options Appraisal process, possible options to meet needs are identified and evaluated, and a decision on the early suitability of the preferred option is made. The "build or no-build" decision is the first decision gate at the end of this strategic phase of brief development. The "Strategic Brief" of the proposed PPP project is the main deliverable of this phase.

- The Feasibility phase: In this phase, alternatives are analyzed, and a decision on the PPP's suitability is made. Parameters of different project options are further analyzed by identifying possible risks/uncertainties of each option, analyzing their impact, and identifying suitable response strategies. Following that, the project value for money is assessed in terms of potential benefits, public sector comparator (PSC), and financial analysis. Additionally, market interest and capacity are analyzed. The "PPP suitability" decision is the second decision gate at the end of this feasibility phase of brief development. The "Feasibility Brief" of the proposed PPP project is the main deliverable of this phase.
- The Procurement phase: In this phase, the preferred option is more clearly defined, and the decision to proceed further with the project is made. The project brief is further developed through stakeholder analysis and their needs, a further Public Sector Comparator, more detailed project parameters and its scope, development of Expression of Interest (EOI) and its evaluation criteria, finalizing the project brief, and finally, Request for Proposal (RFP) and briefing sessions. At the end of this phase, the "Final Project Brief" of the proposed PPP project is the main deliverable.

Through these three phases, an early and well-defined PPP briefing process can be established to ensure that development budgets are well spent. Moreover, such a framework enables oversight agencies to be involved in approving projects on time. It also provides a precise mechanism for identifying and accurately representing all stakeholders' requirements in the briefing stage of PPP projects.

7. Conclusions

The presented research explored the briefing processes within mature PPP markets, specifically focusing on a comparative analysis of three countries: the UK, Canada, and Australia. Briefing lies in transforming input information into a comprehensive brief through a sequence of interconnected activities. By examining these interrelated activities and scrutinizing the phases, stages, and key processes constituting the briefing process, valuable insights are gained into the intricacies of PPP briefing in these nations.

The paper begins by providing an overall understanding of project brief development in construction projects, outlining its processes and stages. It then explores the briefing process for PPP projects, discussing relevant considerations and implementation challenges. Following this, the paper investigates the development process of briefs for PPP projects, defining its main stages, generic processes, and key decision gates as recommended in the literature. A comparative analysis of the briefing process frameworks from three countries among the top in the PPP Market Maturity chart was conducted. Based on this analysis, a "Generic Conceptual Process Framework" for the development of briefs in PPP projects was developed.

The comparative study reveals that despite differences in terminology and specific procedures, the fundamental elements of PPP briefing processes are remarkably similar across these countries. Centralized control by the public sector, clear communication, and systematic decision-making are pivotal for the success of PPP projects.

Unlike the brief for conventional procurement, the brief for a PPP project must provide information not only on the project requirements but also on the project program, risk management, output specification, value for money, and payment mechanism. In addition, the involvement of multiple stakeholders in the briefing process of PPP projects contributes to the complexity of communication and the difficulty of coordinating the project conditions.

The implementation of PPP projects in the three studied countries faces several challenges, as reported in various research works, though they share common issues. In the UK, the PFI model encounters problems such as misleading use of public sector comparators, public skill deficits, misallocation of risks, higher risk premiums, complex contracts, and lack of transparency. Effective governance, stakeholder management, clear legal frameworks, proper risk allocation, and value-for-money objectives are crucial. Similarly, Australia's PPP projects face challenges like inadequate business cases, political interests, and limited objectivity in the Treasury office. In Canada, PPP project challenges include high upfront costs, limited community consultations, and a procurement process that hinders design excellence. Trust in the process relies on stakeholder involvement and the public sector's internal capacity. The mandatory use of public sector comparators to demonstrate value for money is also susceptible to manipulation, favoring the P3 model.

Across these countries, addressing these challenges requires careful risk analysis and management before project implementation. To overcome the challenges of PPP implementation, it is essential to enhance public sector skills through training, improve transparency, optimize risk allocation, and simplify contract structures. Strengthening business cases, mitigating political influence, and ensuring Treasury objectivity are crucial for Australia. Additionally, focusing on increasing community consultations, improving procurement processes, and maintaining integrity in value-for-money assessments will significantly improve PPP implementation.

To localize the above-developed generic conceptual framework for the PPP market in the UAE, case studies of mega PPP projects from the UAE will be analyzed. Additionally, existing governmental procedures for developing PPPs will be examined to gain a deeper understanding of the development processes for PPP construction projects in the UAE and to explore the roles of local government authorities and the private sector in this process. The framework will also be further refined and validated through structured interview sessions with professionals and experts from the UAE PPP market, with the results to be published in future publications. It is recommended that the challenges mentioned above during this process be investigated. The translation of PPP models from other countries can be risky, and the specific challenges of implementing PPPs in the UAE should be studied and reflected in the final model. These insights should be considered while developing the final process framework, with particular reference to the PPP market in the UAE.

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Quantitative Analysis of Critical Success Factors in the Development of Public-Private Partnership (PPP) Project Briefs in the United Arab Emirates

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Abstract: This paper presents the research findings on Public-Private Partnerships (PPP) brief development in the United Arab Emirates. A questionnaire survey was conducted to assess and rank the relative importance of the Critical Success Factors (CSFs) identified in PPP brief development in the UAE. A quantitative analysis was then conducted on the data gathered from the survey, and the results of the analysis are described. The processes of purifying and computing the measurement instruments are also explored using Cronbach's alpha to assess the reliability of scale measurements. The statistical analysis focuses on the importance and ranking of the identified thirty-eight (38) CSFs and their Sub-Success Factors (SSFs). The overall assessment of these factors highlights their importance in a brief development process. Accordingly, these factors are grouped into seven categories, and the developed CSF framework is presented. The categories, listed in descending order, are Regulatory and Legal Factors; Finance and Economic Factors; Risk-Related Factors; Public Sector Capacity-Related Factors; Procurement-Related Factors; Stakeholder-Related Factors; and Social, Cultural, and Ethical Factors. The research findings offer a comprehensive framework of CSFs for brief development tailored to the unique PPP environment of the UAE to ensure project success.

Keywords: Public-Private Partnership (PPP); PPP briefing; Critical Success Factors (CSFs); questionnaire; quantitative analysis; UAE

1. Introduction

The briefing process is the preliminary stage of the design process of a project. It is considered the initial step toward establishing an effective client-architect/designer relationship. Successful briefing can ensure project delivery at the target time, cost, and quality [1]. The briefing process is described as a stage or series of stages within the design or construction process, forming a segment of the overall life cycle of the construction project. Typically, it is developed through a systematic approach to inquiry, making the client's requirements explicit and comprehensible. A clear and comprehensive client brief is essential for reducing change orders and improving project performance [1–3].

In the context of Public-Private Partnership (PPP) projects, the briefing stage is an early phase that serves as the foundation for project development. It establishes the initial framework for the project's lifecycle, ensuring alignment among stakeholders regarding objectives, expectations, and feasibility. The briefing stage in PPP projects is crucial for ensuring project success [4,5]. Tang [6] argued that conventional project briefing models are ineffective for PPP projects due to their generalized nature. He identified key differences in the PPP briefing process: (a) procurement-specific steps, such as preparing a Public

Sector Comparator (PSC) to assess value-for-money (VfM) and compare bids; (b) a more focused feasibility study; and (c) a detailed consideration of financial and risk-related issues. Additionally, PPP briefs should include information on the project program, risk management, output specifications, and payment mechanisms [6].

Critical Success Factors (CSFs) are the essential conditions and elements required for project success [4]. Rockart [7] introduced the concept of Critical Success Factors (CSFs) as a method for identifying key areas where a business must excel to achieve success. This approach builds upon the concept of "success factors", which was first discussed in the management literature by Ronald Daniel in 1961 [7].

In the context of Public-Private Partnership (PPP) projects, Critical Success Factors (CSFs) are essential elements for their successful implementation. They provide guidance for decision-making, enhance project execution, and improve stakeholder satisfaction. A review of the literature reveals that numerous researchers have proposed various CSF lists for the success of PPP projects across all stages [5,8–17]. For example, Tang et al. [18] investigated the CSFs for PPP briefing, with a particular focus on the Australian environment. They identified 50 factors grouped into four main categories: procurement, stakeholders, risk, and finance.

Recently, Cisneros et al. [17] analyzed PPP challenges and CSFs for road Infrastructure in Peru. The authors proposed 17 Critical Success Factors (CSFs) based on an extensive review of the international literature. These CSFs encompass aspects ranging from transparent bidding processes and political support to legal frameworks, community engagement, and technical feasibility. Furthermore, Guerrero et al. [12] examined the Critical Success Factors (CSFs) or determinant features essential for addressing Saudi Arabia's infrastructure gap under a PPP scheme. The study identified five key factors: an effective regulatory and legal framework, adequate risk allocation among stakeholders, clear project briefs with defined client outcomes, robust feasibility studies ensuring business viability, and reliable project value management systems across all stages.

According to Dulaimi et al. [19], the CSFs in PPPs are typically influenced by the specific characteristics of each project. Furthermore, Kwak et al. [20] noted that despite variations in CSF lists, the success or failure of PPP projects generally depends on four key factors: government competence, selecting an appropriate concessionaire, proper risk allocation between the public and private sectors, and securing a sound financial package.

The United Arab Emirates (UAE) has the largest Public-Private Partnership (PPP) market among Gulf Cooperation Council (GCC) countries. PPPs are increasingly being used to accelerate infrastructure development in the UAE [21]. The growth of Public-Private Partnerships (PPPs) in the UAE is driven by various factors, including economic diversification, infrastructure development, and government initiatives to attract private sector participation. The UAE has become a regional leader in adopting PPP models, creating a solid foundation for private sector involvement in government projects. This commitment was further strengthened by Federal Law No. 12 of 2023, introduced by the Ministry of Finance to organize and promote PPPs across various sectors. This law aims to streamline project selection, reduce financial risk to the government, and offer incentives to the private sector. It supports the UAE's broader goals by ensuring efficient project delivery and maximizing private sector contributions. The law also impacts PPP briefing processes by requiring clear guidelines for project development and risk management. According to Helou [22], the law encourages private sector involvement in strategic projects within a transparent framework, enhancing efficiency, leveraging private resources, and speeding up project timelines.

A review of the literature reveals that few studies have focused on the Critical Success Factors associated with the brief development processes of PPP projects, particularly in the context of the UAE. The primary aim of the research presented in this paper is to highlight the importance of CSFs in the brief development of PPP projects in the UAE and to identify, assess, and rank their relative importance through a structured questionnaire.

The paper begins by identifying CSFs for PPP projects in general, based on previous studies, with a focus on the briefing stage. It then outlines the research methodology used for data collection and analysis. The findings are subsequently presented, followed by a discussion of the results and key outcomes.

2. PPP Brief Development and Critical Success Factors: A Review

Several studies have emphasized the critical role of construction project briefing in ensuring successful project delivery. Othman [23] identifies the briefing process as a cornerstone for achieving client satisfaction, citing its pivotal role in "eliciting and communicating the client's requirements to the design and construction teams. Both Mahat et al. and Nasirzadeh et al. [1,2] highlight the importance of a clear and comprehensive client brief in minimizing change orders and enhancing project performance. Yu et al. [24] Identify two main schools of thought on construction project briefing: one treats the brief as a static document finalized after a critical period, while the other views it as a dynamic, iterative process evolving throughout the early project life. The briefing process is often referred to and developed through a stage or series of stages, representing a critical part of the overall life cycle of a construction project. Briefing development can generally be divided into two main phases: strategic briefing and project briefing [25–27]. Based on design specifications that address the client's requirements, as expressed in the strategic briefing [28], the strategic briefing outlines the mission of the business project and its alignment with the corporate objectives of the client organization, whereas the project briefing translates the strategic briefing into physical terms.

In the context of a PPP project, brief development is a critical phase in its lifecycle. It involves the creation of a comprehensive document that outlines the project's objectives, scope, requirements, and framework for engagement with potential private sector partners. In an earlier stage of this research work, the fundamental stages, standard processes, and critical decision points involved in the PPP briefing process were examined and investigated through a comparative analysis of briefing frameworks used in three countries that are among the top in the PPP Market Maturity chart. A conceptual process framework for PPP briefing was proposed. This framework comprises three phases: the strategic, feasibility, and procurement phases. The strategic phase focuses on needs analysis, project parameter definition, scoping, and options appraisal, resulting in a project Strategic Brief. The feasibility phase includes project due diligence, risk management, and financial assessment, culminating in the Feasibility Brief. The procurement phase covers stakeholder consultations, project development, market interest confirmation, issuing a request for proposals, and delivering the Final Project Brief. Appendix A outlines these three phases and their key briefing activities, along with detailed tasks. Further details are presented in [3]. The above process framework was utilized to develop an initial list of success factors associated with the listed activities, which was further refined, as explained in the following sections.

Critical Success Factors in PPP Brief Development

Reviewing the literature, several researchers have investigated Critical Success Factors (CSFs) for PPP projects, proposing various lists of CSFs essential for success throughout all project stages. During the strategic project brief, analyzing the needs of a PPP project is an essential early step in its development. Akintoye and Donnelly [29] emphasized the importance of aligning the briefing with the client's strategic goals. They highlighted the need for unambiguous output specifications that can be effectively interpreted by the 'special purpose vehicle' (SPV). Similarly, Zeegers and Ang [30] stressed that output specifications are central to the contract and require careful attention. Furthermore, Tang et al. [18] identified a brief writer's experience, adequate briefing time, and process control as key procurement-related success factors.

A feasibility study is an essential process in developing a PPP feasibility brief. The success of public services and infrastructure projects in PPP schemes is directly influenced

by the initial feasibility study conducted during the briefing stage [31]. Amponsah [32] emphasized that comprehensive feasibility studies with robust financial and economic analyses can help prevent issues and delays during negotiation and procurement. Tang et al. [18] identified a practical budget, program, and proposed commercial arrangements as key finance-related factors for a successful PPP briefing in Australia.

Financial and economic analyses are also essential components of the feasibility study. The Asian Development Bank [33] highlighted project financing as a critical factor for the private sector in PPP infrastructure projects, noting that accessible financial markets encourage private sector involvement, especially in inefficient or mature markets. Li et al. [11] also supported this, ranking "available financial market" third in their study of Critical Success Factors in the UK PPP/PFI environment. Financial assessment is a crucial part of a feasibility study for PPP brief development. It includes tasks such as building the Public Sector Comparator (PSC), creating the PPP reference model, establishing the payment mechanism, and proving affordability. Several other feasibility and finance-related success factors in PPP briefing are identified and included in Appendix A.

In addition, stakeholder management is a key aspect of PPP briefing development. Efficient and effective stakeholder relationships are crucial for the success of PPP projects. Furthermore, transparency and trust are also vital in the process [18]. Alan [34,35] noted that stakeholders are less likely to engage if they feel decisions are predetermined or distrust the process, leading to participation or withdrawal. They argued that stakeholder management could be more complex due to the involvement of "user clients" and "paying clients". Thus, the briefing process must effectively capture and satisfy the commercial and/or social needs of all stakeholders that constitute the client group.

The decision-making processes of various stakeholders during the briefing stage can also be influenced by cultural and ethical issues. Culture and ethics play a significant role in decision-making during this phase [36]. Effective management of the PPP briefing team requires an understanding of the backgrounds and values of the stakeholders. Cultural and ethical differences become particularly important when international investors and stakeholders come from diverse countries with varying cultures, values, and business environments. According to Yu [37], cultural dimensions, such as language, time orientation, use of space, and religion, must be carefully considered during the briefing stage. Furthermore, ethical decision-making is shaped by personal values, organizational culture, government regulations, and societal norms.

Risk management is another important process in the brief development of a PPP project. A considerable number of risks arise from the complexity of PPP arrangements, including documentation, financing, taxation, technical details, and agreements. Effective risk identification and assessment must begin during the project inception stage. Unlike conventional procurement, PPP risks are allocated to the party best positioned to manage them [38–40]. This requires a risk-transfer strategy, where risks that can be better managed by the private sector are transferred to the private party, while those more suitable for the public sector are retained [41]. According to research by [41–43], delivery risks should be allocated to the private sector, while the public sector can more effectively manage site acquisition and legal and policy risks. Shen et al. [44] asserted that shared risks, such as development, market, financial, and force majeure, can be managed collaboratively. Gunnigan [42] argued that while the private sector is well suited to managing design, construction, operation, and industrial action risks, the public sector should retain ultimate responsibility for the operation of services critical to society to prevent their failure, regardless of how the risk is allocated.

The public sector's capacity is crucial for managing PPP projects. UNESCAP [45] emphasized that the qualifications and experience of public staff, along with the technical capacity of government agencies, are key to addressing challenges and planning for contingencies. Additionally, having defined government mechanisms, such as a PPP Unit, and accessible PPP documentation and best practices are vital for effective briefing and project success.

The availability and effectiveness of a proper regulatory and legal framework are critical for PPP brief development, ensuring that laws are in place to address legal issues and support the procurement process [45]. It is the public sector's role to provide an independent, fair, and efficient legal system to attract top-tier partners, which is essential for the bankability and stability of PPP agreements. Pongsiri [46] highlighted two benefits of a well-defined framework: first, it ensures efficient partnerships that are aligned with legal systems and policy objectives; second, it protects the private sector from expropriation by enabling arbitration and ensuring fair recovery of costs and profits.

In the UAE PPP environment, Dulaimi et al. [19] analyzed critical success and failure factors through three case studies, highlighting factors related to Public Sector Capacity in PPP briefings, including political support and stability, government assistance throughout the project, and the financial capacity to meet PPP obligations. Additionally, Abdou and Al Zarooni [47] developed a preliminary list of potential CSFs for UAE healthcare projects procured under PPP schemes. Almarri and Abu-Hijleh [48] identified nine key CSFs for PPP implementation that are agreed upon in both the UK and UAE, including public-private commitment, risk allocation, competent public agencies, transparent procurement, strong private consortiums, political support, cost-benefit assessment, and good governance. Recently, Alteneiji et al. [49] investigated possible CSFs for PPP in affordable housing in the UAE. The most identified CSFs were good governance, government guarantees, commitment and responsibility of the public and private sectors, favorable and efficient legal frameworks, political support and stability, and demand for and debt-paying ability of the project.

Based on a comprehensive review of the available literature, with a particular focus on CSFs in PPP projects and the briefing stage, an initial list of 218 success factors for PPP briefing was compiled. These factors were categorized into three stages of brief development and their corresponding activities and tasks, as discussed earlier. A detailed list is included in Appendix A. This extensive list of factors was reviewed to assess their similarity, detail, and importance, as well as to determine whether similar factors could be combined or grouped. The initial list was subsequently refined, condensed, and reorganized into 151 candidate factors distributed across seven main categories: (1) Procurement-Related Factors, (2) Stakeholder-related Factors, (3) Risk-related Factors, (4) Finance and Economic Factors, (5) Public Sector Capacity-related Factors, (6) Regulatory and Legal Factors, and (7) Social, Cultural, and Ethical Factors.

The following section outlines the research methodology used to develop the final CSF list for the questionnaire survey, providing detailed descriptions of the data collection process as well as the analysis and discussion of the results.

3. Research Methodology

The work presented in this paper is part of a comprehensive research project aimed at developing a framework for Critical Success Factors (CSFs) in Public-Private Partnership (PPP) briefing, with a specific focus on the UAE context. The goal of this framework is to improve the efficiency and effectiveness of a brief development process for PPP projects in the UAE. This paper focuses specifically on the quantitative analysis of data gathered through a questionnaire survey to assess and rank the relative importance of the CSFs identified during the briefing stage of PPP projects in the United Arab Emirates (UAE). Figure 1 illustrates the stages of the research methodology and the main processes involved in developing the above framework.

As discussed earlier, the initial list presented in Appendix A was refined, condensed, and reorganized into 151 candidate success factors categorized into seven main groups. Subsequently, five in-depth semi-structured 'elite interviews' were conducted with PPP experts and key personnel from both the public and private sectors in the UAE. According to Marshall and Rossman [50], elite interviews focus on a specific group of interviewees who offer unique benefits due to the valuable insights and information they possess.

However, accessing these individuals can be challenging due to their busy schedules and high-level responsibilities.

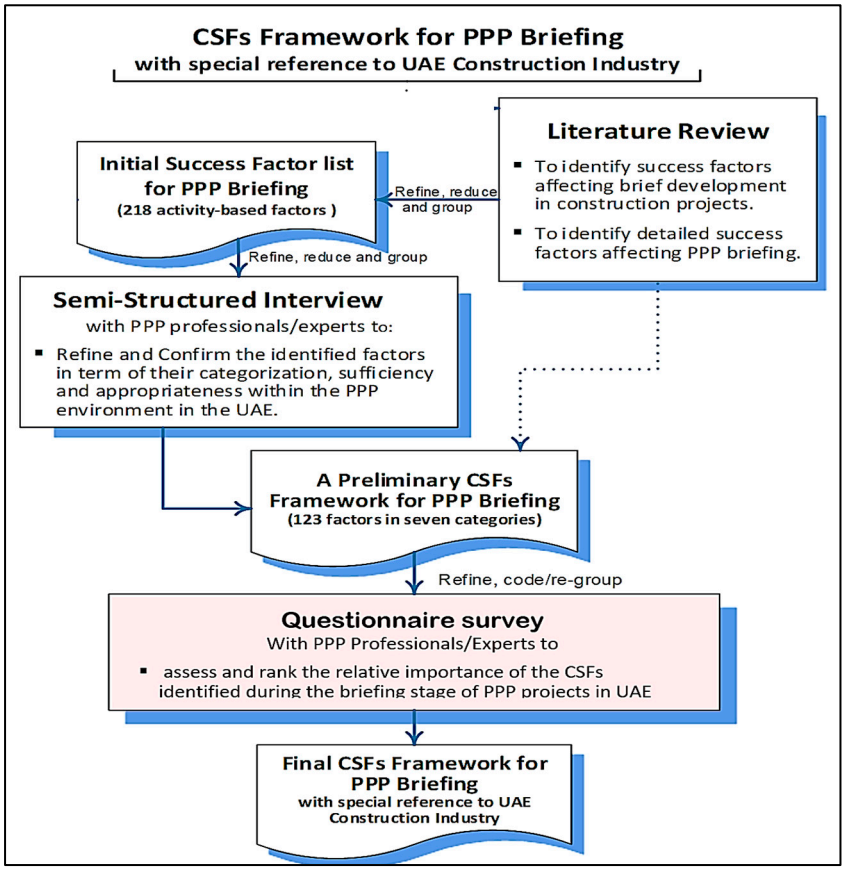

Figure 1. The Research Methodology for Developing the Critical Success Factors Framework for PPP Briefing with Special Reference to the UAE context.

The interviewees were asked to evaluate the identified 151 candidate success factors for relevance and completeness, suggest any new factors specific to the UAE's PPP environment, and highlight additional issues that could influence the success of the PPP briefing. Feedback from these interviews was used to refine and condense the list of candidate success factors, resulting in a final set of 123 CSFs that were categorized into seven distinct groups. These refined factors were further classified as either Critical Success Factors (CSFs) or Sub-Success Factors (SSFs). The refinement process involved evaluating the factors to determine their level of detail or importance, combining similar factors, and grouping or sub-categorizing others. Insights from the reviewed literature also informed potential high-level sorting and grouping of the factors.

As a result, the final CSFs Framework for PPP Briefing, specifically tailored to UAE PPP projects, was developed. This framework includes 38 CSFs and 103 SSFs organized into the seven categories included in Appendix B. The first two columns present the finalized list of CSFs and their SSFs grouped by category. For instance, in Procurement-Related Factors (coded as 'A'), each CSF is labeled A1, A2, and so on, while their corresponding SSFs are labeled A11, A12, etc.

Following that, a questionnaire survey was designed, implemented, and analyzed as the primary focus of this study. The survey aimed to collect data from a large sample of PPP experts in the UAE, capturing their opinions and perceptions of the identified CSFs and associated SSFs and ranking the relative importance of these CSFs during the briefing stage of PPP projects in the UAE.

The Development and Implementation of the Questionnaire

A standardized questionnaire was developed to gather opinions and perceptions from PPP experts in the UAE regarding the identified Critical Success Factors (CSFs). The questionnaire included two types of questions: closed-ended questions with predefined answer options and scaled-response questions using a five-point Likert scale. It was divided into two parts: Part I collected general background information, while Part II focused on rating the CSFs and SSFs using the finalized framework, which included 38 CSFs and 103 SSFs organized into seven categories, as discussed earlier. The questionnaire also included a cover sheet detailing the study description and instructions, with privacy for responding organizations assured. Each section was clearly titled for easy navigation, and questions were presented in a table format. The questionnaire concluded with submission instructions and an optional section for respondents to request key findings. Questions were carefully worded, with multiple revisions made to ensure clarity, and instructional statements were provided to explain each scale point.

After creating the questionnaire, it was essential to validate its accuracy and clarity. This step ensured that the questionnaire reliably measured the intended information and that the questions were straightforward, thus allowing the respondents to provide clear and understandable answers. Five experienced academic researchers with expertise in questionnaire design reviewed the instrument and provided feedback that contributed to its improvement.

The questionnaire was then subjected to a pilot test with two PPP briefing process experts. During the pilot study, the participants completed the questionnaire and provided feedback on various aspects, including completion time, instruction clarity, question simplicity, wording clarity, and overall understanding. The questionnaire was formatted as an interactive PDF, making it easy for respondents to select rating options. It was distributed to professionals selected from a database of PPP experts, with an emphasis on those experienced in the UAE PPP market. The administration of the questionnaire spanned three months and resulted in 104 responses.

4. Data Analysis Process

The analysis of data obtained from the questionnaire responses consisted of two main phases. The first phase, explained in this section, focuses on two primary objectives: (1) examining the respondents' profiles and (2) testing the reliability of the data using item-to-total correlation and Cronbach's alpha statistical measures.

The second phase explores the value and contribution of the collected data in relation to the questionnaire's objectives, which focuses on the importance and ranking of the thirty-eight (38) CSFs and their Sub-Success Factors (SSFs). It also addresses the purification and computation processes of the measuring instruments. This will be discussed in detail in Section 5.

4.1. Respondents and Their Categories: Descriptive Analysis

This section provides an overview of the respondents and their categories with the aim of describing the sample profile in the study. Frequency analysis was used to categorize participants based on their experience, market sector category, overall experience in PPP projects, and the PPP project sector.

4.1.1. Experience of Respondents

As mentioned earlier, this study aimed to obtain a sample of professionals with experience in various types of PPP projects within the UAE context, ensuring that the findings are generalizable to a broader industry. Table 1 shows the overall respondents' professional experience. More than half of the respondents (53.8%) had more than 20 years of work experience. Additionally, 21.2% had between 11 and 15 years of experience, 13.5% had between 15 and 20 years, and 9.6% had between 6 and 10 years of experience. Finally, only a very few respondents (1.9%) had limited work experience (0–5 years).

Table 1. Overall professional experience.

	Frequency	Percent	Valid Percent	Cumulative Percent
0–5 Years	2	1.9	1.9	1.9
6–10 Years	10	9.6	9.6	11.5
11–15 Years	22	21.2	21.2	32.7
16–20 Years	14	13.5	13.5	46.2
More Than 20 Years	56	53.8	53.8	100.0
Total	104	100.0	100.0	

4.1.2. Market Sector Category

Table 2 reveals that the majority of respondents (63.5%) came from private sector companies, while 36 respondents (34.6%) worked in the public sector.

Table 2. Market sector category.

Frequency	Percent	Valid Percent	Cumulative Percent	Frequency
Public	36	34.6	34.6	34.6
Private	66	63.5	63.5	98.1
Other	2	1.9	1.9	100.0
Total	104	100.0	100.0	

4.1.3. Overall Experience in PPP Projects

As illustrated in Table 3, 44.2% of the respondents had between 0 and 5 years of experience, while more than half (45.8%) had over six years of experience in PPP projects. Only a small proportion of respondents (9.6%) had an extended work experience of 16 years or more in the market sector category.

Table 3. Overall professional experience in PPP projects.

	Frequency	Percent	Valid Percent	Cumulative Percent
0–5 Years	46	44.2	44.2	44.2
6–10 Years	32	30.8	30.8	75.0
11–15 Years	16	15.4	15.4	90.4
16–20 Years	4	3.8	3.8	94.2
More Than 20 Years	6	5.8	5.8	100.0
Total	104	100.0	100.0	

4.1.4. Respondents' Experience with PPP Project Type and PPP Briefing Process

The respondents had diverse experiences with various UAE PPP projects. The sample consisted of 104 responses covering eight different project types. Table 4 illustrates the distribution of respondents' experiences by type of PPP project in the UAE. About 13.5% of the respondents had experience in educational projects, while only six respondents (5.8%) had experience in healthcare projects. Nearly one-quarter (23.1%) of the respondents had experience in the social housing sector and 19.2% had experience in transport projects. Additionally, 9.6% of the sample had expertise in environmental projects, while eight respondents (7.1%) had experience in both institutional and industrial projects. Finally, 13.5% (14 respondents) had experience with infrastructure PPP projects. The majority of respondents (66.3%) had experience with the PPP briefing process.

Table 4. Distribution of respondents' experience by type of PPP project in the UAE.

Type of PPP Project	Frequency	Percent
Educational	14	13.5
Healthcare	6	5.8
Social Housing	24	23.1
Transport project	20	19.2
Environmental	10	9.6
Institutional project	8	7.7
Infrastructure	14	13.5
Industrial	8	7.7
Total	104	100.0

4.2. Data Preparation and Purification of Measures

According to [51], researchers must follow several steps after collecting data to obtain meaningful results during the analysis stage. This section discusses these steps in detail.

4.2.1. Data Preparation

Several steps were taken to prepare the data for analysis. First, the raw data were reviewed to identify and correct errors and omissions, ensuring that minimum data quality standards were met. Second, the study variables were coded into formats suitable for analysis using the Statistical Package for the Social Sciences (SPSS), with each variable assigned a unique label to configure the software. Finally, the data were manually entered into SPSS after each questionnaire was checked for errors and omissions. These steps ensured that the data were ready for analysis.

4.2.2. Purification of Measures

After recording and entering the data, it is crucial to ensure that the measurements are reliable and valid. This is important for several reasons: it strengthens the research methodology, supports result triangulation, and provides a clearer understanding of the studied phenomena. In this study, validity and reliability were assessed using item-to-total correlation, which is considered the most common procedure among researchers to guarantee the reliability of a multi-item scale [52]. This method helps in deciding whether to retain or remove items based on their correlation with others in the same category, ensuring that they share a common core [53]. Items with an item-to-total correlation score of 0.30 or higher were retained as highly reliable [54]. Reliability estimation also considers the average correlation between items within a category, known as "internal consistency" [55]. The Cronbach's alpha coefficient, a widely accepted reliability measure, was used for this purpose. This technique has been proven to be useful in estimating reliability in most research contexts. According to [55], a reliability score of 0.5 to 0.6 is considered sufficient. The following section discusses the process of computing reliability, which was applied to all measuring instruments across the seven categories previously identified.

4.2.3. Reliability Analysis Results

Reliability analysis involved calculating item-to-total correlations and implementing Cronbach's alpha coefficient. All items showed a strong item-to-total correlation, exceeding the accepted threshold of 0.30. The reliability coefficient ranged from 0.756 to 0.956, which is significantly higher than the accepted level of 0.60 [55]. These findings confirm the reliability of the scales used in this study.

4.2.4. Content Validity

Content validity refers to the extent to which the measures used accurately capture the domain of properties or characteristics of the construct being studied [56,57].

A measure is considered to have content validity if there is general agreement among participants and researchers that the instrument's items adequately cover all content

domains of the variables being measured [55]. To ensure content validity, the researcher must carefully define the research problem, items to be scaled, and scale to be used. This logical process is somewhat intuitive and unique to each researcher [54]. However, before a measurement scale can be applied in empirical research, it must meet specific criteria [58], including ensuring content validity. This involves carefully defining what is to be measured, conducting a thorough literature review, and conducting interviews with the target population. Additionally, having experts review the scale is crucial for ensuring its accuracy. The scales should also be pretested, with open-ended questions included to identify any additional items that may need to be considered [58]. As discussed earlier, the CSFs listed in the final draft of the questionnaire survey were identified through a comprehensive review of relevant literature. Several interviews with PPP experts, along with a pilot study, further validated the CSFs and their content, ensuring the survey's content validity.

5. Results and Discussion

This section covers the second phase of data analysis, building on the data validation and purification discussed earlier. SPSS software was used to analyze the data. The CSFs and their SSFs were measured using a Likert-type scale ranging from 1 to 5, where one means "not important" or "not at all", 2 means "slightly important", 3 means "neutral" or "moderately important", 4 means "very important", and five means "extremely important". To calculate the means for CSFs, if a factor has SSFs, its mean is based on the average of the SSFs' means from the respondents' ratings. If a CSF has no SSFs, its mean is calculated directly from the respondents' ratings. For more details, refer to Appendix B, which shows the Factors Ranking Analysis of CSFs and their SSFs.

5.1. Overall Critical Success Factors Ranking

Table 5 presents a comprehensive assessment and ranking of all thirty-eight Critical Success Factors (CSFs) within the context of PPP projects. Notably, the top 21 CSFs are ranked above 4, highlighting their significant importance. Among these factors are those related to the "Procurement" category, such as having a well-defined project brief with clear goals, objectives, and deliverables, as well as selecting an appropriate PPP model. In the "Stakeholder-related factors" category, identifying key stakeholders and understanding their needs, requirements, and interests are crucial. Addressing "Risk-related" factors is also essential, as is the proper identification and implementation of mitigation strategies for anticipated risks and threats. Government support is crucial, particularly for providing guarantees for political, legal, and regulatory risks that fall beyond the control of private investors. Additionally, flexibility in project design to adapt to changing market demands is crucial.

Table 5. Ranking of All Critical Success Factors for the Brief Development of PPP Projects.

ID	Critical Success Factors (CSFs)	Group	Mean *	Rank
F5	Clear authority and responsibility between the public and private sector	Regulatory and legal	4.4231	1
C1	Proper identification of anticipated risks/threats to the PPP project	Risk	4.2821	2
F2	Approved governance model by relevant authorities for the PPP venture	Regulatory and legal	4.2692	3
E1	Political support and stability: refer to Sufficient political backing and a stable environment for long-term project success.	Public sector capacity	4.2500	4
A1	Clear the project's goal, objectives, and deliverables in the brief	Procurement	4.2423	5
C4	Proper mitigation/reduction strategy for anticipated risks/threats to the PPP project	Risk	4.2404	6
F1	Availability of effective regulatory and legal frameworks for PPP	Regulatory and legal	4.2154	7
B1	Identification of the influential stakeholders	Stakeholder	4.1731	8
C2	Proper analysis and assessment of anticipated risks/threats to the PPP project	Risk	4.1563	9

Table 5. *Cont.*

ID	Critical Success Factors (CSFs)	Group	Mean *	Rank
E3	Governmental assistance during the PPP project undertaking	Public sector capacity	4.1538	10
F4	Adherence to applicable and up-to-date legal and regulatory frameworks	Regulatory and legal	4.1538	10
F6	Proper dispute resolution mechanism	Regulatory and legal	4.1538	10
A3	Appropriateness of the selected PPP model	Procurement related	4.1346	13
F3	Project scope to match the authorized mandate of the public agency	Regulatory and legal	4.1154	14
C5	Government guarantees for political/legal/regulatory risks beyond the control of private investors	Risk	4.0962	15
D2	Business and economic viability of the feasibility study	Finance and Economy	4.0865	16
D4	Financial capacity and reliability of the private sector	Finance and Economy	4.0833	17
D3	Sound commercial and financial package/arrangements	Finance and Economy	4.0692	18
C6	Flexibility of the project design solution to meet possible future changes in market demand	Risk	4.0192	19
E4	Government financial capacity to support PPP financial requirements	Public sector capacity	4.0192	20
B3	Identification of the stakeholders' needs, requirements, and interests	Stakeholder	4.0096	21
C3	Proper risk allocation and sharing among project stakeholders	Risk	3.9904	22
B7	Team selection and empowerment	Stakeholder	3.9615	23
D1	Favorable financial and economic climate	Finance and economic	3.9375	24
E2	Qualified and experienced public staff to manage the PPP briefing process	Public sector capacity	3.9359	25
B5	Stakeholder management strategies	Stakeholder	3.8846	26
B4	Adequate engagement of user groups throughout the briefing process	Stakeholder	3.8526	27
A2	Clear and precise process for formulation and control of the brief	Procurement	3.8341	28
G4	Acceptable tariff level	Social, cultural, and ethical	3.7692	29
A4	Adequate resources allocated to the briefing process	Procurement	3.7548	30
B6	Proper communication and coordination between stakeholders during the brief development	Stakeholder	3.7418	31
G5	Consideration of socioeconomic aspects	Social, cultural, and ethical	3.7308	32
B2	Addressing stakeholders' possible power and influence	Stakeholder	3.7115	33
A5	Flexibility of the brief and the management of change	Procurement	3.6538	34
G3	Consideration of cultural and ethical values of the end users/user group during the brief's development	Social, cultural, and ethical	3.6538	35
E5	Effective government mechanisms for documentation and lessons learned	Public sector capacity	3.5705	36
G2	Work environment during the brief development	Social, cultural, and ethical factors	3.5423	37
G1	Community participation, acceptance, and support	Social, cultural, and ethical	3.3558	38

* Mean is based on a five-point Likert scale.

Similarly, the highlighted Finance and Economy-related factors involve assessing the business and economic viability of feasibility studies, as well as evaluating the financial capacity and reliability of the private sector. Public Sector Capacity-related factors include political support and stability, governmental assistance throughout the PPP project, and the government's financial capacity to meet PPP financial obligations. Lastly, Regulatory and Legal-related factors focus on establishing clear authority and responsibility between the public and private sectors, gaining approval from relevant authorities for the governance model of the PPP venture, and ensuring effective regulatory and legal frameworks.

Adherence to applicable laws, robust dispute resolution mechanisms, and alignment of the project scope with the public agency's authorized mandate are also essential.

Furthermore, 16 factors earned rankings between 3.5 and 4, spanning several critical dimensions. Firstly, in the procurement-related category, the focus is on establishing a clear and precise process for shaping and overseeing the project brief. This includes allocating sufficient resources to the briefing process while allowing flexibility and adaptability.

Additionally, Stakeholder-related factors involve careful selection and empowerment of the project team, implementation of effective stakeholder management strategies, active engagement of user groups throughout the briefing process, and establishment of robust communication and coordination among stakeholders. Addressing potential stakeholder influence is also crucial in this category. Likewise, Risk-related factors emphasize the proper allocation and sharing of risks among project stakeholders, which is essential for mitigating potential challenges. The Finance and Economic Factors category underscores the importance of a favorable financial and economic environment to support the success of PPP projects. Furthermore, Public Sector Capacity-related factors highlight the need for qualified and experienced public staff to oversee the PPP briefing process. Effective government mechanisms for documentation and knowledge transfer further enhance project efficiency.

Lastly, Social, Cultural, and Ethical Factors cover various considerations, such as establishing acceptable tariff levels, incorporating socioeconomic aspects, addressing the cultural and ethical values of end users or user groups during brief development, and fostering a supportive work environment. Notably, only one factor—community participation, acceptance, and support—ranked between 3.5 and 3. For a detailed breakdown of these factor rankings within the seven categories and their corresponding CSFs and sub-factors, please refer to Appendix B.

5.2. One-Sample t-Test of Statistical Significance of All CSFs

A one-sample *t*-test was conducted to determine whether the observed means of the Critical Success Factors (shown in Table 5) were significantly different from the mid-point of 3.0. The results show that the differences were highly significant ($p < 0.01$), confirming that all the critical factors for the PPP briefing process were rated positively. The following sections analyze each of the seven categories in the developed CSF framework. The one-sample *t*-test results for the statistical significance of the PPP briefing's CSFs are shown in detail in Appendix C.

5.3. Procurement-Related Factors

The ranking of Critical Success Factors (CSFs) in the Procurement category is illustrated in Table 6. The top-ranked factor had clear project goals, objectives, and deliverables in the project brief, with a score of 4.2423. This aligns with the idea proposed by Abdul-Aziz [59], who emphasized that clear goals, objectives, and deliverables are essential for a project's success. It also supports Akintoye and Donnelly [29]'s view that the client group must specify output requirements in a way that the "special purpose vehicle" (SPV) can understand. Additionally, Yu et al. [24] It highlights the importance of understanding the client's strategic goals for a successful briefing.

Table 6. Ranking of procurement-related factors.

One-Sample Statistics					
CSFs	**N**	**Mean**	**Rank**	**Std. Deviation**	**Std. Error Mean**
A1	104	4.2423	1	0.73560	0.07213
A3	104	4.1346	2	0.94569	0.09273
A2	104	3.8341	3	0.78584	0.07706
A4	104	3.7548	4	0.91441	0.08967
A5	104	3.6538	5	0.93756	0.09194

Key areas of focus include clear project goals and specifications, alignment with the client's objectives, integration into planning processes, and effective management of the Expression of Interest (EOI) stage in brief development. As detailed in its SSFs, achieving clear project goals and deliverables requires clarity of the project objectives, proper output specifications, alignment with the client's strategic objectives, integration with national and local planning, and effective management of the Expression of Interest (EOI) stage during brief development.

The second-ranked factor, with a score of 4.1346, is the appropriateness of the chosen PPP model. Since various PPP models exist, selecting the right one is crucial for optimizing results. This aligns with interview findings that emphasize the importance of endorsement by relevant authorities and selecting a model suited to the project's type and scope.

The third and fourth factors, with scores of 3.8341 and 3.7548, respectively, focused on a clear and controlled briefing process, along with sufficient resource allocation. These findings align with Tang et al. [18], who highlighted the importance of the brief writer's experience, adequate time, and process control as key Procurement-Related Factors in PPP briefing.

Finally, 'flexibility of the brief and the management of change' ranked last in this category, highlighting the importance of a well-established framework for formulating the brief. The briefing process should involve clear goals and objectives, strong public sector leadership, continuous monitoring and control, well-defined criteria for selecting options, and setting decision priorities with key stakeholders. Additionally, establishing a realistic timeline for completion and ensuring a clear and precise brief at the conclusion of the process are essential elements.

It is worth mentioning that the recent procurement regulations introduced by UAE Federal Law No. 12 of 2023 provide a constructive framework for implementing Public-Private Partnerships (PPP). These detailed regulations enhance transparency, accountability, and fairness in PPP projects by setting clear guidelines for proposal evaluation. By promoting structured processes, the law ensures consistency and guarantees that PPP projects are executed with clear expectations and rigorous oversight, ultimately leading to improved project outcomes. Regarding brief formulation and project requirements, the law empowers federal entities by assigning them responsibility for preparing project briefs and requirements in alignment with their strategic goals.

While the Ministry of Finance maintains oversight of the regulatory framework, federal entities ensure that the briefing process adheres to established guidelines and project standards. This includes setting clear goals, preparing technical and financial specifications, and identifying risk management strategies. Federal entities thus play a pivotal role in shaping project briefs to align with both public and private sector needs while considering national priorities and sector-specific requirements.

5.4. Stakeholder-Related Factors

The ranking of Stakeholder-related Factors from the respondents is presented in Table 7. 'Identification of influential stakeholders' ranked first with a score of 4.1731, which is an essential consideration in any government project. This was followed by "Identification of stakeholders' needs, requirements, and interests" with a score of 4.0096. This aligns with the research by Kelly et al. [60], who emphasize the early identification of influential stakeholders. It also supports the arguments of Juaim and Hassanain [61] and Jing et al. [62], who highlighted the enriching role of stakeholders in the briefing process and the importance of their proper identification.

"Team selection and empowerment" secured the third position with a score of 3.9615, emphasizing the critical role of team quality in determining project outcomes. This finding echoes the research findings explained in [24,63,64], which highlights the importance of selecting experienced team members. Yu et al. [24] also underscore the value of empowering the stakeholder group in decision-making. Stakeholder management strategies ranked fourth in this category (3.8846), emphasizing the need to define stakeholder roles, devise a

consultation plan, ensure that output specifications are realistic, and effectively address stakeholder conflicts and coalitions.

Table 7. Ranking of stakeholder-related factors.

One-Sample Statistics					
CSFs	**N**	**Mean**	**Rank**	**Std. Deviation**	**Std. Error Mean**
B1	104	4.1731	1	0.76884	0.07539
B3	104	4.0096	2	0.76317	0.07484
B7	104	3.9615	3	0.76225	0.07475
B5	104	3.8846	4	0.87488	0.08579
B4	104	3.8526	5	0.77282	0.07578
B6	104	3.7418	6	0.69988	0.06863
B2	104	3.7115	7	0.89111	0.08738

The fifth and sixth rankings go to "engaging user groups throughout the briefing process" (3.8526) and "stakeholder communication and coordination" (3.7418), where skilled project managers play a crucial role. The final aspect, "addressing stakeholder power and influence" (3.7115), aligns with research by Tang et al. [18], who highlight the importance of efficient stakeholder relationships in PPPs, emphasizing transparency and trust for success.

5.5. Risk-Related Factors

In the Risk-related factor category, Table 8 reveals the respondent rankings. "Proper identification of anticipated risks/threats" ranked first (4.2821), followed by "Mitigation/reduction strategy for anticipated risks/threats" (4.2404). These findings align with the research by Allan [38], which emphasizes the need for thorough risk identification and assessment. Additionally, they support the idea that PPP projects should incorporate a risk-transfer strategy, transferring risks to the private sector that is best equipped to manage them and retaining those better handled by the public sector as part of the project planning process [41]. To ensure a successful PPP briefing, it is essential to start early with a risk register, focus on partner-related and supply chain risks, establish a robust risk-mitigation plan, and recruit expert staff to assess the strategy.

Table 8. Ranking of Risk-related factors.

One-Sample Statistics					
CSFs	**N**	**Mean**	**Rank**	**Std. Deviation**	**Std. Error Mean**
C1	104	4.2821	1	0.70866	0.06949
C4	104	4.2404	2	0.85042	0.08339
C2	104	4.1563	3	0.89289	0.08756
C5	104	4.0962	4	1.20290	0.11795
C6	104	4.0192	5	1.14044	0.11183
C3	104	3.9904	6	1.11255	0.10909

"Proper analysis of anticipated PPP project risks" ranked third (4.1563), aligning with Ozdoganm and Birgonul [65], which emphasizes the importance of comprehensive risk assessment during the briefing stage. This involves estimating risk probabilities, quantifying consequences, calculating risk values, analyzing cash flows and financial risks, assessing transferable and retained risks, and conducting realistic long-term risk evaluations. Government guarantees for political, legal, and regulatory risks beyond the control of private investors ranked fourth (4.0962). Ozdoganm and Birgonul [65] also highlight the government's pivotal role in ensuring the success of the PPP briefing by providing protection against these risks.

Fifth and sixth are "flexibility of the project design solution to meet possible future changes in market demand" (4.0192) and "proper risk allocation and sharing among stakeholders" (3.9904). In PPP projects involving diverse stakeholders, responsibilities are crucial, emphasizing the need for adaptable design solutions to address potential shifts in market demand while maintaining the project's requirements.

5.6. Finance and Economic Factors

Table 9 shows the ranking order of finance- and economics-related factors from all respondents' perspectives. "Business and economic viability of the feasibility study" claimed the top spot (4.0856), followed closely by "Financial capacity and reliability of the private sector" (4.0833). Amponsah [32] emphasized that comprehensive feasibility studies with strong financial and economic analyses help avoid negotiation and procurement issues. Many researchers agree on the importance of robust feasibility studies [8,10,11,15,32,47,53,66–68]. Similarly, Tang et al. [18] underscored the need for well-defined commercial arrangements in a project brief. As detailed in its SSFs, achieving the business and economic viability of the feasibility study requires key elements, including a robust PPP reference model, a reliable Public Sector Comparator (PSC), value-for-money (VfM) analysis, bankability assessment, market intelligence, and a practical project budget and procurement plan. Additionally, strong private sector finances, expertise in long-term lending within the financial sector, and cost-effective technical solutions are equally crucial.

Table 9. Ranking of finance and economic factors.

One-Sample Statistics					
CSFs	**N**	**Mean**	**Rank**	**Std. Deviation**	**Std. Error Mean**
D2	104	4.0865	1	0.83897	0.08227
D4	104	4.0833	2	0.90991	0.08922
D3	104	4.0692	3	0.68480	0.06715
D1	104	3.9375	4	0.83554	0.08193

However, the importance of the private sector's financial capacity and reliability is clear. This reflects the sector's strong financial standing, experience in making long-term lending decisions, and ability to provide cost-effective technical solutions, as highlighted in the CSF's SSFs.

"Sound commercial and financial package/arrangements" ranked third (4.0692), aligning with findings from the Asian Development Bank [33], which emphasizes the critical role of project financing in PPP schemes. They argue that a robust financial market serves as an incentive for private sector involvement in efficient and mature markets. Similarly, research by Tang et al. [18] highlights the need for well-defined commercial arrangements, including contract duration, payment mechanisms, and financial agreements, in the project brief. The key elements, as detailed in the SSFs, include flexible price regulations, a feasible payment structure, profit transfer options, appropriate tariff levels, and an adjustment formula for interest and exchange rates for investors.

Financial and economic climate' ranked last in this category (3.9375), aligning with the views of Harrington [69] and UNESCAP [45], who emphasized that a stable economic environment attracts foreign investment in PPP projects and mitigates the risk of project failure caused by macroeconomic shocks. Therefore, as outlined in the SSFs, a stable economic climate, effective financial regulations, appropriate financial systems for PPPs, a robust financial market, access to long-term financing, limited competition from other projects, stable currencies, and low fixed interest rates are all critical for establishing a favorable financial and economic climate.

5.7. Public Sector Capacity-Related Factors

As shown in Table 10, in the Public Sector Capacity category, "Political support and stability" (4.25) ranked first, emphasizing the importance of creating a conducive environment for successful project execution, especially in PPPs, by providing both political backing and a stable environment for long-term planning and investment. According to research by Alteneiji et al. [49], political support and stability ranked highest in the literature review. They asserted that it is one of the most critical elements of economic development, representing a consensus among all local studies in the UAE. Similarly, Ong and Lenard [70] noted that political stability, government support, and incentives are crucial for privately financed projects, particularly in developing countries, where political instability is a major concern for build–own–operate–transfer (BOOT) projects. Given concession periods of 20 to 40 years, long-term political stability is essential. This aligns with the research by Dulaimi et al. [19], which highlights the importance of political support and stability in the UAE PPP project environment, as stakeholders require political leadership to intervene, understand the perceived risks of such projects, and ensure sustained political support for providing infrastructure services. Together, political support and stability create a conducive environment for successful project execution, especially in PPPs, by providing both the backing and the secure environment needed for long-term planning and investment.

Table 10. Public Sector capacity-related factors.

One-Sample Statistics					
CSFs	**N**	**Mean**	**Rank**	**Std. Deviation**	**Std. Error Mean**
E1	104	4.2500	1	0.87855	0.08615
E3	104	4.1538	2	0.82166	0.08057
E4	104	4.0192	3	1.15734	0.11349
E2	104	3.9359	4	0.75481	0.07402
E5	104	3.5705	5	1.04140	0.10212

"Governmental assistance during PPP project execution" ranked second (4.1538), emphasizing the need for support from line agencies and local governments during PPP projects, consistent with Dulaimi et al. [19] findings. "Government financial capacity to support PPP financial requirements" ranked third (4.0192), supporting the findings of [69], which emphasize the importance of integrating PPP financial needs into the government's budget process.

Fourth place (3.9359) went to "Qualified and experienced public staff to manage the PPP briefing process". This finding is supported by [45,61,64,69,71], who highlight the value of competent staff with PPP management qualifications and experience, emphasizing the need for adequately qualified public staff during the briefing process.

Lastly, "Effective government mechanisms for documentation and lessons learned" ranked lowest in this category (3.5705), underscoring the importance of accessible PPP documentation, best practices in the public domain, a shared e-documentation system for stakeholders, and a public database of feedback and lessons learned from completed PPP projects for successful PPP briefing.

5.8. Regulatory and Legal Factors

In the Regulatory and Legal Factors category, Table 11 reveals respondent rankings. "Clear authority and responsibility between public and private sectors" secured the top position (4.4231), emphasizing the need for a clear allocation of authority and responsibilities for each partner. This aligns with research by UNESCAP [45] and Chan et al. [72], who also stress the importance of clearly defined roles. The "Approved governance model by relevant authorities for the PPP venture" ranked second (4.2692), highlighting the importance of obtaining proper approvals from relevant authorities. Multiple authors, including [5,10,11,15,46,66,68], have highlighted the necessity of having the required laws

and legal structures in place for PPP processes. "Availability of effective regulatory and legal frameworks for PPP" ranked third (4.2154), supporting Othman [23] and Yu et al. [24]'s recommendations for alignment with updated policies and guidelines. This underscores the importance of a robust, transparent, and stable regulatory framework that includes clear land planning laws, transparent procurement systems, and statutory control measures.

Table 11. Ranking of regulatory and legal factors.

One-Sample Statistics					
CSFs	**N**	**Mean**	**Rank**	**Std. Deviation**	**Std. Error Mean**
F5	104	4.4231	1	0.82075	0.08048
F2	104	4.2692	2	0.83876	0.08225
F1	104	4.2154	3	0.88819	0.08709
F4	104	4.1538	4	0.83920	0.08229
F6	104	4.1538	5	1.12145	0.10997
F3	104	4.1154	6	0.97848	0.09595

Fourth place went to "Adherence to applicable and up-to-date legal and regulatory frameworks" (4.1538), aligning with research by Tang et al. [18] and Yu et al. [64], who stress the need for understanding statutory and lease control measures throughout the PPP project for successful briefing. This emphasizes the importance of following applicable design and operation standards while keeping up with updated regulatory frameworks. Also ranked fourth (4.1538) is "Proper dispute resolution mechanisms", underscoring the need for effective conflict and dispute resolution processes, as noted by Chan et al. [72]. Lastly, "Project scope matching the authorized mandate of the public agency" ranked last, highlighting the importance of aligning the project scope with the public agency's authorized mandate.

It is worth noting that the recently introduced Federal Law adds rigor to the regulatory and legal framework governing PPPs in the UAE. The law clarifies the authority and responsibilities between the public and private sectors, aligning with the top-ranked Critical Success Factor (CSF) in the regulatory category. Additionally, the requirement for government approval of PPP governance models and the emphasis on transparency in procurement strengthen legal compliance and project accountability. This legislative shift ensures that PPP projects align with national strategic objectives and financial sustainability. By formalizing procedures such as project selection, budgetary alignment, and risk mitigation, the decree reduces uncertainty in the PPP process and enhances long-term project viability. Ultimately, the law provides a crucial foundation for the successful application of CSFs, reinforcing the importance of adhering to legal frameworks, transparent project evaluations, and risk-sharing mechanisms, as discussed in this paper.

5.9. Social, Cultural, and Ethical Factors

Table 12 shows the ranking order of the factors related to the social, cultural, and ethical categories from the respondents' perspective. "Acceptable tariff level" secured the top spot (3.7692), as expected, emphasizing the importance of tariffs that align with community acceptance and considering the social and economic impact of PPP projects. Close behind, "Consideration of socioeconomic aspects" ranked second (3.7308), highlighting the need for all parties to recognize the social and economic implications of PPP projects.

Ranking third (3.6538) is "Consideration of cultural and ethical values of end users/user groups". Research by Othman [23] and Yu et al. [24] emphasizes the importance of managing the cultural and ethical values of end users and user groups involved in decision-making. Furthermore, the work environment during brief development ranked fourth (3.5423), highlighting the significance of rewards, long-term job commitment, openness, trust, stakeholder commitment, and honesty.

Finally, "Community participation, acceptance, and support" ranked last (3.3558), underscoring the community's ability to initiate, coordinate, and support PPP projects

during development. This reflects the importance of community involvement, suggestions, and understanding during project brief development, as noted by UNESCAP [45].

Table 12. Ranking of social, cultural, and ethical factors.

One-Sample Statistics					
CSFs	**N**	**Mean**	**Rank**	**Std. Deviation**	**Std. Error Mean**
G4	104	3.7692	1	1.10805	0.10865
G5	104	3.7308	2	1.02617	0.10062
G3	104	3.6538	3	1.00261	0.09831
G2	104	3.5423	4	1.11082	0.10892
G1	104	3.3558	5	1.17967	0.11568

5.10. Overall Discussion of All Categories

The survey results shown in Table 13 reveal a clear hierarchy of importance for the success of PPP project briefings in the UAE context. At the top are Regulatory and Legal Factors, followed by Finance and Economic Factors, Risk-related Factors, Public Sector Capacity, Procurement, Stakeholder Factors, and, finally, Social, Cultural, and Ethical Factors.

Table 13. Ranking of categories overall.

ID	Category	Mean	Rank
F	Regulatory and Legal Factors	4.2147	1
D	Finance and Economic Factors	4.1587	2
C	Risk-Related Factors	4.1571	3
E	Public Sector Capacity-related Factors	4.0423	4
A	Procurement-Related Factors	4.0115	5
B	Stakeholder-Related Factors	3.9835	6
G	Social, Cultural, and Ethical Factors	3.6038	7

The prominence of Regulatory and Legal Success Factors, ranked as the top category in this study, aligns with the findings of Tang et al. [73], who explored procurement-related success factor frameworks for PPP briefings in Hong Kong. Their research underscores the pivotal role of procurement decisions made during the early briefing stages, establishing that clear, well-defined regulatory and legal frameworks are foundational to the success of PPP projects.

These findings emphasize the critical importance of strong financial and economic foundations for PPP success, which is consistent with global research [8,10,11,15,32,47,53,66–68]. The top-ranked factor, "Business and economic viability of the feasibility study," underscores the universal need for comprehensive planning and rigorous financial analysis, aligning with Amponsah's [32] and Tang et al.'s [18] findings on the importance of feasibility studies and clear commercial arrangements. Similarly, the private sector's "Financial capacity and reliability" highlights its essential role in providing financial stability, long-term lending expertise, and cost-effective solutions. Furthermore, The focus on "Sound commercial and financial arrangements" mirrors global best practices, as emphasized by the Asian Development Bank [33] and Tang et al. [18], highlighting the role of structured agreements in fostering private sector confidence. The "Financial and economic climate" factor reflects the ongoing global challenge of ensuring macroeconomic stability, aligning with Harrington [69] and UNESCAP [45] emphasis on stable environments to attract investment and reduce risks.

The universal importance of comprehensive risk management was emphasized to ensure the success of PPP projects. "Proper identification of anticipated risks" and "Mitigation strategies" ranked highest, reflecting widely accepted best practices in identifying and transferring risks to stakeholders best equipped to manage them, consistent with Allan [38] and Li and Akintoye [41]. Similarly, "Proper risk analysis" aligns with Ozdoganm and Birgonul's [65] emphasis on quantifying risks and evaluating financial impacts. The role

of government guarantees in addressing uncontrollable risks reinforces the critical role of the public sector in fostering investor confidence globally. "Flexibility in design solution" and "proper Risk allocation" highlight the challenges in balancing adaptability with stakeholder responsibilities.

The analysis underscores the global importance of political stability and support for PPP success. This reflects its critical role in fostering long-term planning and investment, aligning with Alteneiji et al. [49] and Ong and Lenard [70], who emphasized its significance for economic development and risk mitigation, particularly in long-term concession projects. Further, Dulaimi et al. [19] highlighted its pivotal role in sustaining infrastructure projects within the UAE context. Other key success factors, such as governmental assistance and financial capacity, highlight the need for operational and financial integration within public frameworks, as noted by [19,69]. Meanwhile, qualified public staff emphasizes the value of expertise in managing PPPs, aligning with findings from research by [45,61,64,69,71]. These findings align with international standards while showcasing the UAE's emphasis on political and institutional stability, reflecting its adaptability in addressing both global and regional PPP challenges.

In the "Procurement-Related Factors" category, the findings highlight the universal importance of clarity, alignment, and strategic planning in the procurement phase of PPP projects. Clear project goals, objectives, and deliverables emerged as the most critical factor, reaffirming the global consensus that precise and aligned project briefs are essential for success and aligning with the findings of research by Abdul-Aziz [59], Akintoye and Donnelly [29], and Yu et al. [24] Furthermore, the focus on appropriate PPP model selection and controlled briefing processes further emphasizes the need for tailored approaches that effectively balance stakeholder needs with the project scope.

The findings related to stakeholders underscore their critical role in ensuring the success of PPP projects, aligning with global research, which highlights the importance of early identification, engagement, and empowerment. The top-ranked factor in this category, "Identification of influential stakeholders", emphasizes its foundational role, consistent with the studies of Kelly et al. [60], Juaim and Hassanain [61], and Jing et al. [62]. This also complements findings in the Social, Cultural, and Ethical Factors category, where understanding stakeholder needs and cultural differences emerged as important considerations. Similarly, team selection and empowerment align with the findings of research by [24,63,64], where team quality and the value of empowerment were emphasized as vital for achieving project goals. Together, these findings reaffirm global best practices while highlighting the importance of integrating stakeholder management strategies across all stages of PPP development.

The findings in the Social, Cultural, and Ethical Factors category align with global research, emphasizing the importance of community alignment, cultural considerations, and ethical governance in PPP success. Key priorities, such as acceptable tariffs and socioeconomic impacts, reflect the universal need for equity and inclusivity, resonating with the studies by Othman [23] and Yu et al. [24]. The lower ranking of community participation highlights both a persistent challenge and an opportunity to strengthen engagement strategies, aligning with UNESCAP's [45] recommendations for deeper stakeholder involvement to enhance project acceptance and success.

6. Conclusions

This paper presents a comprehensive quantitative analysis to assess the relative importance of Critical Success Factors (CSFs) in the development of Public-Private Partnership (PPP) project briefs in the UAE. Using a structured questionnaire, responses from experienced PPP professionals were analyzsed to evaluate 38 CSFs and 103 Sub-Success Factors (SSFs) across seven key categories: Regulatory and Legal Factors, Finance and Economic Factors, Risk-related Factors, Public Sector Capacity, Procurement-Related Factors, Stakeholder Factors, and Social, Cultural, and Ethical Factors. The first part of the paper focuses on preliminary data analysis, including a descriptive examination of respondent profiles

and response distribution alongside initial interpretations. The reliability test, conducted to ensure the validity of the measurements using item-to-total correlation and Cronbach's alpha values, confirmed the data's suitability for further analysis. This analysis revealed the following conclusions:

- The importance and ranking of 38 CSFs and 103 Sub-Success Factors (SSFs) across seven main categories were established.
- This study reinforces the importance of a holistic approach in managing the development of PPP briefs, incorporating Critical Success Factors (CSFs) across legal, financial, and social dimensions to achieve long-term success in the UAE's rapidly evolving construction landscape.
- The findings revealed that Regulatory and Legal Factors ranked highest, emphasizing the importance of clear legal frameworks and well-defined roles between the public and private sectors to ensure project success. Finance and Economic Factors and Risk-related Factors followed closely, highlighting the significance of financial stability, sound commercial arrangements, and effective risk management strategies. Public Sector Capacity, including political support and governmental assistance, also emerged as a critical element, underscoring the role of qualified public staff and sustained political backing for PPP projects. Procurement-related and Stakeholder-related factors were also recognized as vital, particularly the need for clear project objectives, stakeholder engagement, and effective communication throughout the briefing process. Social, Cultural, and Ethical Factors, though ranked last, remain crucial for addressing community involvement, cultural values, and the socioeconomic impact of PPP projects.
- The importance of the Critical Success Factors was clearly indicated in the UAE Federal Law No. 12 of 2023 regarding Public-Private Partnerships (PPPs) in the UAE, which provides a robust legal foundation for effective collaboration between the public and private sectors. The law specifically emphasized the risk-sharing mechanisms and accountability measures in the PPP process, directly reinforcing the CSFs identified in this paper.
- From a practical perspective, the developed CSF framework is a valuable tool for practitioners and decision-makers in PPP brief development in the UAE. Aligning the framework with UAE Federal Law No. 12 of 2023 enables project teams to establish clear legal, financial, and operational parameters during the briefing phase. Comprehensive stakeholder engagement, as emphasized in this study, can mitigate risks and align diverse project participants. Applying the framework during feasibility studies and procurement planning facilitates actionable and well-defined project briefs, ultimately improving the project outcomes.
- Although the research findings provide a comprehensive framework of CSFs for brief development tailored to the UAE's unique PPP environment, they primarily focus on PPP projects in general. Future studies could explore the relative importance of CSFs across specific PPP sectors in the UAE, particularly as more PPP projects are anticipated in the future pipeline, including those in the transport, education, healthcare, and other sectors.
- This study has certain limitations that present opportunities for future research. The sample size focuses on the UAE context, which currently has a limited number of PPP projects and experts compared to more mature markets. Future research could address this limitation by expanding the sample to include a larger pool of experts actively involved in developing various PPP initiatives across the UAE.

In conclusion, the research described in this paper highlights the critical importance of identifying and implementing Critical Success Factors (CSFs) during the briefing stage of future PPP projects to ensure their successful execution in the UAE. By focusing on the early stages of the project lifecycle, this study emphasizes the role of CSFs in establishing a strong foundation for project development, aligning stakeholder objectives, and mitigating potential risks. The findings demonstrate that a comprehensive and well-structured briefing

process tailored to the UAE's unique PPP environment is essential for achieving efficiency, stakeholder satisfaction, and long-term project viability. These insights offer valuable guidance for practitioners, policymakers, and researchers aiming to optimize the briefing stage for PPP projects in the UAE and beyond.

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Appendix A. Initial Activity-Based Success Factors List for PPP Briefing

Briefing Phases	Briefing Activity	Briefing Tasks	Briefing Phases
Strategic Phase (Strategic Project Brief)	**1. The Needs Analysis**	**1.1.** Identify long-term business/service needs.	■ An accepted need for the service/product [65] ■ A near-monopoly condition for the service/product [65] ■ Clear long-term demand for the products/services in the market [31] ■ Understanding of the functions the institution performs in the public interest or on behalf of the public service [74]
		1.2. Demonstrate that the project is aligned with the institution's strategic objectives	■ Understanding the client's strategic goals [24] ■ Alignment with the latest government policies and strategies [29,31,75] ■ Integration of the project with national and local planning processes [45]
		1.3. Identify and analyze the available budget(s)	■ Integration of the project's financial/financing support requirements with the government's budget process [45] ■ Identification of the government's future budgetary commitments [74] ■ Identification of the line items currently in the institution's budget that may no longer be incurred as a result of the proposed project [74]
		1.4. Ensure the institution's commitment and capacity	■ Established government mechanisms are in place to coordinate PPP needs [45,76]. ■ Staff at relevant government agencies have the necessary resources, qualifications, and information to manage the PPP process [19,45]. ■ The PPP process has sufficient political support and stability [19,45]. ■ Staff possess awareness of legal, financial, and basic technical issues in PPP projects [45,77]. ■ Staff demonstrate competence in routine operations related to PPP development [45,77]. ■ The technical capacity is sufficient to ensure construction and service standards are met [19,45]. ■ Staff have the ability to access external expertise, including feasibility studies and risk-mitigation strategies [19,45]. ■ PPP documentation and best practices are available in the public domain [45]. ■ Adequate resources/facilities and expertise to train in PPP [45,77]. ■ Provision exists for assisting line agencies and local governments in undertaking PPP projects [45,76].

Briefing Phases	Briefing Activity	Briefing Tasks	Briefing Phases
Strategic Phase (Strategic Project Brief)	**2. Project Parameters and Scoping**	**2.1.** Perform user group analysis	■ Identification of key user groups, the nature of their relationships, and the project's impact on them [74] ■ Development of a user group consultation plan [74]
		2.2. Get User Group Input	■ Adequate representation of user groups and client groups [24,37] ■ Clear identification of end-user requirements [18,24,37,64] ■ Understanding of the cultures and traditions of different end users/user groups [23] ■ Proper utilization of users' values and knowledge [27,78] ■ Strict control and management of the client/user groups through the brief/output specification to avoid the brief becoming a 'wish list' [24,37,79]
		2.3. Develop project parameters and output specifications	■ Commitment of all participants in the briefing process [61] ■ Open and effective communication [18,24,37,64,72] ■ Involvement of the owner in the briefing process [61] ■ Consultation with facility managers [24] ■ Clear goals and objectives [2,8,18,21] ■ Clarity of project requirements (functional, technical, and behavioral) [30,61] ■ Facilitation of active communication through stakeholder workshops [18,24,30,37,64] ■ Formal procedures for gathering requirements [80] ■ Assessment that the output specifications meet the institution's ongoing service needs [24] ■ Identification of service interface expectations [80] ■ Setting of defined and measured service quality [31] ■ Adequate experience with the building process by the owner [61] ■ Productive conflict resolution [72] ■ Establishment of priority levels for various project requirements [61] ■ Review of Post-Occupancy Evaluation (POE) and post-project evaluation findings from the client's last similar project [24]
		2.4. Define the scope of the project (project definition)	■ Clear outcomes from previous activities/steps (institution's needs, strategic objectives, and output specifications) [74]. ■ Identification of significant government assets to be used for the project (e.g., land and equipment) [74].
		2.5. Draft statement of requirements.	■ Thorough documentation of findings, conclusions, and decisions made [18,64].
	3. Option Appraisal	**3.1.** Identify possible solution options to meet the need	■ Early considerations of suitability for a PPP [18,67] ■ Early indication of the PPP market [81]
		3.2. Evaluate each solution option	■ Excellent technical capability (including relevant previous experience) [82] ■ Understanding the advantages and disadvantages of each solution option [51] ■ Examination of the risks, benefits, and potential impacts on the government for each option [51] ■ Objective criteria for option evaluation being known and applied (clear evaluation criteria) [83].
		3.3. Early considerations of suitability for a PPP	■ Clarity of the output specification [84]. ■ Adequate estimation of probable cash flows (inflows and outflows) and financing costs [85]. ■ Thorough examination of opportunities for risk transfer (or risk sharing) [81].
		3.4. Choose the preferred solution option.	■ Objective criteria for option evaluation being known and applied (clear evaluation criteria) [83] ■ Determining the appropriate decision-making method [24,37] ■ Consistency of the analysis and selection with any infrastructure investment policies and guidelines applicable at the time [75]

Briefing Phases	Briefing Activity	Briefing Tasks	Briefing Phases
Feasibility Phase (Feasibility Project Brief)	**4. Project due diligence**	**4.1.** Legal issues	■ Compatibility of the preferred option(s) with current statutory and institutional arrangements [31] ■ A favorable legal framework (mature, reasonable, and predictable) [31] ■ A mature legal framework for the realization of possible PPP projects [65] ■ Knowledge of statutory and lease control of the project [18] ■ Use of updated regulations [23] ■ Investigation of any regulatory matters that might impact the private party's ability to deliver as expected for greenfield projects [74] ■ Clearly defined legal basis for private sector participation in PPP [86] ■ Clear authority for land acquisition procedures, rights of way, and all PPP types" [65,86,87] ■ Regulated price and quality of PPP monopolies to protect consumers and others [88] ■ Sufficiently flexible price regulation to adjust to major cost changes [88] ■ Adequate powers and resources to regulate PPP [45] ■ Adherence to applicable codes and municipal standards for the project type [61]. ■ Adequate, transparent, and clearly defined procurement system by the government [65] ■ Adequate regulatory framework of the public institution [65]
		4.2. Site ownership and availability	■ Establishment of the following [74]: ○ Land ownership ○ Land availability and any title deed endorsements ○ Any land claims, if applicable ○ Lease interests in the land, if applicable ■ Experts appointed to undertake surveys of [74]: ○ Environmental matters. ○ Geotechnical matters. ○ Heritage matters. ○ Zoning rights and town planning requirements. ○ Municipal Integrated Development Plans. ■ All related NOCs and approvals being identified, compiled, and verified if the institution nominates a particular site [74,89].
		4.3. Environmental Impact Assessment	■ Clear and transparent environmental laws, available from a single source [45,90] ■ Project's consistency with environmental decisions [65] ■ The environmental sustainability of the project [31] ■ Sufficient public acceptance of the project [65]
		4.4. Socioeconomic assessment.	■ Setting of socioeconomic targets that the institution wishes to achieve in the project [45] ■ Impact assessments follow well-defined guidelines, considering key variables such as population density, type of terrain, and type of project [45] ■ Prices of the services consistent with comparable services [65] ■ Possibility of government subsidies for prices [65] ■ An understanding and supportive community [31] ■ Full understanding and acknowledgment of the social character of PPP [91] ■ An acceptable level of tolls/tariffs [31] ■ Possibility of creating more job opportunities [31] ■ Establishing community advisory groups by the government as a means of two-way communication between the project team and the community, particularly concerning urban design and master planning issues [79] ■ Appropriate and efficient management of community expectations [79]

Briefing Phases	Briefing Activity	Briefing Tasks	Briefing Phases
Feasibility Phase (Feasibility Project Brief)	**5. Risk Management**	**5.1.** Identify project risks **5.2.** Assesses the impact of risks **5.3.** Estimate the likelihood of the risks occurring **5.4.** Calculate the cost of the risks and ranges of possible outcomes **5.5.** Allocate risks to the party or parties best able to manage them **5.6.** Identify strategies for mitigating risks	■ Commencement of risk register [18] ■ Special risk assessment [18] ■ Quantification of consequences of risks [18] ■ Estimation of risk probabilities [18] ■ Calculation of risk values [18] ■ Identification of desired risk allocation [18] ■ Possible allocation of responsibilities and risks between the government and the private sector [18] ■ Accurate measurement of risk management/mitigation [18] ■ Calculation of transferable and retained risks [18] ■ Realistic assessment of demand projections to quantify long-term risks and revenues [65] ■ Minimizing cash-flow risk by the government through possible property development rights [65] ■ Guarantees provided by the government against political, legal, or regulatory risks beyond the control of private investors [65] ■ Flexibility to decide appropriate risk allocation [31] ■ Risk-mitigation strategies proposed by staff [45] ■ Sensible and manageable arrangements for risk sharing [45]
	6. Financial Assessment	**6.1.** Construct the Public Sector Comparator (PSC)	■ Costing of a project on PSC lines based on recent, actual costs of a similar project or best estimates [19,74] ■ Allocation of sufficient resources to project development to ensure high-quality analysis of cash flows and risks [19,75] ■ Feedback from completed (local or regional) projects [18,61,64] ■ Skillful guidance and advice from the Ministry/Department of Finance and/or a financial adviser to develop project risks and ascribe the PSC [75].
		6.2. Construct the PPP reference model and set out the payment mechanism	■ Use of identical output specifications as those used in the PSC model [74] ■ Experience of the transaction advisor [74] ■ Market knowledge and experience to construct a market-related PPP reference model [74].
		6.3. Demonstrate affordability	■ Careful analysis of the expected costs of the project over the entire project term, including the costs of managing a PPP agreement, as well as operating and maintenance costs [74]. Existing budgetary commitments of the institution [19,74].
		6.4. Value-for-money (VfM) Analysis	■ Robust outcome from the PSC, reference model, and risk assessment based on the requirements of the output specifications [74] ■ Reasonable and appropriate assumptions [74]
		6.5. Assess bankability	■ Estimation of revenue based on realistic assumptions and the most appropriate baseline case [92] ■ Consistent attention to financing needs in the project feasibility study [92] ■ Suitable type of debt to finance long-term PPP projects [92]
		6.6. Conduct market testing	■ Adequate market capability and appetite [74] ■ Identification of the capacity of the public and private sectors to provide the assets/services [74] ■ Awareness of project size and complexity [74] ■ Comparison to similar cases [74]

Briefing Phases	Briefing Activity	Briefing Tasks	Briefing Phases
Procurement Phase (Project Brief)	**7. Consultations with relevantStakeholders**	**7.1.** Perform a detailed Stakeholder analysis	■ Identification of key stakeholders, the nature of their relationships, and the project's impact on stakeholders [74] ■ Knowledge of client's responsibility [18] ■ Assessing the commitment, interest, and power of individual stakeholders [24,37] ■ The client should define the composition of the stakeholder group [24] ■ Understanding different cultural and ethical characteristics of the individual stakeholders [24,37] ■ Proper identification of influential stakeholders [62] ■ Assessing the attributes of stakeholders (power, urgency, and proximity) [62,93] ■ Understanding stakeholders' areas of interest and their constraints [62]
		7.2. Develop consolation plan	■ A proper consultation plan for user groups and stakeholders throughout the brief development process [24,74] ■ Clarity of stakeholders' roles [18,64] ■ Sufficient consultation with stakeholders [18,24,37,64] ■ Experience of stakeholder groups [18,64] ■ Productive Conflict Resolution [72] ■ Adequate representation of both user groups and client groups in the development of the brief [18,24,64] ■ Identifying strategies to address issues raised by stakeholders [93] ■ Clarification of stakeholders' roles and responsibilities [18]
		7.3. Conduct discussions and record correspondence	■ Initial consultation with the relevant treasury department about budgetary and affordability issues [74] ■ Balancing the needs/requirements of different stakeholders [18,24,37,64] ■ The stakeholder group should be empowered by the client within precisely defined limits [24] ■ The stakeholder group must be empowered to make decisions as a team in the briefing process [24] ■ Commitment of all participants in the briefing process [61] ■ Empowerment of stakeholders to make decisions [24,37] ■ Efficient Coordination [72] ■ A structured or facilitated workshop to improve communication among stakeholders [24] ■ Communication among stakeholders is crucial to the success of the briefing process [24] ■ Management of stakeholders with corporate social responsibilities (economic, legal, environmental, and ethical) [62] ■ Proper use made of users' values and knowledge [27,78] ■ Proper analysis and compromise in conflicts and coalitions among stakeholders [62] ■ Utilization of different methods to document and effectively communicate the brief [61] ■ Open and effective communication with stakeholders, the team, and project representatives [18,24,61,64,72] ■ Good facilitation of the briefing passed on to stakeholders [18,24,64] ■ Frequent and proper communication with and engagement of stakeholders [62] ■ Facilitating knowledge sharing among stakeholders [24] ■ Building openness and trust among stakeholders and end-user groups [18,64,72] ■ Require all parties to be involved and committed [24,61]

Briefing Phases	Briefing Activity	Briefing Tasks	Briefing Phases
Procurement Phase (Project Brief)	**8. Project Development**	**8.1.** Assemble resources–steering committee, project director, procurement team	■ Proper PPP implementation involves assembling experienced cross-functional teams, including a steering committee, project director, and procurement team [94,95]
		8.2. Develop a project plan	■ Practical/realistic budget and program [18,24,37,64] ■ Skillful guidance and advice from the project manager [18] ■ Excellent technical capability [64]
		8.3. Appoint a Transaction Advisor	■ Precise terms of reference for the transaction advisor focused on clear deliverables [96]. ■ Fair, equitable, transparent, competitive, and cost-effective procurement of the transaction advisor in line with the government's constitutional mandate for hiring services [96]. ■ No separate retention or subsequent hiring of additional consultants for the project outside of the transaction advisor, enhancing investor confidence [96] ■ A contract between the institution and the transaction advisor that incentivizes the quality completion of milestones according to the PPP project cycle, on time and within budget [96] ■ Experience in similar transactions [96] ■ Protection against very costly, avoidable mistakes [96] ■ Access to national and international best practices [96] ■ Technical strength in the institution's team [96]
		8.4. Conduct further development for the PSC **8.5** Conduct further development for the project brief	■ Development of a framework agreed upon by the key parties [18] ■ The brief should act as a reference document available to all project parties [24] ■ The brief should contain details of the procedures necessary to facilitate the absorption of the project into the client's core business following completion [24] ■ The brief should describe the potential changes to the client's organization resulting from the construction project [24] ■ The brief should outline the contribution of the project to the client's core business [24] ■ Setting a deadline to freeze the development of the brief [61] ■ Flexibility of the brief to accommodate changes [18,24,64]
		8.6. Develop EOI evaluation criteria	■ Clear evaluation criteria [97]
	9. Confirming Market Interest and Capacity	**9.1.** Develop and issue Expression of Interest (EoI) invitations **9.2.** Evaluate responses and develop a shortlist **9.3.** Finalize the project brief RFP with a draft PPP agreement **9.4.** Marketing PPP project	■ An EoI document with sufficient information [75] ■ An EoI stating the results to be delivered before the government proceeds with private investment [75] ■ An EoI that does not require potential bidders to expend significant resources on preparing a response [75] ■ A briefing session for parties contemplating a response to the EoI [75] ■ Consensus building [18,24,37,64] ■ Proper priority setting [18,64] ■ Utilization of different methods to document and effectively communicate the brief [61] ■ Clear and precise briefing documents [18,24,37,64] ■ Agreement on the brief by all relevant parties [18,24,37,64]
	10. Request for Proposals	**10.1.** Publish notices inviting pre-qualified companies/consortia to submit proposals.	■ Prequalification is crucial for identifying suitable bidders [98]
		10.2. Conduct a briefing workshop with the bidders.	■ Use of face-to-face contact as a communication method [61] ■ Experience of the client [18,61,64] ■ Good facilitation [18,64]

Other CSFs Related to the Whole Briefing Process in PPP Projects	
	■ Adequate time for briefing [18,61,64] ■ Feedback from completed projects [18,61,64] ■ Client's experience [18,61,64] ■ Selection of the briefing team [18,64] ■ Knowledge of client's business [64] ■ Experience of the brief writer [18,24,37,64] ■ Control of the process [18,24,37,64] ■ Commitment of all participants in the briefing process [61] ■ Timely and proper decision-making at various stages of the development and implementation of the brief [61] ■ Allocation of a separate service fee for developing the brief [61] ■ Involvement of the project manager in the briefing process [61] ■ Support from Top Management [72] ■ Mutual trust [72] ■ Long-Term Commitment [72] ■ Productive Conflict Resolution [72] ■ Understanding of team dynamics [24,37] ■ Development of a framework agreed upon by key parties [18] ■ Issues resolved in a timely and responsive manner [72] ■ The brief writer determines the appropriate decision-making method in the briefing process [24,37] ■ The brief writer makes decisions based on information received from stakeholders [24] ■ Effective decision-making by client representatives [24,37] ■ Control of the briefing process [18,24,37,64] ■ Clear management structure [18,64] ■ Honesty [18,24,37,64] ■ Openness and trust [18,64] ■ Open and effective communication [18,24,37,64,72] ■ The brief is the primary vehicle for knowledge sharing among the project team [24] ■ Culture and ethics affecting decision-making in the briefing process [24]

Appendix B. Ranking Analysis of CSFs and Their SSFs: Mean and Level of Importance of All Factors

Item Code	Item	SSFs Mean	SSFs Rank	CSFs Mean	CSFs Rank	Categories Mean	Categories Rank
A	**Procuremen- Related Factors**					**4.0115**	**5**
A1	Clear the project's goal, objectives, and deliverables in the brief.			4.2423	1		
A11	Clarity of the project goal and objectives set by the client/owner	4.4231	1				
A12	Proper project output- specifications developed to meet the client's/owner's service needs and standards	4.3077	2				
A13	Demonstration of the project's alignment to the client's/owner's strategic objectives	4.1731	4				
A14	Integration of the PPP project with the national and local planning processes	4.0962	5				
A15	Adequate preparation and management of the Expression of Interest (EOI) stage of the PPP project in the brief's development	4.2115	3				
A2	Clear and precise process for formulation and control of the brief			3.8341	3		
A21	A framework for the brief's formulation to be agreed by key partners	3.9038	3				
A22	A briefing process with clear goals and objectives	3.9038	3				

Item Code	Item	SSFs Mean	SSFs Rank	CSFs Mean	CSFs Rank	Categories Mean	Categories Rank
A23	Lead given by the public sector and its continuous control and monitoring of the briefing process	3.7885	6				
A24	Clear and applicable criteria for the selection of options	3.8462	5				
A25	Establishment of priority levels for decisions agreed on by the key parties during briefing	3.7885	6				
A26	Use/application of the Value Management (VM) approach in the development of the brief	3.5192	8				
A27	A realistic timetable set for the completion of the brief	3.9231	2				
A28	Availability of a clear and precise brief at the end of the briefing stage	4.0000	1				
A3	Appropriateness of the selected PPP model	--	--	4.1346	2		
A4	Adequate resources allocated to the briefing process			3.7548	4		
A41	Allocation of a separate service fee for developing the brief	3.7115	4				
A42	Sufficient time to be allowed for the briefing	3.8077	1				
A43	Sufficient human resources to be allowed for the briefing	3.7692	2				
A44	The recruitment of an experienced writer of briefs	3.7308	3				
A5	Flexibility of the brief and the management of change			3.6538	5		
A51	Flexibility in the development of the brief to allow for possible changes	3.6346	2				
A52	The brief should describe the possible changes to the client organization resulting from the PPP project	3.6731	1				
B	**Stakeholder-Related Factors**					**3.9835**	**6**
B1	Identification of the influential stakeholders			4.1731	1		
B11	Identifying influential stakeholders properly	4.2692	1				
B12	Identifying key user-groups	4.0769	2				
B2	Addressing stakeholders' possible power and influence			3.7115	7		
B21	Assessing stakeholders' behavior	3.7885	1				
B22	Predicting the influence of stakeholders accurately	3.6923	2				
B23	Assessing the attributes (power, urgency, and proximity) of stakeholders	3.6538	3				
B3	Identification of the stakeholders' needs, requirements, and interests			4.0096	2		
B31	Identifying end-user/user-groups requirements in the project brief	4.1538	1				
B32	Identifying the client/owner's requirements in the project brief	4.1346	2				
B33	Understanding the areas of stakeholders' interests and their constraints	3.9615	3				
B34	Balancing the needs/requirements of different stakeholders	3.7885	4				
B4	Adequate engagement of user groups throughout the briefing process			3.8526	5		
B41	Representation of both the user groups and client groups in the development of the brief	3.9423	1				
B42	Adequately engaging the user groups throughout the briefing and design stages	3.9615	2				
B43	Proper use of the user-groups values and knowledge	3.6538	3				
B5	Stakeholder management strategies			3.8846	4		
B51	Identifying appropriate decision-making strategies	3.9038	3				
B52	Clarifying the roles and responsibilities of project stakeholders	4.0769	1				

Item Code	Item	SSFs Mean	SSFs Rank	CSFs Mean	CSFs Rank	Categories Mean	Categories Rank
B53	Managing stakeholders with corporate social responsibilities (economic, legal, environmental, and ethical)	3.7308	6				
B54	Publishing a proper consultation plan for user groups and stakeholders	3.8077	5				
B55	Strictly controlling and managing the client/user groups to avoid output specifications becoming a wish list (wish-list syndrome)	3.9615	2				
B56	Proper analysis and compromise in conflicts and coalitions between stakeholders	3.8269	4				
B6	Proper communication and coordination between stakeholders during the brief development			3.7418	6		
B61	Good facilitation of briefing should be given to stakeholders	3.7308	4				
B62	Good facilitation in the briefing for stakeholders	4.0385	1				
B63	Communication with and engaging stakeholders properly and frequently	3.9808	2				
B64	Using different methods to document and effectively communicate the brief	3.5962	6				
B65	Proper methods of e-based communications among stakeholders	3.4423	7				
B66	Facilitating the sharing of knowledge among the stakeholders	3.6346	5				
B67	Using face-to-face contact as a communication method in critical decision stages of the brief	3.7692	3				
B7	Team selection and empowerment			3.9615	3		
B71	Empowering the stakeholder group as a team to make decisions in the briefing process	3.8654	2				
B72	Selecting team members with relevant experience to develop an effective brief	4.0577	1				
C	**Risk-Related Factors**					**4.1571**	**3**
C1	Proper identification of anticipated risks/threats to the PPP project			4.2821	1		
C11	Commencement of a risk register/log early in the briefing stage	4.3654	2				
C12	Identifying partner-related risks in the PPP projects	4.4038	1				
C13	Identifying supply chain risks in the PPP projects	4.0769	3				
C2	Proper analysis and assessment of anticipated risks/threats to the PPP project			4.1563	3		
C21	Proper estimation of anticipated risk probabilities	4.1154	6				
C22	Proper quantification of the consequences of risks	4.2115	2				
C23	Proper calculation of risk value	4.1923	3				
C24	Thorough analysis of cash flows and financial risks	4.3269	1				
C25	Proper calculation of transferable and retained risks	4.1538	5				
C26	Examining the impact of risks/benefits on government options	4.1731	4				
C27	Realistic long-term risk assessment	4.0962	7				
C28	Special risk assessment	3.9808	8				
C3	Proper risk allocation and sharing among project stakeholders			3.9904	6		
C31	Determining the desired risk allocation	3.9615	2				
C32	Appropriate risk allocation in the following areas: concession agreements, guarantees/support/comfort letters, loan agreements, operation agreements, insurance agreements, design and construct contracts	4.0192	1				
C4	Proper mitigation/reduction strategy for anticipated risks/threats to the PPP project			4.2404	2		

Item Code	Item	SSFs Mean	SSFs Rank	CSFs Mean	CSFs Rank	Categories Mean	Categories Rank
C41	Setting an effective management plan for risk mitigation/reduction	4.1538	2				
C42	Recruiting expert staff to assess the risk-mitigation strategy	4.3269	1				
C5	Government guarantees for political/legal/regulatory risks beyond the control of private investors.	--	--	4.0962	4		
C6	Flexibility of the project design solution to meet possible future changes in market demand	--	--	4.0192	5		
D	**Finance and Economic Related Factors**					**4.1587**	**2**
D1	Favorable financial and economic climate			3.9375	4		
D11	Stable economic climate	4.0577	4				
D12	Effective financial regulatory regime in place	4.0769	3				
D13	Availability of proper financial systems for PPP arrangements	4.3077	1				
D14	Available financial market	4.0192	5				
D15	Availability of long-term finance	4.2308	2				
D16	Limited competition from other projects	3.2500	8				
D17	Stable currencies of securitization (debts and equity finance)	3.9231	6				
D18	Financing with fixed low interest rates	3.6346	7				
D2	Business and economic viability of the feasibility study			4.0865	1		
D21	Constructing a robust PPP reference model	4.0577	3				
D22	A reliable Public Sector Comparator (PSC)	3.8846	6				
D23	A value-for-money (VfM) analysis	4.3077	1				
D24	Proper assessment of bankability	4.0577	3				
D25	Market intelligence study: Investigation of private sector capability and capacity to deliver the required services	4.0577	3				
D26	Practical budget and procurement program of the project	4.1538	2				
D3	Sound commercial and financial package/arrangements			4.0692	3		
D31	Flexible price regulations sufficient to adjust to major cost changes	4.0000	4				
D32	The setting up of a feasible payment structure and mechanism	4.0962	2				
D33	The ability to transfer profits out of the country	4.0577	3				
D34	Appropriate tariff level(s) and suitable adjustment formula for investors	4.1923	1				
D35	The ability to deal with fluctuations in interest/exchange rates	4.0000	4				
D4	Financial capacity and reliability of the private sector			4.0833	2		
D41	Good private sector financial standing	4.2115	1				
D42	The financial sector experienced in assessing long-term lending decisions	4.1538	2				
D43	Cost-effective technical solution	3.8846	3				
E	**Public Sector Capacity-Related Factors**					**4.0423**	**4**
E1	Political support and stability refer to Sufficient political backing and a stable environment for long-term project success.	--	--	4.2500	1		
E2	Qualified and experienced public staff to manage the PPP briefing process			3.9359	4		
E21	Adequate public staff qualifications and experience in the briefing process	4.0192	1				
E22	Adequate technical capacity in relevant government agencies for tackling/undertaking similar PPP projects	3.9231	2				
E23	Adequate PPP resources/facilities and expertise training	3.8654	3				

Item Code	Item	SSFs Mean	SSFs Rank	CSFs Mean	CSFs Rank	Categories Mean	Categories Rank
E3	Governmental assistance during the PPP project undertaking	--	--	4.1538	2		
E4	Government financial capacity to support PPP financial requirements	--	--	4.0192	3		
E5	Effective government mechanisms for documentation and lessons learned.			3.5705	5		
E51	Availability of PPP documentation and best practices in the public domain	3.5577	2				
E52	Proper e-documentation system among all stakeholders for the brief's development and all the decisions made	3.5000	3				
E53	Availability of feedback and lessons learned from PPP-completed projects as a database in the public domain	3.6538	1				
F	**Regulatory and Legal-Related Factors**					**4.2147**	**1**
F1	Availability of effective regulatory and legal frameworks for PPP			4.2154	3		
F11	Robust, transparent, and stable regulatory framework for PPP procurement	4.2885	2				
F12	Clear land planning laws and regulations	4.0962	5				
F13	Fairness and transparency of the government's procurement system	4.1346	4				
F14	Clear ownership issues	4.3654	1				
F15	Clear statutory control measures	4.1923	3				
F2	Approved governance model by relevant authorities for the PPP venture	--	--	4.2692	2		
F3	Project scope to match the authorized mandate of the public agency	--	--	4.1154	6		
F4	Adherence to applicable and up-to-date legal and regulatory frameworks			4.1538	4		
F41	Adherence to applicable design and operation codes and standards for the type of project	4.1154	2				
F42	Updated regulatory framework in place	4.1923	1				
F5	Clear authority and responsibility between the public and private sector	--	--	4.4231	1		
F6	Proper dispute resolution mechanism	--	--	4.1538	5		
G	**Social, Cultural, and Ethical Related Factors**					**3.6038**	**7**
G1	Community participation, acceptance, and support			3.3558	5		
G11	Ability of the community to suggest PPP projects, coordinate and participate with the government during the development of the project brief	3.2885	2				
G12	Community acceptance, supportiveness, and understanding were obtained during the development of the project's brief	3.4231	1				
G2	Work environment during the brief development			3.5423	4		
G21	Rewards and incentives to encourage the PPP staff	3.3462	5				
G22	Long-term job commitment to increase the productivity of project staff	3.3846	4				
G23	Openness and trust between stakeholders	3.5769	3				
G24	Commitment of all participants in the briefing process	3.6346	2				
G25	Honesty among stakeholders	3.7692	1				
G3	Consideration of cultural and ethical values of the end users/user group during the brief's development	--	--	3.6538	3		
G4	Acceptable tariff level	--	--	3.7692	1		
G5	Consideration of socioeconomic aspects	--	--	3.7308	2		

Appendix C. One-Sample *t*-Test of the Statistical Significance of the PPP Briefing's CSFs

ID	CSF	t	df	Sig. (2-Tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
A1	Clear the project's goal, objectives, and deliverables in the brief	17.223	103	0.000	1.24231	1.0993	1.3854
A2	Clear and precise process for formulation and control of the brief	10.825	103	0.000	0.83413	0.6813	0.9870
A3	Appropriateness of the selected PPP model	12.235	103	0.000	1.13462	0.9507	1.3185
A4	Adequate resources allocated to the briefing process	8.418	103	0.000	0.75481	0.5770	0.9326
A5	Flexibility of the brief and the management of change	7.112	103	0.000	0.65385	0.4715	0.8362
B1	Identification of the influential stakeholders	15.560	103	0.000	1.17308	1.0236	1.3226
B2	Addressing stakeholders' possible power and influence	8.143	103	0.000	0.71154	0.5382	0.8848
B3	Identification of the stakeholders' needs, requirements, and interests	13.491	103	0.000	1.00962	0.8612	1.1580
B4	Adequate engagement of user groups throughout the briefing process	11.250	103	0.000	0.85256	0.7023	1.0029
B5	Stakeholder management strategies	10.312	103	0.000	0.88462	0.7145	1.0548
B6	Proper communication and coordination between stakeholders during the brief development	10.808	103	0.000	0.74176	0.6056	0.8779
B7	Team selection and empowerment	12.864	103	0.000	0.96154	0.8133	1.1098
C1	Proper identification of anticipated risks/threats to the PPP project	18.449	103	0.000	1.28205	1.1442	1.4199
C2	Proper analysis and assessment of anticipated risks/threats to the PPP project	13.206	103	0.000	1.15625	0.9826	1.3299
C3	Proper risk allocation and sharing among project stakeholders	9.078	103	0.000	0.99038	0.7740	1.2067
C4	Proper mitigation/reduction strategy for anticipated risks/threats to the PPP project	14.874	103	0.000	1.24038	1.0750	1.4058
C5	Government guarantees for political/legal/regulatory risks beyond the control of private investors	9.293	103	0.000	1.09615	0.8622	1.3301
C6	Flexibility of the project design solution to meet possible future changes in market demand	9.114	103	0.000	1.01923	0.7974	1.2410
D1	Favorable financial and economic climate	11.443	103	0.000	0.93750	0.7750	1.1000
D2	Business and economic viability of the feasibility study	13.207	103	0.000	1.08654	0.9234	1.2497
D3	Sound commercial and financial package/arrangements	15.923	103	0.000	1.06923	0.9361	1.2024
D4	Financial capacity and reliability of the private sector	12.142	103	0.000	1.08333	0.9064	1.2603
E1	Political support and stability	14.510	103	0.000	1.25000	1.0791	1.4209
E2	Qualified and experienced public staff to manage the PPP briefing process	12.645	103	0.000	0.93590	0.7891	1.0827
E3	Governmental assistance during the PPP project undertaking	14.321	103	0.000	1.15385	0.9941	1.3136
E4	Government financial capacity to support PPP financial requirements	8.981	103	0.000	1.01923	0.7942	1.2443
E5	Effective government mechanisms for documentation and lessons learned.	5.587	103	0.000	0.57051	0.3680	0.7730
F1	Availability of effective regulatory and legal frameworks for PPP	13.955	103	0.000	1.21538	1.0427	1.3881
F2	Approved governance model by relevant authorities for the PPP venture	15.432	103	0.000	1.26923	1.1061	1.4323

ID	CSF	t	df	Sig. (2-Tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
F3	Project scope to match the authorized mandate of the public agency	11.625	103	0.000	1.11538	0.9251	1.3057
F4	Adherence to applicable and up-to-date legal and regulatory frameworks	14.022	103	0.000	1.15385	0.9906	1.3170
F5	Clear authority and responsibility between the public and private sector	17.682	103	0.000	1.42308	1.2635	1.5827
F6	Proper dispute resolution mechanism	10.493	103	0.000	1.15385	0.9358	1.3719
G1	Community participation, acceptance, and support	3.076	103	0.003	0.35577	0.1264	0.5852
G2	Work environment during the brief development	4.979	103	0.000	0.54231	0.3263	0.7583
G3	Consideration of cultural and ethical values of the end users/user group during the brief's development	6.651	103	0.000	0.65385	0.4589	0.8488
G4	Acceptable tariff level	7.080	103	0.000	0.76923	0.5537	0.9847
G5	Consideration of socioeconomic aspects	7.262	103	0.000	0.73077	0.5312	0.9303

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A Triadic Competency Requirement Model for Successful Win-Win Optimization in Public–Private Partnerships: A Structural Equation Modelling

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Abstract: Public Private Partnership (PPP) initiatives are often promoted as a mechanism for achieving win-win outcomes. However, recent studies highlight the realisation as a hurdle due to gaps in public and private sector competencies. PPP studies have typically focused on specific competency areas and have typically overlooked assessing the interrelationships among various competency dimensions, although these interconnections reflect how competencies function in real-world projects. Therefore, this study sets the pace in the development and modelling of a holistic competency requirement model for the public and private sectors in PPP schemes. A comprehensive literature review coupled with expert validation through piloting identified and categorised the competencies while Structural Equation Modelling (PLS-SEM) was adopted in model development. Findings indicated that public and private sector competencies for win-win optimisation should capture functional requirements, which are PPP scheme and type dependent, organisational requirements which highlight the institutional build of the project parties and relational/behavioural competency requirements that capture the traits and alliancing attributes. The study recommends the strategic alignment of public and private sector roles, skills, and capabilities before initiating infrastructure development to cultivate an environment conducive to achieving win-win outcomes in PPPs. This study challenges the conventional isolated approaches to PPP competencies with an integrated approach that deepens the understanding of successful infrastructure development in PPP.

Keywords: competency requirements modelling; public private partnerships; win-win optimisation; Structural Equation Modelling (SEM)

1. Introduction

Public–private partnerships (PPP), as compared to traditional infrastructure procurement, have been popularised to facilitate the achievement of a win-win situation amongst the stakeholders involved. PPPs have been adopted in both developed and developing economies, primarily for procuring energy and transport infrastructure [1,2] Consequently, PPP is perceived to permeate win-win achievement in its build-up. However, recent studies have questioned the practical realisation of this in project implementation [3–5]. These studies report the existence of issues like lop-sidedness in contracts, negotiation, power imbalances, and devious behaviours, amongst others, which do not reflect win-win pursuance in practice. A comprehensive review of PPP studies by Eshun et al. [6] emphasised the contention by McKeon [7] that the realisation of win-win remains a challenge in PPP practice. The study posited that apt public and private sector competencies are critical to successful project implementation and the optimisation of win-win desires of project stakeholders.

Competencies in PPP studies have mostly focused on individual traits, and the literature is deficient in a clear assessment of competencies of both the private and public actors as individual traits and also as a team or collaborative partners. Previous PPP studies on competencies have focused on traits and skills, hence addressing certain aspects such as trust [8] and other leadership skills [9]. However, project management studies accentuate that competency modelling should encapsulate technical skills, knowledge, capacities, and personal traits or behaviour.

Despite the importance of competency modelling and development in real-world practice, scholars have been sceptical about the concept of competencies and have, therefore, not fully explored it. Additionally, PPP studies that captured competencies focused solely on certain aspects without assessing the interrelations between the different competency requirements as an integrated approach, which is what happens in reality [10]. Hence, an integrative approach is required in competency development to bridge this gap in PPP infrastructure schemes toward win-win outcomes and project success.

The long-period nature of PPPs calls for sustainable collaborative partnering. The establishment of an integrating partnership model that highlights the roles of all parties is ideal [11]. To achieve this, unique capabilities and skills in managing PPP arrangements are essential, especially at the organisational level, which can be complex. However, little empirical research has been done on what represents the basis for management proficiency and competence in partnerships and alliances [12]. Several studies have stated that there are few empirical studies that explore the exact and needed skills, values, and attitudes (competencies) of the governing parties in PPP implementation [11,13,14]. Furthermore, competency facets in the overall management of PPP by the public and the private sector are lacking and need attention to address the uniqueness of PPPs for a more collaborative and win-win-oriented partnership [6,15].

Some PPP studies have identified various required competencies of parties involved in the partnership. For instance, Devkar et al. [16] developed PPP competencies and summarised a couple of technical capabilities required of project actors in the implementation of PPP. Soecipto and Verhoest [17] identified competencies focused on project governance and implementation capacities. Most studies were inclined to the behaviour and relationships among stakeholders [18–20]. Mistarihi et al. [12] identified competencies that captured technical capabilities and relational or behavioural competencies of the project actors. However, these do not present an all-inclusive model of public and private sector competencies as exists in practice. Also, they do not assess the relationships between these competencies towards critical criteria as win-win achievement despite being pivotal in PPPs.

The study by Eshun et al. [6] conceptualised a win-win scenario in PPP and highlighted critical enablers such as having a reasonable financial plan (concession period and price), fairly allocating risks, meeting project success criteria or objectives, practising flexible contracting and engaging in strategic win-win solicitation during negotiation for contract closing, constitute enablers for win-win achievement in PPPs. Given that the public and private sector competencies drive these win-win strategies, this study seeks to develop and model a holistic competency requirement model for the public and private sectors in PPP schemes. The modelling integrates individual and corporate level competencies as well as technical, organisational/governance, relational and behavioural competencies. This study becomes the first to close this gap and adopts a model development approach that deals with a fusion of various theoretical management concepts for desirable results in PPP implementation.

2. Literature Review

2.1. Competency Requirements Modelling in PPPs

Competence in project implementation is viewed in two dimensions from an epistemological standpoint, i.e., the individual approach, which is concentrated on individual behaviours, and the other required at the organisational level or collective approach [21]. A typical PPP scheme is characterised by a cluster of experts, and competencies are developed

in relation to their collective effort in the private and public sectors, respectively. To enhance the effective implementation and management of PPP projects, competency development should target both individual expertise and collective organisational capability. This dual focus ensures a comprehensive approach to skill-building that supports successful project outcomes across all levels [12]. Competency modelling should capture three core areas: the skills and abilities that individuals or organisations should possess, task-oriented actions that reflect current duties, and personal traits or characteristics that describe how individuals behave [12,22]. This study proposes organisational, functional, and relational competencies as essential for successful win-win achievement in PPP implementation. The integration of these competencies creates a more practical framework for establishing competency requirements, guiding both public and private entities in policy development, and enabling relevant, practice-oriented analyses to drive continuous improvement.

2.1.1. Organizational Competency Requirements

Organisational competency requirements encompass the capabilities of key project stakeholders, particularly in terms of institutional structure, to support mutually beneficial outcomes. Infrastructure PPPs employ diverse strategies, processes, and practices—such as joint ventures involving both national and international partners—which make robust administrative structures essential. This competency, as seen in Table 1, reflects the foundational abilities that organisations, including government and private sector entities, must possess to function effectively as unified entities in the PPP framework.

Table 1. Organisational Competency Requirements for win-win optimisation in PPPs.

ID	Organizational Competence	Delineation	References
OC01	Well established regulatory and policy framework (including policies)	The existence of stringent working laws and policies that facilitate the development and implementation of PPPs. Good regulatory quality.	[23–26]
OC02	Effective dispute resolution mechanisms and rule of law	The existence of experts and well-developed process and structure for addressing conflicts, controversies and prevent corruption throughout the implementation of the project.	[23,24,27,28]
OC03	Well established public/local community engagement protocol	This refers to the existence of well-established procedures and the ability to engage users, community or the public to assess their level of interest and need for the project.	[28]
OC04	Politically stable environment	The ability to maintain a sound political environment that supports the continues development and operation of PPP projects i.e., PPP project continuity irrespective of political dynamics.	[17,23,26,28]
OC05	Standardized and well-defined administrative procedures	Having and efficient and standardized processes for approval and documentation activities in the development of the PPP	[26,28]
OC06	Effective contract administration procedures and experts	Having enough capacity to adequately draft and manage the contract arrangements of projects.	[17,24,26]
OC07	Well-built institutional/administrative capacity	This captures the entire composition of the organization, institution, or joint venture having well-established structures to run the day-to-day administrative procedures in delivering PPP projects.	[17,24,26]
OC08	Knowledge and technology transfer mechanisms	Existence of appropriate measures to enable the easy transfer and receipt of technology and knowledge to enable continuous running of the project beyond transfer	[17,26,29]

Table 1. *Cont.*

ID	Organizational Competence	Delineation	References
OC09	Strong bargaining techniques and capacity	Efficient experts and structural composition to poise them right to bargain effectively	[16,26,29,30]
OC10	Development and training culture and structure	The existence of routine exercises and procedures for training and development of personnel	[8,25]
OC11	Enterprise/Firm qualification, reputation and professional expertise	Commendable industrial qualification and certification of the firms	[8,26]
OC12	Efficient concessionaire (private partner) selection capacity	Having appropriate system for the selection of a reputable private sector with needed capacity to deliver as required. This includes selection criteria and procedures and experts involved in the process.	[20,31]
OC13	Commendable infrastructure PPP experience	Adequate firm and personnel's maturity in the development of infrastructure PPPs through planning, financing, constructing and operation	[8,12,23,25,26]
OC14	Adequate personnel/employee capacity	The appropriate number of workers or staff or experts required to effectively implement the PPP project.	[8,25]
OC15	Efficient subnational authorities (well established PPP unit)	A specialized PPP unit mainly and directly responsible for the overseeing the development and management of PPP projects.	[8]
OC16	Project conceptualization, identification and appraisal structures	The ability of the practitioners to sample out and select relevant projects which will be successful on PPP mode i.e., to select the right project at the right time to be executed at the right place which will yield success and improve its viability	[16,17,26]

2.1.2. Functional Competency Requirements

The functional competency category focuses on the skills and requirements necessary to meet performance metrics, objectives, and success criteria for PPP projects. These competencies depend on the type of infrastructure being delivered and the specific PPP model chosen, which defines the roles and responsibilities of project parties who must be equipped to execute the project effectively. This category (see Table 2) encompasses task-oriented competencies, outlining the immediate actions required for successful PPP implementation. Emphasising collective expertise, this competency category highlights the collaborative efforts of professionals within both public and private sectors, with specific skills adapted to the demands of each unique PPP project.

Table 2. Functional Competency Requirements for win-win optimisation in PPPs.

ID	Functional Competency	Delineation	References
FC01	Intellectual capacity with core technical knowledge and ability	This refers to the practitioners having the required level of skills, intellect, and equipment capacity for executing the type of project whether transport, energy, sewage, water treatment etc.	[8,12,25,28,32]
FC02	Financial capacity and planning efficiency	Project actors must have the needed funding with reliable financing facilities as well as develop efficient financial plans and models capable of handling the life cycle cost of the project.	[24,26]

Table 2. *Cont.*

ID	Functional Competency	Delineation	References
FC03	Efficient stakeholder management skills	Since PPP development involves engaging various stakeholders, the actors must be able to manage these stakeholders throughout the implementation of the PPP project.	[16,29]
FC04	Operational maturity and maintenance capacity	The ability to operate and maintain the project facility to meet required productivity and maintenance requirements	[12,16,25,28,32]
FC05	Construction technology capacity	This refers to the ability to execute the construction works efficiently to meet the desired project specification	[12,24,25,28,30–32]
FC06	Well prepared investment climate with stable microeconomic indicators	Existence of a good and stable economic environment that will enable the smooth operation of the project and meet the estimated cashflow	[8,17,24,25,30,32]
FC07	Project planning process management	The capacity to conduct effective planning such as feasibility studies and making sound project forecasts	[32]
FC08	Innovation oriented hallmark	Existence of innovative structures and conduct of parties in the development of the PPP project	[28,30]
FC09	Risk tolerance and control capacity	The tendency of exhibiting high-risk tolerance with highly specialized treatment strategies for managing project risks	[25,28]
FC10	Risk identification and evaluation ability	Practitioners must be able to effectively ascertain risks and uncertainties as well as evaluate their impact on the project to facilitate project planning.	[25,26,30,33]
FC11	Optimum risk allocation knowhow	Since risk allocation is very critical in PPPs practitioners must be able to effectively assign risk to the best party capable of preventing, controlling and managing the consequence of the risk during project delivery.	[8,24,26,28,32]
FC12	Environmental Sustainability Consciousness and management capacity	Practitioners must be able to exhibit concern to the environmental impact of developing the project	[26,32,33]
FC13	High technological capacity	The practitioners must be able to exhibit and use advanced technologies and be able to keep up with the global technological advancement and dynamics	[32]
FC14	Quality and Reliable service provision capacity	Project practitioners must be able to deliver consistent and good quality services to the public	[12,16,25,30]
FC15	Governmental guarantee/incentive provision capacity	The ability of the contracting party to support the PPP project with certain incentives like interest rate guarantee, price guarantee, tax rebates etc.	[12,23–25,32]
FC16	High Project commercialization expertise	The ability to successfully run the business component of the PPP project to facilitate the repayment arrangements.	[8,23,26,28]
FC17	Project management and governing skills	Exhibiting high level of project management and Different project types require different styles of efficient management	[25,26]

2.1.3. Relational Competency Requirements

These address the traits and self-concepts integral to a competency requirements model, focusing on the behavioural and synergistic attributes essential for fostering alliance and mutual goals among project stakeholders. Behavioural competencies, linked to personal motives and traits, are crucial for promoting cooperation and trust in PPPs. These competencies are among the most influential factors in project performance, outlining how public and private entities should interact to achieve a successful, mutually beneficial outcome in PPP projects [20]. This category, as listed in Table 3, encompasses the normative dimensions of the project actors as individuals and as teams.

Table 3. Relational/behavioural Competency Requirements for win-win optimisation in PPPs.

ID	Relational/Behavioural Competency	Delineation	References
RC01	Mutual accountability	The display of responsibility acceptance of obligations and willingness to give satisfactory reasons to each other (private and public partners)	[8,18,19,27,28,33]
RC02	Consensus-based decision-making custom	The practice of engaging and obtaining approval from all relevant stakeholders in decision-making.	[8,18,28,33]
RC03	Transparency and integrity virtues	The practice of demonstrating honesty and truthfulness in dealings especially in information sharing.	[31,34,35]
RC04	Equity principled project actors	The habit of ensuring that each stakeholder gets what is due them without cheating or utilizing power dominance/undue influence	[8,36,37]
RC05	High-level commitment ability to parties and project	This refers to both party's willingness and enthusiasm of both parties to offer or exert effort towards the or on behalf of the partnership relationship and the success of the project	[8,18,25,26,28]
RC06	Value appreciation	The tendency of individuals to understand, desire and thrive to ensure the value creation in dealings	[8,31,38]
RC07	Efficient Collaborative interactions between parties	The desire of both parties to obtain concerted effort and engage themselves through frequent and open discussion and communication of project matters to each other.	[18,37,39]
RC08	Mutual Respect	The recognition and reliance on the character and ability of each other (private and public actors) that they have valuable/vital contributions to make in the partnership	[19,40]
RC09	High ethical values and due diligence attitude	The existence of self-governing principles that projects a virtuous behaviour thus the conscious effort of parties to avoid committing an offense.	[20,31,41,42]
RC10	Emotional intelligence	The ability to comprehend and manage one's own emotions as well as that of others in a positive way.	[19,20,32,43]
RC11	Good leadership skills	This refers to the proactive and initiative-taking nature of practitioners to organize people towards achieving a goal	[18,19,25,26,28,30,43,44]

Table 3. *Cont.*

ID	Relational/Behavioural Competency	Delineation	References
RC12	Effective dialogue and communication skills	The ability to convey and express information and ideas effectively and openly. (Relevant in contract development and negotiation)	[20,27]
RC13	Good teamwork and interdependence ability	The ability to work effectively in an organized group where lies the belief in and reliance on each other's role play in the implementation of the project.	[20]
RC14	Creative thinking and learning abilities	The level of inventiveness and use of original ideas by project parties	[8,16,27,33]
RC15	Mutual Trust	The confidence that each party (private and public actors) will fulfil their obligations and behave as duly expected	[27,43]
RC16	Cultural intelligence	The ability to manage, relate and work with culturally diverse people and situations (i.e., the varying beliefs, language, value interpretation, etc. of both parties)	[8,17–19,26,27]
RC17	Conflict resolution and problem-solving skills	The ability of project actors when disagreements arise to discuss, manage and effectively resolve disputes. Thus, the practice of coming together and combining resources to solve project issues effectively.	[20]

Figure 1 presents the Triadic Public and Private Competency Requirement framework from the comprehensive literature review, detailing organisational, functional, and relational competency requirements that facilitate win-win realisation and overall PPP project success.

2.2. Hypothetical Modelling of PPP Competency Requirements

The development of competency requirements is extensive; therefore, studies achieve this feat by categorising them. The categorisation adopted in this study followed a theoretical ideology that describes the combination of knowledge, skills, and characteristics needed to effectively perform from the private and the public sector perspective. This enabled the siphoning of adequate and exhaustive variables or indicators to be measured. This study proposes that competency capability requirements fall into three main categories that must work collectively to support the public and private parties in achieving mutually beneficial outcomes in PPP schemes. This integrated approach strengthens the critical role of each party, enhancing the likelihood of a successful, win-win partnership.

Eshun et al. [6] evidencing a comprehensive literature review highlighted enablers of win-win achievement in PPP as the development of an equitable financial plan (WE01), attainment of project-specific success objectives/criteria (WE02), optimum assessment and allocation of project risks (WE03), effective engagement of project stakeholders (WE04), flexible contracting (WE05), and strategic contract negotiation and closing (WE06). The moderating role of private and public sector competencies in implementing these enabling strategies cannot be understated [45]. This underscores the concept that relational, functional, and organisational competencies collectively drive the achievement of win-win outcomes in PPPs. The identified variables were validated through expert interviews projecting the hypothesised model shown in Figure 2. The study engaged six experts in finalising the research framework. Research Hypothesis H1, H2 and H3 posit that organisational, relational/behavioural and functional competencies of the public and the private sectors have a positive influence on the win-win enablers/strategies. The study

further theorises the mediating role of the functional and organisational competencies to the relational/behavioural competencies, hence testing H4 and H5, as seen in Figure 2.

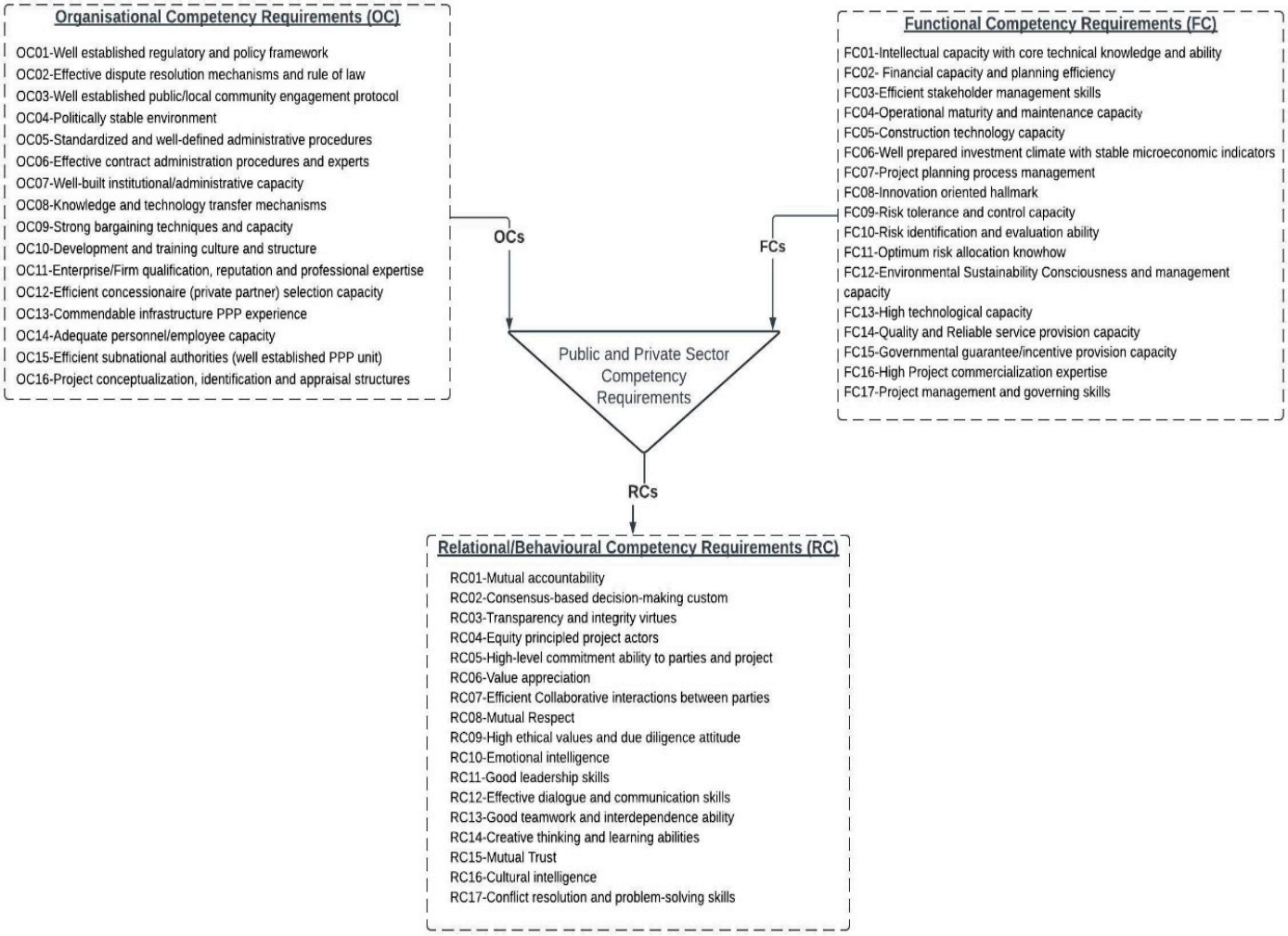

Figure 1. The Triadic Public and Private Competency Requirements Framework.

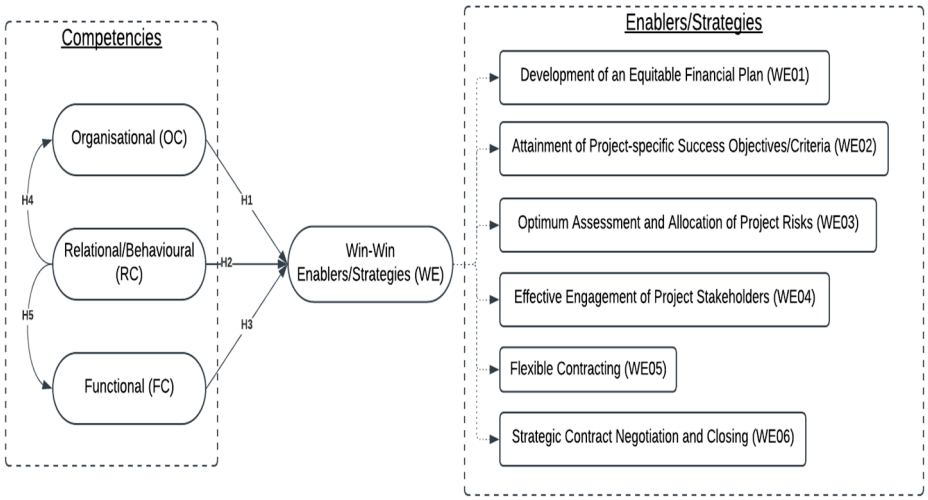

Figure 2. Hypothetical competency model for win-win optimisation in PPP.

3. Research Methods

The research methods included a comprehensive literature review, expert validation, pilot and questionnaire survey to provide a detailed understanding and modelling of the competency requirements prior to modelling and testing. The study adopted a mixed method to allow the complementing strengths of both methods for a plausible research outcome [46,47].

3.1. Data Collection

An initial literature review was conducted to explore a wide range of studies in PPP and project management studies. Journal articles and books accessed through Scopus, Web of Science, and Google Scholar were analysed for the study. The review explored concepts of competencies, the role of the public and private actors, success factors and enablers of win-win achievement in project implementation. Studies on competency requirement modelling were analysed to understand the categorisation and ensure theoretical consistency [48]. The review identified 50 comprehensive competencies, which were categorised and validated by experts, resulting in 17 functional competency requirements, 16 organisational competency requirements, and 17 relational/behavioural competency requirements. The pilot and expert validation survey conducted allowed for the refining of identified factors, improving validity and ultimately enhancing the reliability of the final research outcomes [49]. The study adopted an open-ended survey tool to elicit expert views on the final elements, and these were used in the main survey.

The finalised factors were structured into a questionnaire and distributed to PPP experts and practitioners in Ghana and Nigeria. The study adopted the non-probability sampling technique using purposive and snowballing to obtain a representative sample of practitioners. The respondents were tasked to indicate agreement on the factors posited as competency requirements and strategies for win-win optimisation in PPP. These measurement items were evaluated on a five-point Likert scale to prevent data fatigue and reluctance from respondents to expand choices. Moreover, the five points are commonly adopted for most PPP and construction management studies that use Structural Equation Modelling (SEM) [50,51]. The pre-screening data available were hundred and eighty-nine; however, after rigorous sorting and screening, the suitable dataset used in the study was one hundred and seventy-six. Additionally, concerning country datasets, eighty-five and ninety-one were from Ghana and Nigeria, respectively. This makes a good representation as Sub-Saharan countries like Nigeria and Ghana have a strong need and high potential for leveraging PPP models [52].

Table 4 captures details of the professionals engaged in the survey as well as some general information and perspectives in relation to their experience with the implementation of infrastructure PPPs. These respondents include both practitioners from the public and the private sector, as well as some academics who have been involved in these dealings through research and consultancy. The professionals classified under the others include other administrative workers such as contracts managers, finance and accounts officers, administrative assistants, facilities managers, administrative consultants, and procurement officers. These professionals were purposively sampled to ensure plausible association with these projects and to ensure the reliability of the findings produced by the study.

3.2. Data Analysis

The competency model developed utilised Structural Equation Modelling (SEM) to measure and analyse relationships between observed and latent variables, allowing for the assessment of complex multivariate causal interactions. SEM examines the relationships between variables by integrating factor analysis, multiple regression analysis, and path analysis [53]. Specifically, the study employs Partial Least Squares Structural Equation Modelling (PLS-SEM), which is well-suited for evaluating these relationships within the model. Most studies have adopted this method in modelling complex relationships, eluding the previously used covariance-based modelling to understand and make plausible

interpretations of PPP infrastructure delivery [50,54,55]. PLS-SEM is a causal-predictive approach to SEM that emphasises prediction in estimating statistical models whose structures are designed to provide causal explanations [56]. Moreover, the ability to analyse mediating and moderating variables within a model enhances its rigour and makes it more suitable than regression analysis, aligning well with this study's goals for hypothesis testing [57].

Table 4. Respondents profile.

Demographics	Category	Frequency	Percentage
Profession	Researcher/Professor	16	9
	Engineer	31	18
	Quantity surveyor	28	16
	Project Manager	34	19
	Architect	12	7
	Construction Manager	23	13
	Others	32	18
Years of Experience	Below 5 years	26	15
	5 to 10 years	45	26
	11 to 15 years	43	24
	16 to 20 years	33	19
	Above 20 years	29	16
Type/Job Affiliation	Central Govnt/Ministries	21	12
	Public sector consultant	28	16
	Private sector consultant	13	7
	Private Corporation	61	35
	Sub-Govnt Contracting Authority	37	21
	Academia	16	9
Number of Projects	1 to 5	17	10
	6 to 10	29	16
	11 to 15	35	20
	16 to 20	30	17
	21 to 30	42	24
	over 30	23	13

PLS path models consist of two linear equations: the inner and outer models, also known as the structural and measurement models, respectively. The outer (measurement) model represents the relationship between an observed variable and its corresponding latent variable, while the inner (structural) model captures the relationships between latent (unobserved) variables [58]. PLS-SEM involves three main steps: (i) Preliminary planning, which addresses factors like sample size, potential use of secondary data, distribution assumptions, statistical power, and model fit; (ii) Assessment of the measurement model, where reflective indicators (e.g., loadings, reliability measures) and formative indicators (e.g., VIF, redundancy analysis, indicator weight significance and relevance) are analysed to strengthen model reliability; and (iii) Assessment of the structural model, which evaluates the model's explanatory and predictive power [57].

3.2.1. Reflective Measurement Model Assessment

Composite Reliability (CR) and Cronbach's Alpha (CA) are the most commonly used metrics for assessing the internal reliability and consistency of constructs. CR accounts for the varying loadings of indicators, allowing for differing reliability contributions across items, while CA assumes equal reliability across all indicators, which can result in an underestimation of the internal consistency of a latent variable [59]. A satisfactory coefficient for internal consistency reliability is typically considered to be around 0.7 in the early stages of research and 0.8 or higher in more advanced stages. Values below 0.6 indicate weak consistency. Indicator reliability describes the extent to which a latent variable explains the variance in its associated indicators. This reliability is assessed by examining the loadings of

reflective indicators, with a target of at least 50% of the indicator's variance being explained by the latent variable. Indicator loadings should exceed 0.7, be significant at the 0.05 level, and differ from zero to confirm reliability [60]. Fornell and Larcker [61] suggest using the Average Variance Extracted (AVE) as a measure for assessing convergent validity. To meet this criterion, the latent variable should explain at least 50% of the variance in its indicators, indicated by an AVE value of 0.5 or higher. Additionally, discriminant validity ensures that constructs are distinct from one another; hence, each latent variable's AVE should be greater than the highest squared correlation with any other latent variable [57].

3.2.2. Assessment of the Structural Model

The multiple determination coefficient (R^2) is a key criterion for evaluating each dependent construct within PLS-SEM. R^2 indicates the proportion of total variance in the dependent variable that is explained by the latent variables. In path models within PLS-SEM, R^2 values of 0.19, 0.33, and 0.67 are generally interpreted as weak, moderate, and substantial, respectively. Following this, the regression coefficient is examined as the next step in assessing the structural model's validity. Research hypotheses are unsupported if the direction of the path in the hypothesised relationship contradicts the model's specified sign. To be impactful, some researchers suggest setting the regression coefficient, which measures the strength of the relationship between latent variables, at a threshold of 0.1 or higher [57]. Additionally, resampling techniques such as bootstrapping or jackknifing are used to test significance, typically at a 0.05 level, to assess robustness [62].

4. Model Development and Interpretations

This section reports the results of the PLS-SEM analysis for the competency requirement modelling. The study aims to effectively model competencies required of the private sector and the public sector in typical PPP schemes to drive win-win-oriented goals and overall project success. Hence, the systematic report of the PLS-SEM analysis is key to building the model.

4.1. Initial Measurement Model Specification

The initial model assumes a reflective structure, as indicated in the hypothetical model in Figure 2. Featuring a triadic categorisation of competency requirements, namely organisational (org_comp_req), relational/behavioural (rel_beh_comp_req), functional competency requirements (func_comp_req), and win-win enablers or strategies (win_win_enbs). The model consists of fifty-six observed variables, of which seventeen evaluate relational and behavioural aspects, sixteen focus on organisational elements, and another seventeen assess functional factors. The remaining six variables serve as enablers for the win-win construct shown in Figure 3.

4.2. Initial Measurement Model Evaluation

Measurement model evaluation usually involves assessing indicator reliability, convergent validity, and internal consistency. Reflective indicators are often deemed reliable with standardised loadings above 0.7, though some suggest a threshold of 0.4 may also be acceptable [63]. To ensure item reliability, each construct should explain at least 50% of the variance in its items [57]. This study, therefore, applied a criterion of 0.7 for reliability. Tables 5–7 display the patterned matrix, showing the loadings for each variable construct reliability and validity evaluations of the initial measurement model. The results reveal that some loadings fall below the threshold of 0.7, and these will be excluded from further analysis. The evaluation of internal consistency reliability is carried out using three approaches: Cronbach's alpha [64], composite reliability (CR) [65], and Dijkstra-Henseler's rho (rho_A) [66]. The use of rho_A is particularly recommended as it addresses the limitations and conservative tendencies associated with Cronbach's alpha [67]. In assessing discriminant validity, the average variance extracted (AVE) for a construct is compared to the squared shared variance between that construct and all other constructs within the

reflective framework [57]. Ideally, the square root of the AVE should exceed the correlation with any other factor [61]. Additionally, the Heterotrait-Monotrait (HTMT) ratio serves as another metric for evaluating discriminant validity, with correlations ideally remaining below 0.9 [68].

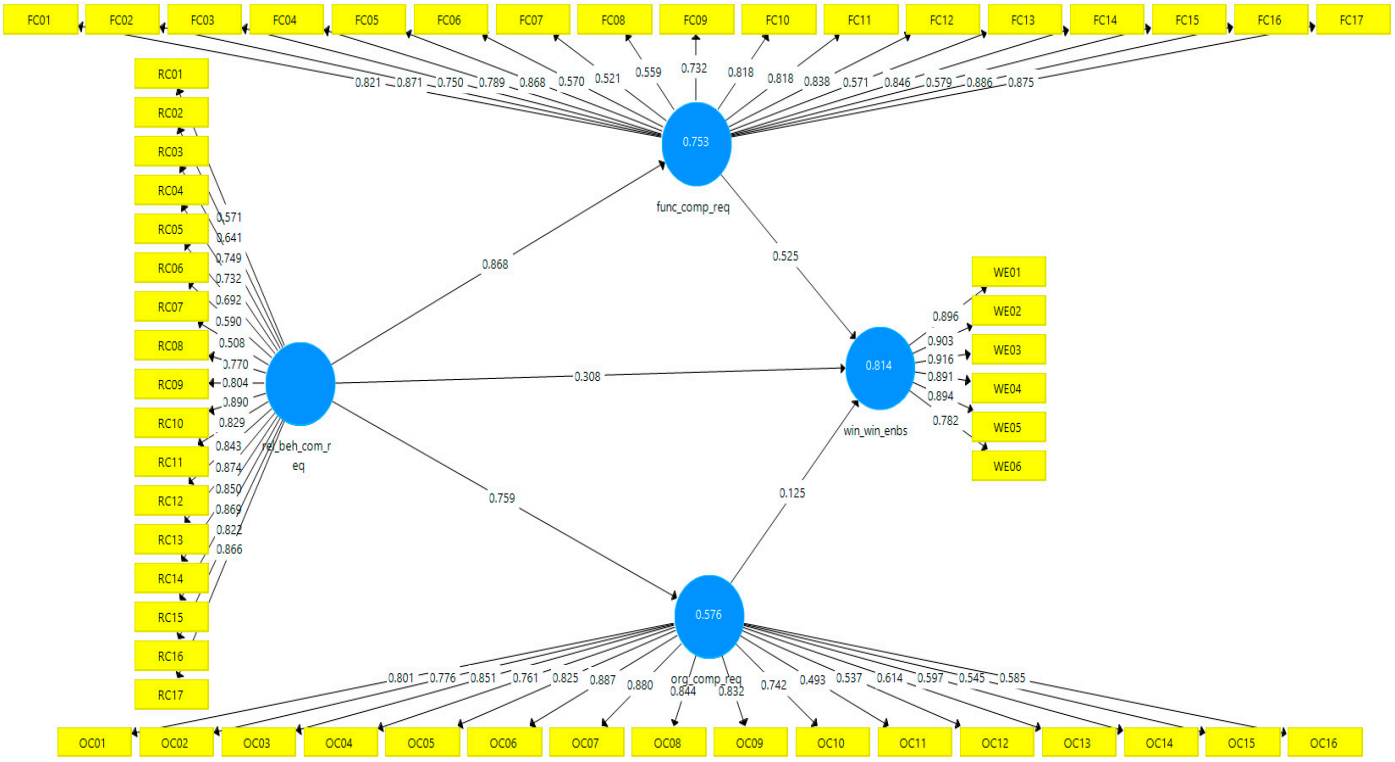

Figure 3. Initial Measurement Model.

Table 5. Initial outer loadings of the measurement model.

Code	func_comp_req	org_comp_req	rel_beh_com_req	win_win_enbs
FC01	0.821			
FC02	0.871			
FC03	0.750			
FC04	0.789			
FC05	0.868			
FC06	0.570 *			
FC07	0.521 *			
FC08	0.559 *			
FC09	0.732			
FC10	0.818			
FC11	0.818			
FC12	0.838			
FC13	0.571 *			
FC14	0.846			
FC15	0.579 *			
FC16	0.886			
FC17	0.875			
OC01		0.801		
OC02		0.776		
OC03		0.851		
OC04		0.761		
OC05		0.825		

Table 5. *Cont.*

Code	func_comp_req	org_comp_req	rel_beh_com_req	win_win_enbs
OC06		0.887		
OC07		0.880		
OC08		0.844		
OC09		0.832		
OC10		0.742		
OC11		0.493 *		
OC12		0.537 *		
OC13		0.614 *		
OC14		0.597 *		
OC15		0.545 *		
OC16		0.585 *		
RC01			0.571 *	
RC02			0.641 *	
RC03			0.649 *	
RC04			0.632 *	
RC05			0.692 *	
RC06			0.590 *	
RC07			0.508 *	
RC08			0.770	
RC09			0.804	
RC10			0.890	
RC11			0.829	
RC12			0.843	
RC13			0.874	
RC14			0.850	
RC15			0.869	
RC16			0.822	
RC17			0.866	
WE01				0.896
WE02				0.903
WE03				0.916
WE04				0.891
WE05				0.894
WE06				0.782

Notes: * Reflective loadings of variables below 0.7 criterion.

Table 6. Construct reliability and validity of the initial measurement model.

Constructs	CA	rho_A	CR	AVE
func_comp_req	0.951	0.962	0.957	0.576
org_comp_req	0.941	0.955	0.948	0.541
rel_beh_com_req	0.954	0.960	0.960	0.589
win_win_enbs	0.942	0.943	0.954	0.777

Notes: CA—Cronbach's Alpha, CR—Composite reliability, AVE—Average Variance Extracted.

Table 7. Discriminant validity of the initial measurement model (HTMT).

Constructs	func_comp_req	org_comp_req	rel_beh_com_req	win_win_enbs
func_comp_req	-	-	-	-
org_comp_req	0.695	-	-	-
rel_beh_com_req	0.897	0.793	-	-
win_win_enbs	0.917	0.744	0.900	

Notes: HTMT—Heterotrait-Monotrait.

4.3. Final Measurement Model Evaluation

The evaluation of the initial model revealed that several observed variables failed to meet the required loading thresholds of 0.7. To enhance the model and ensure optimal

results, these variables were removed, and the analysis was conducted iteratively while carefully monitoring both construct and scale reliability criteria [67]. The final measurement is illustrated in Figure 4, demonstrating acceptable factor loadings (see Table 8), along with confirmed construct reliability and validity (Table 9) and discriminant validity (Table 10). The results indicate that all reflective loadings exceeded the 0.7 threshold. Specifically, the highest and lowest loadings recorded were 0.903 and 0.736 for functional competency requirements, 0.917 and 0.763 for organisational competency requirements, 0.912 and 0.803 for relational behavioural competency requirements, and finally, the win-win enablers had loadings of 0.917 and 0.781. Furthermore, the reliability results—measured by Cronbach's Alpha, rho _A, and composite reliability (CR)—were all above 0.7, indicating strong reliability. Additionally, convergent validity was confirmed, as the average variance extracted (AVE) for each component exceeded the largest squared correlation with any other latent component [67]. The HTMT correlations also fell within the acceptable range based on the criteria established for the study. The final model, after thorough scrutiny and iterative eliminations that met all necessary specifications, demonstrates that the constructs adequately measure their intended variables. Therefore, it is deemed suitable for further analysis within the structural model [68].

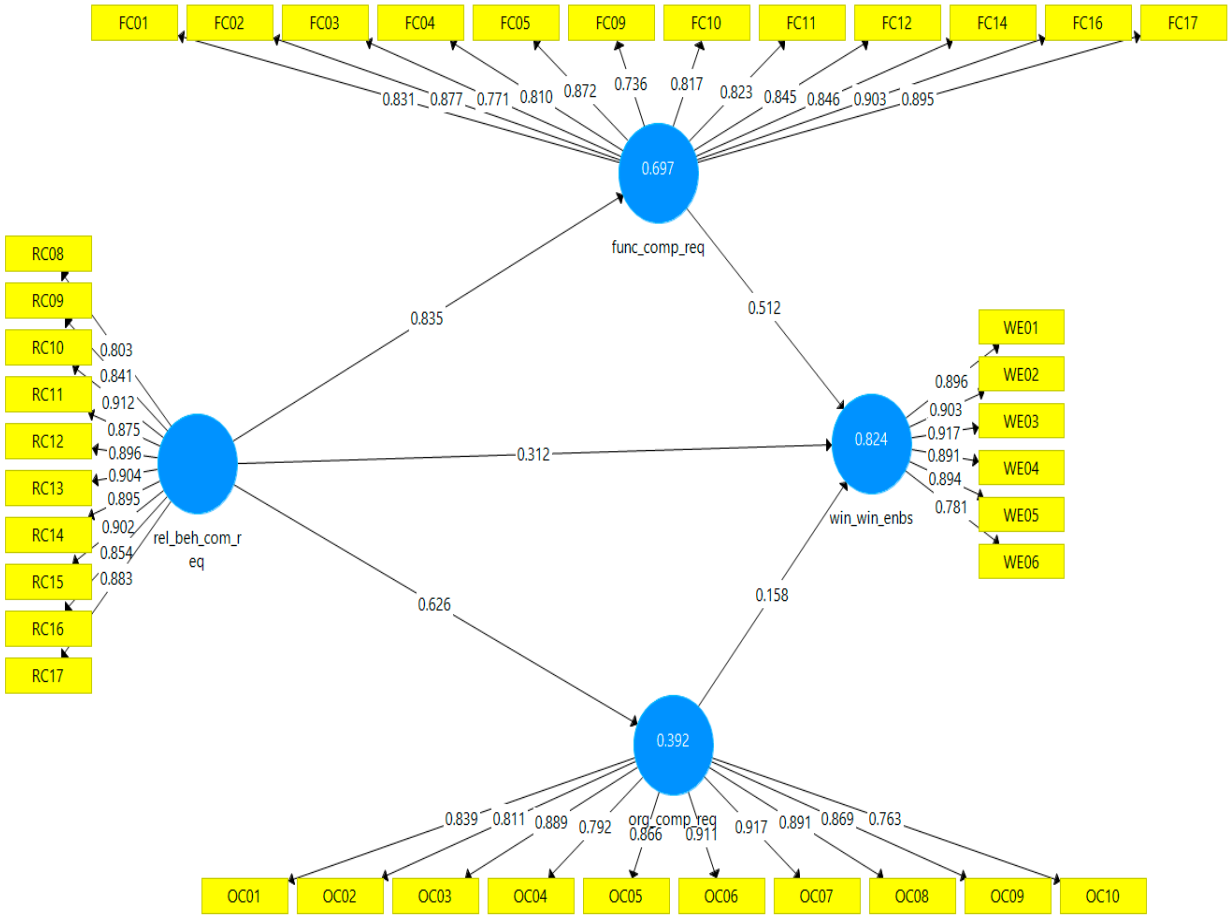

Figure 4. Final Measurement Model.

The final measurement model encapsulates 10 relational/behavioural competencies, 12 functional competencies, 10 organisational competencies, and all 6 win-win enablers/strategies.

Table 8. Final outer loadings of the measurement model.

Code	func_comp_req	org_comp_req	rel_beh_com_req	win_win_enbs
FC01	0.831			
FC02	0.877			
FC03	0.771			
FC04	0.810			
FC05	0.872			
FC09	0.736			
FC10	0.817			
FC11	0.823			
FC12	0.845			
FC14	0.846			
FC16	0.903			
FC17	0.895			
OC01		0.839		
OC02		0.811		
OC03		0.889		
OC04		0.792		
OC05		0.866		
OC06		0.911		
OC07		0.917		
OC08		0.891		
OC09		0.869		
OC10		0.763		
RC08			0.803	
RC09			0.841	
RC10			0.912	
RC11			0.875	
RC12			0.896	
RC13			0.904	
RC14			0.895	
RC15			0.902	
RC16			0.854	
RC17			0.883	
WE01				0.896
WE02				0.903
WE03				0.917
WE04				0.891
WE05				0.894
WE06				0.781

Table 9. Construct reliability and validity of the Final Measurement model.

Constructs	CA	rho_A	CR	AVE
func_comp_req	0.961	0.962	0.965	0.700
org_comp_req	0.959	0.964	0.965	0.733
rel_beh_com_req	0.966	0.968	0.971	0.769
win_win_enbs	0.942	0.943	0.954	0.777

Notes: CA—Cronbach's Alpha, CR—Composite reliability, AVE—Average Variance Extracted.

Table 10. Discriminant validity of the initial measurement model (HTMT).

Constructs	func_comp_req	org_comp_req	rel_beh_com_req	win_win_enbs
func_comp_req	-	-	-	-
org_comp_req	0.841	-	-	-
rel_beh_com_req	0.826	0.845	-	-
win_win_enbs	0.720	0.742	0.856	

Notes: HTMT—Heterotrait-Monotrait.

4.4. Specification and Evaluation of Structural Model

The assessment of the structural model demonstrates both the strength and significance of the hypothesised relationships (See Figure 2). This study employs a two-stage approach to derive path values within the structural model. This method not only surpasses other techniques in parameter recovery but also enhances statistical power [69], making it widely recommended for use at the structural modelling stage [57]. The initial phase of this technique is similar to the repeated indicators method [69]. It entails running the PLS path model to derive latent variable values for the constructs. These latent variable scores are saved and subsequently used to specify the model for further evaluation, with the higher-order construct forming the structural model in the second phase [56]. Additionally, the hypothesised mediating effect is assessed at this stage. The study employs a complete bootstrapping method with five thousand samples, as larger sample sizes are recommended for achieving more stable and reliable results. A significance level of 95% was applied to all computations. For estimating confidence intervals, the study utilised the bias-corrected and accelerated bootstrap method, recognised for its stability and efficiency in computing time [56]. Figure 5 shows the structural model with the path coefficients and *p* values to the specified criteria for the model.

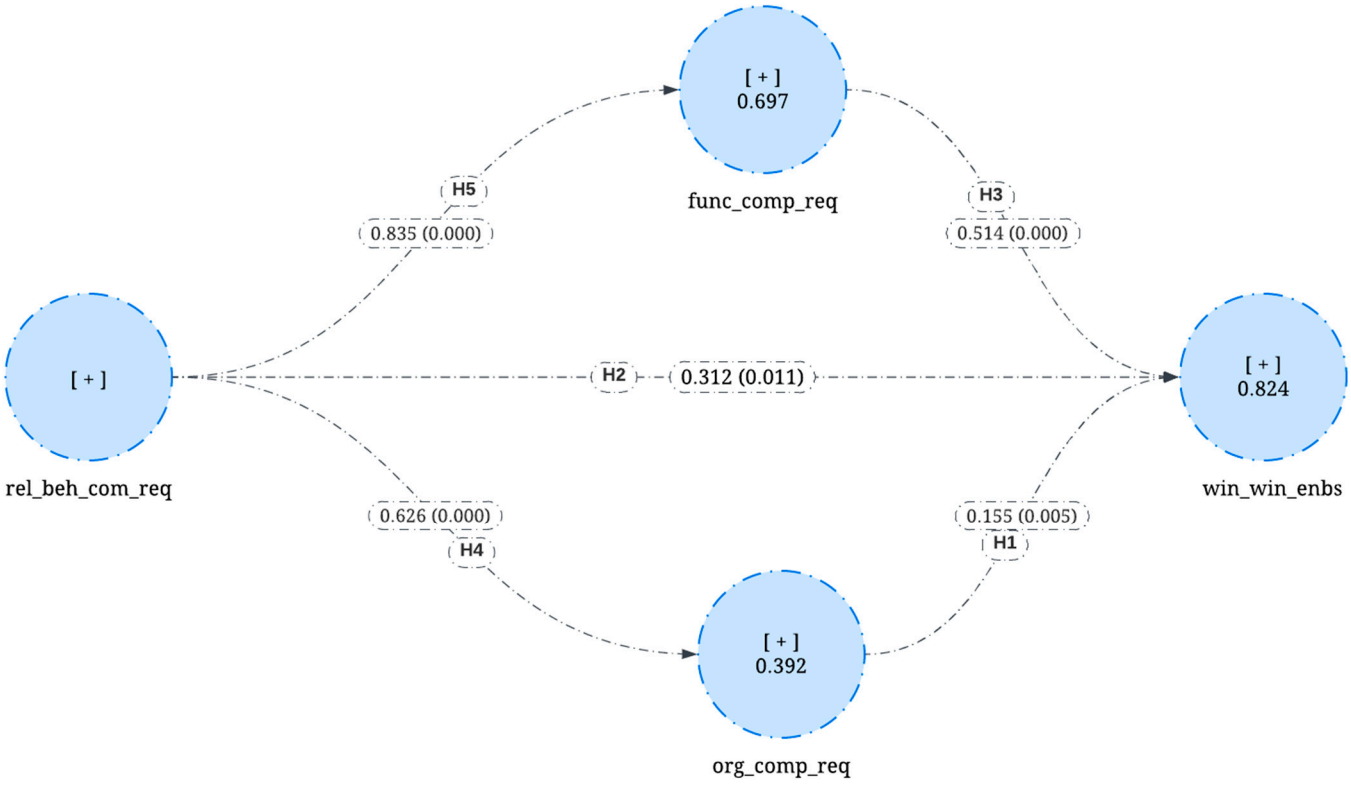

Figure 5. Structural Model with path coefficients and *p*-values.

This study utilised the coefficient of determination (R^2) and the significance of the path coefficients to evaluate the structural model. The R^2 value indicates the total variance explained by each input feature, and its interpretation can vary by context. For example, an R^2 value of 0.10 in stock predictions is considered satisfactory [70]. Similarly, Hair et al. [71] notes that while high R^2 values can be reasonable in certain contexts, they may also suggest overfitting, particularly in terms of out-of-sample predictions. Several factors may contribute to this phenomenon, prompting Henseler and Sarstedt [72] to recommend caution in interpretations, as theoretical concepts often justify higher values. The robust theoretical and practical foundations of this model produced acceptable R^2 values, as illustrated in Table 11. Although these values are satisfactory and do not exceed 0.90—which could raise concerns about overfitting [57]—the R^2 value is influenced by

the number of exogenous factors included in the model; generally, more factors lead to higher R^2 values [57]. Notably, the coefficients are significant at the 95% confidence interval, indicating the structural model's soundness.

Table 11. R-square statistics.

Factors	Coef	Stdev	T-Statistics	*p*-Values	95% CI	
					Lower	Upper
func_comp_req	0.697	0.055	12.659	0.000	0.595	0.808
org_comp_req	0.392	0.067	5.876	0.000	0.272	0.535
win_win_enbs	0.824	0.028	29.019	0.000	0.774	0.884

Notes: CI—confidence interval, Coef—coefficients, Stdev—standard deviation.

Further evaluation of the structural model confirmed that the hypotheses were supported. The results indicate that the path coefficients reflect the strength of regression among the latent variables in the model. According to Hair et al. [71], coefficients exceeding 0.1 demonstrate influence and can be categorised by strength. Sarstedt et al. [56] classifies these coefficients as follows: a weak influence is indicated by values from 0.1 to 0.3, a moderate influence is from 0.3 to 0.5, and a strong influence is represented by values above 0.5. However, the acceptance of the structural model is contingent upon the *p*-value and t-statistics, with values above 1.67 deemed acceptable for t-statistics and below 0.05 acceptable for *p*-values [57].

From the modelling results on the three clusters identified as competency requirements for PPPs, it is evident that relational/behavioural, functional, and organisational competencies positively influence the achievement of win-win enablers. However, the extent of these positive relationships among the constructs varies. These findings broadly support the theoretical perspectives of numerous studies, indicating that the realisation of the win-win principle relies significantly on both the private sector and the public sector competencies at the individual and corporate levels [6]. The model validated the win-win enablers and strategies, as all components successfully passed the rigorous analytical process of PLS-SEM modelling.

Additionally, the findings reveal that relational/behavioural competencies have a strong, positive influence on both organisational and functional competencies, emphasising their mediating role in reaching a win-win outcome. As shown in Table 12, this hypothesis is supported, highlighting that the relationship dynamics and behaviours between parties are crucial to the successful implementation and win-win realisation of the partnership. These relational competencies are essentially channelled through organisational and functional competencies in practice, reinforcing their interconnected role. The mediation effects were statistically significant, lending further credibility to these relationships as key enablers in achieving the partnership goals of the PPP scheme.

Table 12. Assessment of the structural model.

Relationship	PCoef	Stdev	T-Stat	*p*-Values	95% CI		Decision
Direct Effects					Lower	Upper	
func_comp_req -> win_win_enbs	0.514	0.124	4.153	0.000	0.272	0.756	Accept
org_comp_req -> win_win_enbs	0.155	0.056	2.795	0.005	0.051	0.269	Accept
rel_beh_com_req -> func_comp_req	0.835	0.033	25.283	0.000	0.771	0.899	Accept
rel_beh_com_req -> org_comp_req	0.626	0.053	11.793	0.000	0.522	0.731	Accept
rel_beh_com_req -> win_win_enbs	0.312	0.123	2.530	0.011	0.089	0.566	Accept
Mediation effects							
rel_beh_com_req -> org_comp_req -> win_win_enbs	0.197	0.037	2.643	0.008	0.032	0.176	Accept
rel_beh_com_req -> func_comp_req -> win_win_enbs	0.429	0.106	4.064	0.000	0.228	0.638	Accept

Notes: CI—confidence interval, PCoef—Path coefficients, Stdev—standard deviation.

5. PPP Competency Model Discussion and Implications

The PPP competency requirement model developed in this study sets the pace for a holistic partnership model that highlights the roles of the project actors towards the achievement of the win-win, integrating organisational, functional, and relational/behavioural competencies of the project actors.

5.1. PPP Organisational Competencies

In a typical PPP, the private and the public sectors are multi-stakeholder in composition; hence, the administrative capacity and build-up of each sector must be adequate to adopt the PPP route. These competencies exist irrespective of the type of PPP or the infrastructure project, be it transport, energy, water ICT, etc. The existence of a well-established regulatory and policy framework with a politically stable environment is a necessary competency for the public sector [25,73]. Moreover, the public sector should have a well-structured public/local community engagement protocol for project needs assessment and public cooperation in the project [28]. It is imperative for both the public and the private sectors to have effective contract administration procedures and experts with standardised and well-defined managerial procedures and capacity to enhance PPP implementation [26]. Effective dispute resolution mechanisms, strong bargaining techniques and capacity, as well as efficient knowledge and technology transfer mechanisms, are necessary competencies for win-win optimisation and overall PPP success [16,17].

5.2. PPP Functional Competencies

It is essential to emphasise competencies specific to the roles of project stakeholders in infrastructure development, particularly the technical skills that are influenced by the type of PPP model and the nature of the infrastructure involved [12]. Project actors must possess the intellectual and technical expertise necessary to manage the specific project requirements, ensuring that each project milestone is met with precision and alignment with overarching objectives [8]. Additionally, they should prioritise delivering infrastructure that meets both quality and service standards, continuously enhancing their skills and competencies to fulfil these standards effectively [25]. Risk management capacity is a critical competency for project actors [74]. The technical abilities for the identification, assessment, and, most importantly, the allocation of project risks are key for the establishment of a win-win scenario in PPPs [6]. Additionally, the private sector should ensure and continually enhance its competencies in construction technology, project operations, and commercialisation [28]. Project actors' awareness and management skills in environmental sustainability are essential for integrating sustainable practices effectively throughout project implementation [33]. Efficient stakeholder management skills are essential functional competencies for successful PPP.

5.3. PPP Relational/Behavioural Competencies

The study identified competencies designed to fulfil relational and behavioural requirements that project actors should demonstrate to support win-win strategies. These capture relationship and behavioural competencies, i.e., intra and inter-attributes from the individuals to the team level. These competencies foster the goals of alliance and mutual benefit sought by the project parties. Gruden and Stare [20] highlight these traits as particularly influential for project performance, as they cultivate collaboration and positive dynamics among partners. Studies have captured issues of corruption, conflict of interests, poor leadership skills, disputes, lack of trust and transparency, and cultural and communication inefficiencies [18,19]. It is key for the public and private actors to be more conscious of the development of certain behavioural and relationship competencies to eliminate these problems. Mutual respect among project participants, coupled with a strong sense of accountability, is essential for successful PPP alliances. This approach promotes responsibility, acknowledgement of roles, and mutual recognition within the partnership [40]. Transparency among stakeholders promotes the achievement of a win-

win agreement with Brogaard [8]. In addition, cultural and language differences among project stakeholders should not pose barriers to the effective delivery of infrastructure. It is crucial for project actors to intentionally exhibit cultural intelligence and possess strong communication skills to ensure seamless implementation of the project [19,26]. PPP implementation has sometimes led to conflicts among stakeholders, highlighting the importance of emotional intelligence and effective problem-solving skills among project participants to achieve the win-win objective [20,43]. The study emphasises that effective leadership skills, the demonstration of strong ethical values, and the ability to think creatively and learn continuously are essential for successfully delivering public infrastructure projects [33,41].

6. Conclusions

The implementation of PPP infrastructure projects typically involves multiple stakeholders and is complex; hence, it requires special expertise and strategies to manoeuvre the intricacies and obstacles. Infrastructure development through PPPs must optimise the realisation of win-win to foster continued alliancing. The study underscores the defining elements of win-win and the pivotal role of aptness in the public and private sector competencies. The robust modelling approach adopted in the study presented an integrated approach to sculpting the interactions amongst competencies, exposing implementation realities. Most studies have attributed the failures and impediments to successful PPP to strained relationships, lack of mutual trust and respect, financial constraints, meagre risk management, and weak PPP formation or structure, amongst others, typically in developing countries. The model implies that while PPP experts develop enablers within the PPP framework to meet project needs and achieve performance metrics, the successful realisation of these goals relies heavily on the seamless integration of capabilities, specialised expertise, and the cultivation of healthy stakeholder relationships. The study highlights the criticality of relational/behavioural, functional and organisational competencies of the private and public sectors for win-win optimisation. The model emphasises the interdependence of competencies, demonstrating that these elements cannot function effectively in isolation. Instead, they must integrate seamlessly to optimise outcomes and achieve a win-win scenario for all stakeholders involved.

Additionally, given that PPPs are multi-stakeholder in nature, it is essential that relational competencies, both at the inter and intra-sector levels, are highly developed. These competencies significantly influence the distribution of organisational and functional responsibilities. Effective communication, collaboration, and trust-building between diverse parties are critical for the successful execution of PPP projects, as they shape how teams function collectively. Thus, the model depicts the practical scenario of underscoring the mediating effect of the organisational and functional competencies towards win-win optimisation.

For PPP practice, the model offers a comprehensive framework for evaluating competencies, detailing specific parameters that assess the readiness of both the private and public sectors in undertaking a given PPP project in infrastructure development. This framework helps ensure that the stakeholders involved have the necessary organisational, functional, and relational capabilities to successfully implement the scheme. Additionally, practitioners and policymakers can identify project-specific dimensions such as transport, energy, health, or education to align their capabilities with the unique requirements and orientation of the project. This allows them to adapt to sector-specific conditions and the PPP framework in use, ensuring effective implementation and alignment with project goals. Further studies capturing project-specific scenarios and PPP models can be explored to ascertain more dimensions that inform policy and practice.

The study's theoretical contributions extend the existing body of knowledge by proposing a holistic competency model, which may serve as a foundation for future research and practice in the field of infrastructure development. Ultimately, this study highlights that achieving win-win outcomes in PPPs is not merely a theoretical ideal but a practical necessity, requiring intentional actions to align competencies and foster collaboration among all

project participants. The insights gained from this research will be instrumental in guiding future initiatives aimed at optimising the impact of PPPs on infrastructure development.

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Research on the Construction of a Risk Assessment Indicator System for Transportation Infrastructure Investment under Public–Private Partnership Model

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Abstract: This paper is dedicated to developing a risk assessment indicator system applicable to transportation infrastructure investment projects in the public–private partnership (PPP) model. Initially, through practical research, literature reviews, and expert interviews, key risk factors for transportation infrastructure investment projects in the PPP mode were identified. Based on these risk factors, a preliminary risk assessment indicator system was established. Subsequently, the principal component analysis (PCA) was used to reduce the dimensions of the indicators, simplify the structure of the system, and highlight key risk factors. Simultaneously, the CRITIC-EWM method was applied to calculate the weights of the indicators. Furthermore, to validate the effectiveness of the indicator system, a questionnaire survey was conducted, collecting 314 responses. Structural equation modeling was applied to validate the effectiveness of the indicator system and examine its application value in practical risk management processes. The primary contribution of this study lies in proposing a method for constructing a risk assessment indicator system that combines quantitative and qualitative analyses, providing new theoretical and practical guidance for risk management of transportation infrastructure investment projects under the PPP mode.

Keywords: public–private partnership; investment in transportation infrastructure; risk assessment indicator system

1. Introduction

In the context of global economic integration and regional economic cooperation, the public–private partnership (PPP) model has emerged as a key mechanism to promote investment and development in transportation infrastructure. During the past decade, countries around the world have shown significant differences in their investment in transport infrastructure [1]. According to the International Transport Forum (ITF), China and Hungary saw a particularly significant growth in investment in transport infrastructure in 2020 [2]. In the past decade, China's investment in transportation infrastructure has continued to grow. Total investment has increased from about CNY 2.05 trillion in 2011 to CNY 3.85 trillion in 2022, with a cumulative increase of more than 87.8%. The cumulative investment exceeds CNY 32.25 trillion, and the investment in 2022 reached CNY 3.85 trillion, reaching an all-time high. With the rapid development of the economy and the acceleration of the urbanization process, the demand for transportation infrastructure is increasing. The PPP model is widely used in the construction and operation of transportation infrastructure such as bridges, highways, and rails. According to PwC's Global Infrastructure Outlook: 2024–2025, released in November 2023, global transportation infrastructure investment is expected to grow at an average annual rate of about 5% from 2014 to 2025. The Asia–Pacific region is the largest market for transportation infrastructure, and its investment is expected

to increase from USD 557 billion to nearly USD 900 billion [3]. However, transportation infrastructure projects usually involve huge investment, a long construction period, and a complex operating environment, and risk management and evaluation have become the key to ensuring project success and maximizing social and economic benefits. Especially in the PPP mode, due to the cooperation between the government and the private sector, the identification, assessment, and distribution of risks are more complicated, which requires the establishment of a scientific and reasonable risk assessment indicator system to guide investment decision-making and risk management of transportation infrastructure.

In the current risk management practice of transportation infrastructure investment projects, there is a common problem that the risk assessment indicator system is not systematic and comprehensive [4,5]. However, in recent decades, with the rapid development of transportation infrastructure and the wide application of public–private partnerships (PPPs), the emphasis on risk management has increased. Both academic and practical circles have conducted a great deal of research on the identification, assessment, and management of risks in investments in transportation infrastructure projects [6]. However, these studies often focus on specific types of risk such as financial, construction, operational, etc., or focus on a certain stage of the project, lacking complete and comprehensive coverage of the risks of transportation infrastructure investment projects [7,8]. Additionally, existing risk management methods and tools often ignore the appetite for risks and the affordability of different stakeholders, as well as the interaction and complexity between risk factors. Therefore, the current situation of risk management of transportation infrastructure investment projects reflects the urgent need to build a systematic, comprehensive, and adaptable risk assessment indicator system, which should be able to fully cover all stages and various risks of the project, taking into account the needs and characteristics of all parties involved in the project, in order to achieve effective identification, assessment, and management of risks, thereby improving the success rate and investment efficiency of the project. Currently, there are still large research gaps and practical needs in this field. It is urgent that academic and practical circles work together to develop and improve the risk assessment indicator system suitable for transportation infrastructure investment projects.

Based on the shortcomings of current research, this study first starts with the identification of risk factors and systematically identifies the main risk factors for transportation infrastructure investment projects under the PPP model through a literature review, expert interviews, and case studies. Then, this paper proposes an indicator system construction method that combines principal component analysis (PCA) and the CRITIC-EWM method, with the aim of screening and determining risk assessment indicators and their weights in a scientific and systematic way. Finally, the validity of the indicator system is tested using the structural equation model (SEM) method. This paper answers the following two questions:

1. How to establish a scientific and systematic risk assessment indicator system?
2. Among the many risk factors, what are the key indicators for assessing the risk of investment in transportation infrastructure?

Compared to existing literature, the innovation of this study is mainly reflected in the following aspects:

1. This study comprehensively identifies and integrates the key risk factors of transportation infrastructure investment projects under the PPP model through a systematic literature review, expert interviews, and case studies. It constructs a comprehensive risk assessment indicator system covering six dimensions: economic, technical, management, policy, social environment, and market. This system not only comprehensively covers the main risks throughout the project lifecycle but also fills the gap of incomplete risk identification in existing research.
2. This study is the first to combine principal component analysis (PCA) and the CRITIC-EWM method to screen and determine risk assessment indicators and their weights. This method not only improves the scientific and systematic nature of the indicator system but also simplifies the indicator structure through dimensionality reduc-

tion, highlighting key risk factors and making the risk assessment more accurate and operational.

Through an in-depth study of the construction and application of the transportation infrastructure investment risk assessment indicator system under the PPP model, this article not only enriches theoretical research in the field of transportation infrastructure investment risk management but also provides a powerful tool and strategy for risk management in practice. It has an important theoretical and practical value in guiding the risk management of transportation infrastructure investment projects.

2. Literature Review

Synthesizing the current relevant research, it is found that the existing research mainly focuses on three aspects: the identification of risk factors of transportation infrastructure investment, the construction method of the indicator system, and the dynamic and adaptability of the indicator system.

Risk factor identification is the basis for constructing an effective risk assessment indicator system. Early research is mainly based on a literature review and expert experience to identify risk factors for transportation infrastructure investment projects [9]. These studies have found that risk factors usually include, but are not limited to, market risk, financial risk, policy and legal risk, technical risk, and environmental risk. Recent work by Chen et al. (2022) on risk propagation in multilayer heterogeneous networks of large engineering projects further emphasizes the complexity and interconnectivity of risk factors in infrastructure projects [10]. In recent years, researchers have begun to use quantitative methods, such as fault tree analysis (FTA) and event tree analysis (ETA), to systematically identify risk factors and improve the completeness and precision of the identification process [5,11]. These studies mainly use qualitative analysis methods, such as expert interviews, case studies, etc., to identify risk factors. However, these studies mainly use qualitative analysis methods, such as expert interviews, case studies, etc., to identify risk factors. Additionally, Luo et al. (2022) utilized machine learning to analyze transport infrastructure connectivity and conflict resolution, highlighting the growing use of artificial intelligence in risk factor identification [12].

The construction method is the key to ensuring the effectiveness and practicability of the risk assessment indicator system. Traditionally, researchers have relied on the analytic hierarchy process (AHP) and the Delphi method to determine the weight and importance of risk indicators [13,14]. These methods focus on the integration of expert opinions; however, although effective, they may be affected by subjective bias. To overcome this limitation, recent studies have proposed the application of complex network theory and artificial intelligence techniques, such as machine learning, to construct and optimize indicator systems [15,16]. For instance, Sun et al. (2022) utilized a game-theoretic approach for multipriority data transmission in vehicular networks, demonstrating the potential of advanced methodologies in risk assessment [17]. These modern methods can process large amounts of data, identify hidden risk factors, and improve the scientificity and accuracy of the indicator system. Despite this, existing research often lacks complete consideration of the dynamic changes of projects and the needs of multiple stakeholders when constructing the indicator system.

In practical applications, transportation infrastructure investment projects typically involve long-term, large-scale investments and are influenced by various factors such as policy, technology, market, and social environment. These factors change continuously throughout the project lifecycle, leading to changes in the nature and extent of risks. Consequently, the risks associated with transportation infrastructure investment are dynamic and unpredictable. Therefore, the risk assessment indicator system needs to be dynamic and adaptable to timely reflect and respond to these changes, thereby improving the effectiveness and accuracy of risk management [18,19]. Early studies tend to ignore this requirement of the indicator system [20], while the latest research has begun to focus on how to adapt the indicator system to environmental changes and project development needs [21,22]. By

introducing time series analysis and dynamic simulation methods, researchers try to make the indicator system reflect and adapt to changes in risk factors over time, to improve the timeliness and effectiveness of risk management [23,24]. For example, Rong et al. (2022) developed a real-time bus waiting time estimation system based on multi-source data, which illustrated the importance of real-time data integration in dynamic risk management [25]. Although research in this area has improved the flexibility and effectiveness of risk management, current methods and tools still face challenges in practical applications, especially the realization of the automatic update and real-time adjustment of the indicator system has not been widely resolved.

On the basis of a comprehensive analysis of the existing research literature, it can be found that the shortcomings of the current research are mainly reflected in the following aspects:

1. Many studies have adopted a static risk assessment framework, ignoring the impact of environmental and condition changes on risk factors in the project life cycle;
2. Existing risk assessment methods often focus on specific types of risk but do not consider the interaction between risk factors and fail to form a comprehensive and systematic risk assessment system;
3. Most studies rely on a single methodology, such as the analytical hierarchy process (AHP) or fuzzy logic, and fail to make full use of the advantages of multiple methodologies to improve the accuracy and reliability of risk assessment;
4. Although some studies have mentioned the dynamic adaptability of risk assessment, specific implementation strategies and tools are still lacking, and it is difficult to cope with the changing risk environment during project implementation.

In summary, many scholars have used evolutionary game methods to study and explore government regulation, low carbon transformation of companies, and quality supervision, which provides a rich research base for the research of this paper. The differences between this paper and related literature include mainly the following points.

1. The study constructs a dynamic risk assessment framework, with particular emphasis on changes and updates of risk factors in the project life cycle, to better reflect the actual risk situation.
2. Through the comprehensive analysis of the multidimensional risk factors of transportation infrastructure investment, a comprehensive risk assessment indicator system is constructed, which covers the interaction between risk factors and reflects the concept of systematic risk management.
3. The combination of principal component analysis (PCA) and CRITIC-EWM is used to improve the scientificity and precision of risk assessment through the complementary advantages of different methods.

The differences between this paper and related literature include mainly the following points:

1. This paper constructs a method to construct a dynamic risk assessment indicator system, which can fully reflect the changes and updates of risk factors in the life cycle of investment projects in transportation infrastructure;
2. Through the comprehensive analysis of the multidimensional risk factors of transportation infrastructure investment, a comprehensive risk assessment indicator system is constructed, which covers the interaction between risk factors and reflects the concept of systematic risk management;
3. The combination of principal component analysis (PCA) and CRITIC-EWM is used to improve the scientificity and precision of risk assessment through the complementary advantages of different methods.

3. Methodology

3.1. Research Framework and Structural Design

3.1.1. Research Framework

Considering the dynamic and complexity of the risk assessment of investment in transportation infrastructure, the logical structure of this paper is systematically revealed by combining qualitative and quantitative methods. First, through a literature review, this study identifies and selects key indicators of risk assessment and establishes the theoretical basis of the research. Subsequently, the principal component analysis (PCA) and CRITIC-EWM methods were used to extract the most representative risk factors from multidimensional data to construct a scientific and reasonable indicator system. On this basis, to further test the effectiveness of the indicator system, the structural equation model (SEM) is used to test the validity and reliability of the evaluation indicator system. The research framework of this paper is shown in Figure 1.

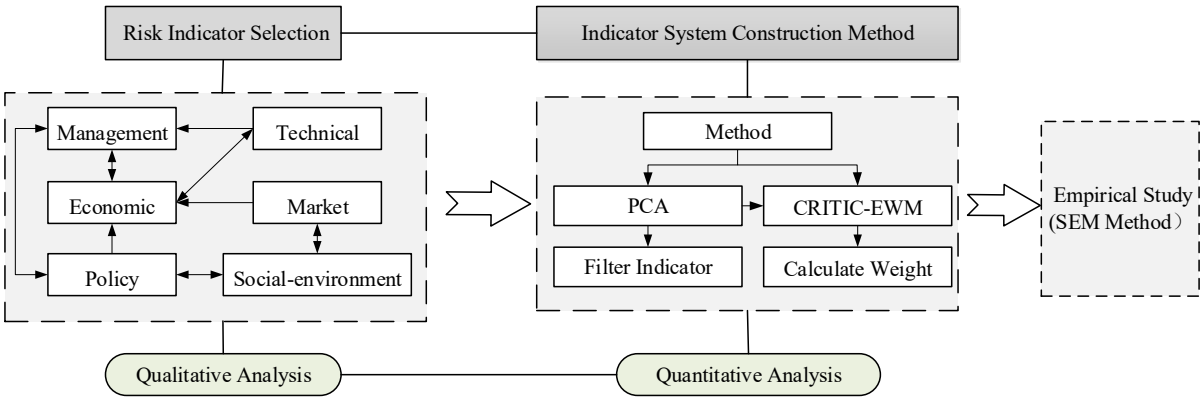

Figure 1. Research framework.

The analysis of the interrelationships between various risk sources is as follows:

Economic risk: economic risk affects cash flow and investment returns, which directly impact technical investment and management resource allocation, thereby increasing technical risk and management risk. Additionally, technical risk involves the feasibility of technical solutions and construction complexity; technical failures or issues can lead to cost overruns and schedule delays, further exacerbating economic risk.

Technical risk: technical risk, by involving the feasibility of technical solutions and construction complexity, directly impacts economic risk through cost overruns and delays if technical issues arise.

Management risk: management risk, through the organization, coordination, and allocation of resources within the project, directly affects the implementation of technical solutions and cost control, thus intertwining with both technical and economic risks.

Policy risk: policy risk, by affecting laws, regulations, and regulatory requirements, changes the financing environment and management framework of the project, thereby closely relating to economic and management risks.

Social–environmental risk: social–environmental risk impacts the social acceptance and environmental effects of the project, increasing policy pressure and market uncertainty, thus interacting with policy and market risks.

Market risk: market risk, through changes in market demand and competitive conditions, directly affects the economic benefits and social recognition of the project, further exacerbating economic risk and social–environmental risk.

3.1.2. Structure of the Indicator System

When designing the risk assessment indicator system for investments in transportation infrastructure, a key step is to divide the risk dimension and design a structured preliminary risk assessment indicator system accordingly. Transportation infrastructure

investment projects face multiple sources of risk due to their long-term, capital-intensive, and significant socioeconomic impact [26]. In the division of risk sources, the research of various countries often focuses on the characteristics of localization and classifies the risk of investment in transportation infrastructure. Furthermore, there are differences in understanding and classifying technical risks and management risks [27,28]. Despite such differences, current research jointly emphasizes the importance of building a comprehensive and systematic risk assessment indicator system when studying the risk of investing in transportation infrastructure. The relevant research on the division of the risk dimensions of investment in transportation infrastructure in the United States and abroad is shown in Table 1.

Table 1. Division of the risk dimension of investment in transportation infrastructure.

Related Research Literature	Risk Dimension Division
Choueiri (2009) [29]	Political Risk, Financial Risk, Technical Risk, Market Risk
Lakshmanan (2011) [30]	Economic Risk, Technical Risk, Market Risk
Labanauskas and Palšaitis (2012) [31]	Economic Risk, Political Risk, Market Risk, Operational Risk
Ang and Marchal (2013) [32]	Environmental Risk, Social Risk, Economic Risk
Sharma (2013) [33]	Legal Risk, Technical Risk, Economic Risk, Construction Risk
Tran and Molenaar (2014) [34]	Construction Risk, Design Risk, Policy Risk
Amiril (2014) [9]	Environmental Risk, Economic Risk, Social Risk, Management Risk
Yucelgazi and Yitmen (2018) [35]	Technical Risk, Financial Risk, Political Risk, Management Risk, Construction Risk, Legal Risk, Natural and Environmental Risk

Based on research findings from domestic and foreign scholars and combined with surveys conducted on major enterprises involved in the investment of transportation infrastructure, such as China Railway Construction Corporation Group Limited (CRCC), China Railway Group Limited (CREC), and China Communications Construction Company Limited (CCCC), this study proposes a structured risk assessment indicator system for the investment of transportation infrastructure. This indicator system is designed based on a summary of relevant academic research and practical survey results, covering six dimensions of risk: economic risk, technical risk, management risk, social and environmental risk, policy risk, and market risk. These dimensions comprehensively cover various risks faced by investments in transportation infrastructure and provide support for the subsequent research of this study. Each risk dimension is briefly outlined as follows:

1. Economic risk reflects financial stability and cost-effectiveness in the investment implementation process, which is the key to investment success. The core of the risk concern in this dimension is capital liquidity and the economic feasibility of the project. In the context of global economic integration, economic risks cover factors such as return on investment, financing costs, and material price fluctuations that may be encountered in the transportation infrastructure investment process. These factors may lead to the project investment return not being as expected, increasing the project's financial pressures and affecting the confidence of investors and related parties.
2. Technical risk focuses on technical problems and challenges that can be encountered in the design, construction, and operation of investment projects in transportation infrastructure. This includes the feasibility of technical solutions, the uncertainty of technological innovation, the complexity of construction technology, and the reliability of equipment. Transportation infrastructure projects are usually large in scale, have high technical requirements, and involve many engineering and technical problems. Immaturity or improper selection of technology may lead to project delays, cost overruns, and even technical failure.
3. Management risk focuses on organizational structure, the decision-making process, and the allocation of resources for transportation infrastructure investment projects. Management risk involves the efficiency and effectiveness of project management, in-

cluding project planning, organization and coordination, resource allocation, schedule control, etc. Improper project management can lead to waste of resources, schedule delays, quality problems, etc., which in turn affect overall performance and return on investment of the project.

4. Social environmental risks include the impact of project construction on the environment, the acceptance of the public, social stability, and other factors. Transportation infrastructure projects often have a significant impact on the local social environment. If the relationship with the local community is not properly handled or the impact on the environment is not effectively assessed and reduced, it may encounter public protests and legal proceedings, resulting in project delays or additional costs.
5. Policy risk refers to the risk caused by changes in government policies and uncertainty of laws and regulations. Transportation infrastructure projects often require long-term planning and construction cycles, and policy changes can affect the legitimacy, economy, and sustainability of the project.
6. Market risk involves changes in market demand, competitive situation, price fluctuations, and other factors. Investment in transportation infrastructure is huge, and the recovery cycle is long. Market risk is reflected mainly in the uncertainty of user demand and the fluctuation of operating income. Accurate prediction of market demand and in-depth analysis of the competitive environment are crucial to reducing market risks and ensuring project success.

3.1.3. Selection of Sample and Data Sources

To ensure the comprehensiveness and scientificity of the evaluation, this study obtains data on 76 transportation infrastructure investment projects that have been implemented by the government and the Center for Social Capital Cooperation of the Ministry of Finance (CPPPC Project Management Database), the National PPP Project Information Monitoring Service Platform of the National Development and Reform Commission, and other official institutions as research samples. The sample information is shown in Table 2.

Table 2. Sample information.

No.	Object	Province	Average Investment (CNY Billion)
1–29	Expressway	Shandong Province, Henan Province, Guangdong Province, Anhui Province, Zhejiang Province, Guangxi Province, Shaanxi Province, Guizhou Province, Heilongjiang Province	63.85
30–36	Municipal highways	Beijing Municipality, Chongqing Municipality, Shandong Province, Zhejiang Province	18.96
37–41	Tunnels	Jiangsu Province, Guangdong Province, Hubei Province	39.54
42–50	Rail Transit	Shandong Province, Jilin Province, Xinjiang Uygur Autonomous Region, Shanxi Province, Gansu Province, Chongqing Municipality	69.76
51–55	Railway	Anhui Province, Zhejiang Province, Shanghai Municipality	56.93
56–61	Bridges	Shanxi Province, Guangdong Province, Hebei Province, Shandong Province, Jiangxi Province	19.84
62–64	Ports	Shandong Province, Jiangsu Province, Hainan Province	32.53
65–71	Channel	Shandong Province, Henan Province, Guangxi Province	66.57
72–76	Airports	Shaanxi Province, Sichuan Province, Guangdong Province, Guangxi Province, Hubei Province	28.82

To ensure the representativeness of the sample and the validity of the data, this study adopted field research and extensive data collection as the primary data acquisition methods. This approach is supported and validated by numerous scholars. According to De Vaus (2013) [36], sample representativeness is key to ensuring that research results are generally applicable. Additionally, Bernard (2017) noted that extensive data collection enhances the comprehensiveness and accuracy of the data, thereby strengthening the reliability of research conclusions [37]. The selection of research objects has been strictly screened, and transportation infrastructure projects of different regions, different scales, and different types have been selected to ensure the breadth and depth of the research. In the actual investigation, in-depth interviews were conducted with the business personnel of the relevant units in the investigation samples to collect first-hand information from the project and ensure that the data obtained could fully reflect the actual situation. In terms of data collection, this study covers a variety of sources, from project evaluation reports, academic literature, government reports, and industry analysis to data published by professional institutions, ensuring the diversity and richness of information. In addition, relevant data is captured using tools such as Python, from which existing risk factors are extracted as supplementary sources of information. In terms of effectiveness evaluation, the managers of relevant business departments, such as the CRCC, CECC, and CCCC, as well as the scientific research backbones in relevant fields, such as Beijing Jiaotong University and the Academy of Sciences of the Ministry of Transport, are invited to correct and supplement the Risk factors collected in each dimension to form a set of Risk factors for transportation infrastructure investment process.

From the perspective of risk sources, economic risk, technical risk, and management risk can be summarized as internal risks, while social–environment risk, policy risk, and market risk can be regarded as external risks. Based on the structure of the indicator system designed above, a preliminary structured risk assessment indicator system is formed. The structure of the indicator system is shown in Figure 2.

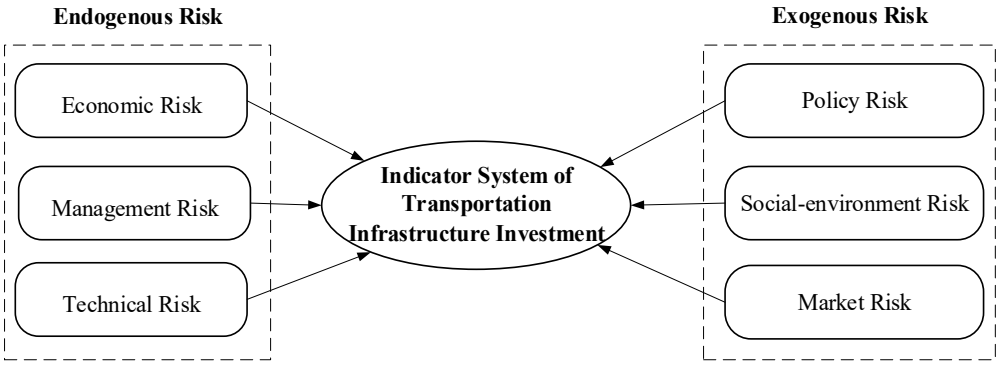

Figure 2. The structure of an indicator system.

Studies such as Fisher et al. (2001) [38], Shi et al. (2018) [39], and Reznikov (2020) [40] agree that it is generally appropriate to retain 7 to 10 indicators for each risk dimension. Based on research by Mishra et al. (2013) [41] and Ermolaeva et al. (2022) [42], combined with the risk indicators summarized in this article, the Risk Assessment Indicator System for Investment in the Transportation Infrastructure is being constructed preliminarily. There are six risk dimensions and 49 evaluation indicators in this indicator system. The details are shown in Table 3.

Table 3. Preliminary risk assessment indicators.

Risk Dimensions	Evaluation Indicators	Indicator Attribute
Economic (E)	E11: Return on Investment	Positive
	E12: Fund Flow Fluctuation	Positive
	E13: Inflation	Negative
	E14: Tax Policy	Negative
	E15: Financing Difficulty	Negative
	E16: Land Acquisition Costs	Negative
	E17: Investment Overrun	Negative
	E18: Labor Costs	Negative
	E19: Material Price Fluctuation	Negative
	E10: Cost of Capital Utilization	Negative
Technical (T)	T21: Design Planning Deviation	Negative
	T22: Technical Implementation Difficulty	Negative
	T23: Material Technology Qualification Rate	Positive
	T24: Technical Personnel Experience	Positive
	T25: Equipment Failure Rate	Negative
	T26: Geological Survey Error	Negative
	T27: Technical Environment Adaptability	Positive
	T28: Technical Standard Compliance Rate	Positive
Management (M)	M31: Management Team Experience	Positive
	M32: Decision Delay Rate	Negative
	M33: Contract Default Risk	Negative
	M34: Budget Overrun Rate	Negative
	M35: Key Personnel Attrition Rate	Negative
	M36: Supply Chain Management	Positive
	M37: Quality Management	Positive
	M38: Incomplete Management System	Negative
Policy (P)	P41: Policy Support Level	Positive
	P42: Policy Change Frequency	Negative
	P43: Positive Intensity of Policy Implementation Intensity	Positive
	P44: Policy Uncertainty	Negative
	P45: Regulatory Compliance Risk	Negative
	P46: Regional Policy Differences	Negative
	P47: Policy–Market Disconnect	Negative
	P48: Government Intervention Risk	Negative
Social–environment (S)	S51: Public Opposition Degree	Negative
	S52: Frequency of Social Conflict Events	Negative
	S53: Land Acquisition and Demolition Risk	Negative
	S54: Environmental Pollution Risk	Negative
	S55: Public Safety Incidents	Negative
	S56: Social Opinion Risk	Negative
	S57: Negative Social Responsibility Fulfillment	Negative
	S58: Social-Cultural Conflict	Negative
Market (C)	C61: Market Demand Fluctuation	Negative
	C62: Intensity of Market Competition	Negative
	C63: Price Fluctuation Risk	Negative
	C64: Market Acceptance	Positive
	C65: Market Regulation	Negative
	C66: Brand Image	Positive
	C67: Market Information Asymmetry	Negative

3.2. Construction of an Indicator System Based on the PCA and CRITIC-EWM Method

In this study, we applied principal component analysis (PCA) and the CRITIC-EWM method to screen and determine risk assessment indicators and their weights. The PCA method simplifies the data structure through dimensionality reduction, highlighting key

risk factors, while the CRITIC-EWM method determines the weights of each indicator by comprehensively considering the correlation and information content among indicators. These methods have been applied and proven effective in multiple studies [43,44]. The specific implementation steps are as follows.

3.2.1. Indicator Data Processing

The Risk Assessment Indicator of Transportation Infrastructure Investment and its quantitative method have been initially established. However, the original indicator data have varying units and dimensions, complicating subsequent calculations. Therefore, it is necessary to standardize the original data, converting each indicator's data to a value between [0, 1]. This standardization is essential for constructing the risk assessment indicator system model. Depending on the different types of indicators, the standardized processing of the indicator data is as follows.

1. Standardization of positive indicator data

Suppose that x_{ij} is the standardized score of the jth sample of the ith indicator, s_{ij} is the original data of the jth sample of the ith indicator, and n is the total number of samples. There is a data standardization formula for positive indicators:

$$x_{ij} = \frac{s_{ij} - \min\limits_{1\le j\le n}\left(s_{ij}\right)}{\max\limits_{1\le j\le n}\left(s_{ij}\right) - \min\limits_{1\le j\le n}\left(s_{ij}\right)},\ i = 1,2,\cdots,n;\ j = 1,2,\cdots,n \tag{1}$$

2. Standardization of negative indicator data

$$x_{ij} = \frac{\min\limits_{1\le j\le n}\left(s_{ij}\right) - s_{ij}}{\max\limits_{1\le j\le n}\left(s_{ij}\right) - \min\limits_{1\le j\le n}\left(s_{ij}\right)},\ i = 1,2,\cdots,n;\ j = 1,2,\cdots,n \tag{2}$$

3. Standardization of interval indicator data

Suppose that s_{ij} is the original data of the jth sample of the ith indicator, q_1 is the right boundary of the optimal interval of the indicator, and q_2 is the right boundary of the optimal interval of the indicator. There is a standardized formula for the interval indicator data:

$$x_{ij} = \begin{cases} 1 - \dfrac{q_1 - s_{ij}}{max\left[q_1 - \min\limits_{1\le j\le n}\left(s_{ij}\right), \max\limits_{1\le j\le n}\left(s_{ij}\right) - q_2\right]}, s_{ij} < q_1 \\ 1 - \dfrac{s_{ij} - q_2}{max\left[q_1 - \min\limits_{1\le j\le n}\left(s_{ij}\right), \max\limits_{1\le j\le n}\left(s_{ij}\right) - q_2\right]}, s_{ij} > q_2 \\ 1 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad , q_2 < s_{ij} < q_1 \end{cases} \tag{3}$$

3.2.2. Degradation of the Indicator Dimension Based on the PCA Method

The PCA method can effectively reduce the dimension of the data, extract the main information, remove interference factors from the evaluation system, and simplify the complexity of the original feature analysis. Specific implementation steps are as follows:

Step 1. Decentralization Processing of Indicator Data.

The risk assessment indicator system for investment in the transportation infrastructure has been established preliminarily. On this basis, the original evaluation matrix $X = \left[x_{ij}\right]_{n\times m}$ is established, and the decentralized matrix $S = \left[s_{ij}\right]_{n\times m}$ is obtained by the Z-score method. The decentralized processing of the indicator data is as follows:

$$s_{ij} = \frac{x_{ij} - \overline{x_i}}{\sqrt{Fc_j}}, i = 1,2,\cdots,n; j = 1,2,\cdots,m \tag{4}$$

$$\overline{x_i} = \frac{1}{m}\sum_{i=1}^{n} x_{ij}, i = 1, 2, \cdots, n; j = 1, 2, \cdots, m \tag{5}$$

$$Fc_j = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_{ij} - \overline{x_i}\right)^2, i = 1, 2, \cdots, n; j = 1, 2, \cdots, m \tag{6}$$

where Fc_j is the variance of column j.

Step 2. Construct the correlation coefficient matrix between indicators.

Calculate the correlation coefficient between each indicator:

$$\xi_{ij} = \frac{\sum_{k=1}^{n}(s_{ki} - \overline{S_i})\cdot(s_{kj} - \overline{S_j})}{\sqrt{\sum_{k=1}^{n}(s_{ki} - \overline{S_i})^2 \cdot \sum_{k=1}^{n}(s_{kj} - \overline{S_j})^2}}, i = 1, 2, \cdots, n; j = 1, 2, \cdots, m \tag{7}$$

In the formula, s_{ki} and $\overline{S_i}$ represent the indicator value and the average value after decentralization, respectively. On this basis, the correlation coefficient matrix $Z = \left[\xi_{ij}\right]_{m\times m}$ is constructed.

Step 3. Calculate the eigenvalues and eigenvectors of the correlation coefficient matrix.

$Z = \left[\xi_{ij}\right]_{m\times m}$ is a positive definite matrix, which must be orthogonal to the diagonal matrix, so there are:

$$U^T Z U = \begin{bmatrix} \lambda_1 & & \\ & \ddots & \\ & & \lambda_m \end{bmatrix} \tag{8}$$

$\lambda_i, U = [u_1, u_2, \cdots, u_m]$ A is the characteristic root and the corresponding characteristic vector.

Step 4. Calculate the contribution rate.

The contribution rate is the result of feedback on the importance of the indicator. The calculation method is as follows:

$$\omega_i = \frac{\lambda_i}{\sum_{j=1}^{m}\lambda_i}, j = 1, 2, \cdots, m \tag{9}$$

where ω_i represents the contribution rate of the ith principal component.

Step 5. Determine the number of principal components.

The indicators are sorted according to the contribution rate, and the threshold α is determined. If the contribution rate β of the first p indicators is greater than the threshold α, the number of principal components is p. Then there are the following.

$$\beta = \sum_{i=1}^{p}\omega_i > \alpha, i = 1, 2, \cdots, p \tag{10}$$

Step 6. Calculate the load and score of each principal component.

According to the eigenvector U obtained by the correlation coefficient matrix, which is the load matrix of the main component, the standardized evaluation indicator matrix $S = \left[s_{ij}\right]_{n\times m}$ is brought into the principal component to obtain the score of the main component.

$$F = [F_1, F_2, \cdots, F_P] = \left[F_{ij}\right]_{p\times m}, i = 1, 2, \cdots, p; j = 1, 2, \cdots, m$$
$$\begin{cases} F_1 = u_{11}S_1 + u_{12}S_2 + \cdots + u_{1m}S_m \\ F_2 = u_{21}S_1 + u_{22}S_2 + \cdots + u_{2m}S_m \\ \vdots \\ F_p = u_{p1}S_1 + u_{p2}S_2 + \cdots + u_{pm}S_m \end{cases} \tag{11}$$

3.2.3. Calculation of the Weight of the Indicator System Based on the CRITIC-EWM Method

In the previous section, the main risk assessment indicators for investment in transportation infrastructure were successfully selected using the PCA method, which laid a solid foundation to build a more concise and effective risk assessment system. However, only identifying the main risk assessment indicators is not enough to complete the construction of the entire assessment system. The next key step is to determine the weight of these indicators to reflect their relative importance throughout the evaluation system. The CRITIC method is an objective weighting method. Determine the weight based on the correlation between indicators, which can effectively avoid subjective interference. It can measure the contrast strength between indicators, but it cannot measure the impact of dispersion. The EWM (entropy weight method) is a method that aims to determine the indicator weight according to the degree of dispersion between the indicators, which can comprehensively and objectively reflect the information content of each indicator. By combining the two methods, a weight determination method can be obtained that can not only reflect the correlation between indicators but also fully consider the amount of information on the indicators. More importantly, the CRITIC-EWM method has good dynamics. With the passage of time and the generation of new data, this method can automatically adjust the weight of each risk assessment indicator so that the evaluation system always maintains the optimal state, which is helpful in constructing a scientific, objective, and dynamic risk assessment indicator system for investments in traffic infrastructure. Therefore, this paper chooses to combine the CRITIC and EWM methods to determine the indicator weight.

1. The CRITIC method.

The CRITIC method reflects the differences and internal conflicts between the indicators through the standard deviation and correlation coefficient. In traditional practice, the correlation coefficient can produce negative numbers, leading to wrong results. When the dimension and magnitude of the data are different, there will be distortion in the calculation results. To solve the above problems, this paper introduces the absolute value of the correlation coefficient area, introduces the Gini coefficient to replace the standard deviation to measure the conflict between the indicators, and obtains the optimized CRITIC weight calculation method. The calculation steps are as follows:

Step 1. Calculating the correlation coefficient matrix.

Suppose that $T = \left[t_{ij}\right]_{p\times m}$ is the evaluation matrix composed of the main evaluation indicators, $Y = \left[y_{ij}\right]_{p\times m}$ is the calculated correlation coefficient matrix, and y_{ij} is the Pearson correlation coefficient between the ith evaluation indicator and the jth evaluation indicator. The calculation method is as follows:

$$y_{ij} = \frac{\sum_{k=1}^{p}(t_{ki} - \overline{T_i})\cdot(t_{kj} - \overline{T_j})}{\sqrt{\sum_{k=1}^{p}(t_{ki} - \overline{T_i})^2 \cdot \sum_{k=1}^{p}(t_{kj} - \overline{T_j})^2}}, i = 1, 2, \cdots, p; j = 1, 2, \cdots, m \tag{12}$$

In the formula, $\overline{T_i}$ and $\overline{T_j}$ represent the mean values of indicator i and indicator j, respectively.

Step 2. Calculate the Gini coefficient.

Suppose that ε_j is the Gini coefficient, which is used to measure the distribution of the indicator information. The calculation method is as follows:

$$\varepsilon_j = \frac{\sum_{i=1}^{p}\sum_{k=1}^{p}\left|s_{ij} - s_{kj}\right|}{2n\sum_{i=1}^{p} s_{ij}}, j = 1, 2, \cdots, m \tag{13}$$

It can be seen from the formula that for $\varepsilon_j \in [0, 1]$, the closer ε_j is to 1, the more unbalanced the distribution of the indicator information and the greater the amount of information contained. The closer ε_j is to 0, the more balanced the indicator information distribution is, the smaller the amount of information it contains.

Step 3. Calculate the information coefficient.

Assuming that γ_j is the information coefficient, there is a positive and a negative correlation between the indicators. To ensure the accuracy of the calculation results, the absolute value of the Pearson coefficient is taken and then included in the calculation of the information coefficient. The calculation method is as follows:

$$\gamma_j = \sum_{i=1}^{p}(1 - |t_{ij}|), j = 1, 2, \cdots, m \tag{14}$$

Step 4. Calculate the amount of comprehensive information from the indicator.

Suppose η_j is the comprehensive information quantity of indicator j, and the calculation method is

$$\eta_j = \varepsilon_j \cdot \gamma_j, j = 1, 2, \cdots, m \tag{15}$$

Step 5. Calculate the weight of indicator j.

$$W_j^1 = \frac{\eta_j}{\sum_{j=1}^{m}\eta_j}, j = 1, 2, \cdots, m \tag{16}$$

where $\sum_{j=1}^{m} W_j^1 = 1, 0 \leq W_j^1 \leq 1$.

2. The EWM method.

This method is used to use the degree of dispersion between indicators to calculate the indicator weight. The calculation steps are as follows:

Step 1. Calculate the weight ratio of the evaluation object.

Suppose that the weight proportion is f_{ij}, and the calculation method is

$$f_{ij} = \frac{t_{ij}}{\sum_{i=1}^{p} t_{ij}}, i = 1, 2, \cdots, p; j = 1, 2, \cdots, m \tag{17}$$

Step 2. Calculate the entropy value.

Assuming that the entropy value is e_j, the calculation method is:

$$e_j = -\frac{1}{\ln m} \cdot \sum_{t=1}^{p} t_{ij} \cdot \ln t_{ij}, i = 1, 2, \cdots, p; j = 1, 2, \cdots, m \tag{18}$$

Step 3. Calculation weight.

$$W_j^2 = \frac{1 - e_j}{\sum_{i=1}^{p}(1 - e_j)} = \frac{1 - e_j}{m - \sum_{i=1}^{p} e_j}, j = 1, 2, \cdots, m \tag{19}$$

where $\sum_{j=1}^{m} W_j^2 = 1, 0 \leq W_j^2 \leq 1$.

3. Combination weight

By combining the weight W_j^1 and the weight W_j^2, the combined weight is obtained:

$$W_j = \frac{W_j^1 \cdot W_j^2}{\sum_{j=1}^{m} W_j^1 \cdot W_j^2}, j = 1, 2, \cdots, m \tag{20}$$

3.3. Construction Indicator System

3.3.1. Standardization of Indicator Data

Integrate all data collected and processed into a raw data set. The statistical results of the raw data set are shown in Table 4.

Table 4. Raw data statistics for each risk assessment indicator.

		E11	**E12**	**E13**	**E14**	**E15**	**E16**	**E17**	**E18**	**E19**	**E10**
E	Mean	4.97%	5.02%	5.10%	4.99	5.06	50.4	5.08%	5.05	5.1%	5.10%
	Max	7.51%	8.90%	7.93%	7.59	7.28	86.4	7.96%	7.97	8.0%	7.52%
	Min	1.92%	1.73%	3.04%	1.50	1.98	25.1	2.07%	2.09	2.3%	2.20%
		T21	T22	T23	T24	T25	T26	T27	T28		
T	Mean	10.06%	9.92%	9.92%	9.95	9.81%	9.88%	9.94	9.92%		
	Max	12.97%	12.3%	11.9%	12.66	12.3%	12.3%	12.19	12.1%		
	Min	7.08%	7.56%	7.22%	7.09	7.45%	7.39%	7.06	7.11%		
		M31	M32	M33	M34	M35	M36	M37	M38		
M	Mean	6.88	6.89%	7.02%	7.0%	6.97%	6.95	6.93	6.95		
	Max	9.40	9.29%	9.24%	9.28%	9.39%	9.53	9.16	9.40		
	Min	4.65	4.78%	5.19%	4.25%	4.81%	4.31	4.49	4.27		
		P41	P42	P43	P44	P45	P46	P47	P48		
P	Mean	2.90	3.01%	3.11	3.08	3.07	2.99	3.06	3.16		
	Max	5.92	6.37%	5.29	5.30	6.21	5.82	5.65	6.03		
	Min	0.23	0.16%	1.01	0.04	0.16	0.76	0.54	0.80		
		S51	S52	S53	S54	S55	S56	S57	S58		
S	Mean	6.02%	5.83%	5.90%	6.02%	5.88%	6.01%	5.92	6.06		
	Max	8.16%	8.26%	8.29%	8.14%	8.30%	8.27%	8.37	8.31		
	Min	2.87%	3.64%	3.56%	3.74%	3.26%	3.66%	3.68	3.92		
		C61	C62	C63	C64	C65	C66	C67			
C	Mean	4.04%	4.00%	4.02%	3.98%	3.94	4.03	3.98			
	Max	6.77%	6.61%	6.81%	8.10%	6.92	6.88	7.41			
	Min	1.18%	1.69%	1.56%	1.38%	1.42	1.47	1.91			

3.3.2. Dimensional Reduction of Risk Assessment Indicators

Through the indicator system constructed above, it can be found that the correlation of the evaluation indicators contained in each dimension is not strong. If the evaluation indicators under each risk dimension are extracted by the overall principal component analysis, it may have a cross-impact on the indicators under each dimension and affect the extraction of comprehensive indicators. Therefore, this article extracts the principal components of each risk dimension, screens the key indicators under each risk dimension, and determines the risk assessment indicator system for investment in the transportation infrastructure investment process.

1. Correlation test of indicators.

The results of the correlation test of the indicators are shown in Table 5.

Table 5. Results of the correlation test.

		E	**T**	**M**	**P**	**S**	**C**
KMO		0.870	0.853	0.745	0.737	0.631	0.6448
Bartlett Sphericity Test	Chi-Square	826.460	719.18	652.08	620.20	610.20	515.18
	DF	45	43	37	52	38	36
	p-value	0.000	0.002	0.007	0.01	0.02	0.014

The closer the KMO value is to 1, the more suitable the original variable is for principal component analysis. It can be seen in Table 5 that the KMO value of the economic risk was 0.970 > 0.5; that is, the evaluation indicators included in the economic risk have a strong correlation, and the next analysis of the principal components can be performed. The p-value of the Bartlett sphericity test was 0.000 < 0.05, indicating that there was a significant

correlation between the evaluation indicators, further illustrating the need for a principal component analysis for each evaluation indicator.

2. Extraction of principal components.

Due to space limitations, this paper only takes economic risk as an example to show the extraction process of principal components. The factor variance contribution is used to measure the relative importance of each factor, which can be explained as the factor's ability to explain the total variance of the original variable. The more important the factor, the higher the variance contribution rate. The explanation of the variation of the economic risk is shown in Table 6.

Table 6. The variance explanation of economic risk.

No.	Characteristic Root			Principal Component Extraction		
	Characteristic	Variance	Accumulation	Characteristic	Variance	Accumulation
1	4.911	49.11	49.11	4.911	49.11	49.11
2	2.18	21.8	70.91	2.18	21.8	70.91
3	0.935	9.35	80.26	0.935	9.35	80.26
4	0.805	8.05	88.31	0.805	8.05	88.31
5	0.606	6.06	94.37	-	-	-
6	0.368	3.68	98.05	-	-	-
7	0.111	1.11	99.16	-	-	-
8	0.052	0.52	99.68	-	-	-
9	0.029	0.29	99.97	-	-	-
10	0.003	0.03	100	-	-	-

This article retained the principal components with a cumulative variance contribution rate of more than 85%, and the cumulative variance contribution rate of a total of four principal components reached 88.31%, which could comprehensively reflect the information of each indicator in the economic risk dimension. Therefore, four principal components were selected for analysis under the economic risk dimension. To facilitate the interpretation of the analysis results, the factor rotation of the component matrix was performed to obtain the rotated component matrix, as shown in Table 7.

Table 7. Rotated component matrix.

No.	Principal Component			
	Component 1	Component 2	Component 3	Component 4
E11	0.018	0.341	0.513	0.272
E12	−0.005	−0.018	0.654	0.245
E13	−0.480	−0.019	−0.043	−0.136
E14	0.209	0.057	−0.288	0.455
E15	−0.606	0.151	0.004	0.303
E16	0.142	0.524	−0.164	0.175
E17	0.184	0.448	0.236	−0.501
E18	0.013	0.529	−0.131	−0.219
E19	0.180	−0.307	0.344	−0.413
E10	0.522	−0.084	−0.085	0.222

According to the analysis results of Table 7, the first principal component represents the two indicators of financial difficulty and capital use cost, which can be summarized as financing efficiency (E1); the second principal component represents two indicators of land expropriation cost and labor cost, which can be summarized as uncontrollable investment (E2); the third principal component represents the two indicators of return on investment and capital flow fluctuation, which can be summarized as investment benefit (E3); the fourth principal component represents the investment over budget indicator, which can

be summarized as budget overrun rate (E4). In summary, the evaluation indicators under the economic risk dimension can be summarized as four indicators: financing efficiency, uncontrollable investment cost, investment benefit indicator, and budget overrun rate.

According to the above method, the principal components of technical risk, management risk, policy risk, social environment risk, and market risk were extracted, respectively. Among them, the evaluation indicators under the technical risk dimension can be summarized as four indicators: technical reliability (T1), technical implementation complexity (T2), engineering quality compliance rate (T3), and technical compatibility rate (T4); the evaluation indicators under the management risk dimension can be summarized as three indicators: decision execution efficiency (M1), management efficiency (M2), and stability of core team (M3). Evaluation indicators under the dimension of policy risk can be summarized as three indicators: stability of the policy environment (P1), effectiveness of the policy (P2), and adaptability to policies and regulations (P3). Evaluation indicators under the dimension of social–environmental risk can be summarized as three indicators: risk of social stability (S1), social acceptance (S2), and adaptability to environmental pressure (S3). The evaluation indicators under the market risk dimension can be summarized as four indicators: market stability (C1), market responsiveness (C2), return volatility (C3), and intensity of market regulation (C4).

3. Calculation of weight coefficients

The PCA method can effectively select representative and relevant evaluation indicators, simplifying complex data structures. However, this method mainly solves the problem of which indicators should be included in the evaluation system and does not solve the problem of how much weight these indicators should have in the specific evaluation process. The importance of each indicator in practical application is different. Some have a direct impact on the success of investments in transportation infrastructure, while others are relatively minor. The calculation of the weight coefficient can reflect in more detail the relative importance of each indicator. The introduction of the weight coefficient also increases the flexibility and adaptability of the evaluation system. When the external environment changes, the weight is adjusted to adapt to the new situation. According to the previous calculation method, the weight coefficients are calculated using the CRITIC and EWM methods, respectively, and then the combined weights are determined. The results of the calculation of the weight coefficient for each indicator are shown in Table 8.

Table 8. Weight coefficient of each indicator.

	Weight Coefficient										
	E1	**E2**	**E3**	**E4**	**T1**	**T2**	**T3**	**T4**	**M1**	**M2**	**M3**
W_j^1	0.0543	0.0384	0.0512	0.0501	0.0467	0.0418	0.0550	0.0532	0.0399	0.0628	0.0519
W_j^2	0.0603	0.0302	0.0536	0.0514	0.0446	0.0358	0.0619	0.0579	0.0325	0.0807	0.0550
W_j	0.0653	0.0232	0.0547	0.0514	0.0416	0.0299	0.0679	0.0615	0.0259	0.1011	0.0570
	P1	P2	P3	S1	S2	S3	C1	C2	C3	C4	
W_j^1	0.0418	0.0377	0.0563	0.0572	0.0398	0.0368	0.0546	0.0475	0.0483	0.0348	
W_j^2	0.0358	0.0290	0.0648	0.0670	0.0323	0.0276	0.0610	0.0461	0.0477	0.0248	
W_j	0.0299	0.0218	0.0728	0.0765	0.0257	0.0203	0.0664	0.0437	0.0460	0.0173	

4. Establishment of the indicator system

After these calculations, the final evaluation indicator system for the risk of investment in transportation infrastructure constructed in this study is obtained, as shown in Table 9.

Table 9. Indicator system for investment risk in transportation infrastructure.

Risk Dimensions	Indicator	Weight	Variance Contribution
Economic	E1: Financing Efficiency	0.0653	88.31%
	E2: Uncontrollable Investment Costs	0.0232	
	E3: Investment Benefit	0.0547	
	E4: Budget Overrun Rate	0.0514	
Technological	T1: Technical Reliability	0.0416	89.89%
	T2: Technical Implementation Complexity	0.0299	
	T3: Engineering Quality Compliance Rate	0.0679	
	T4: Technical Compatibility Rate	0.0615	
Management	M1: Decision Execution Efficiency	0.0259	88.33%
	M2: Management Efficiency	0.1011	
	M3: Stability of Core Team	0.0570	
Political	P1: Policy Environment Stability	0.0299	88.05%
	P2: Policy Effectiveness	0.0218	
	P3: Adaptability to Policies and Regulations	0.0728	
Social-environmental	S1: Social Stability Risk	0.0765	86.37%
	S2: Social Acceptance	0.0257	
	S3: Environmental Pressure Adaptability	0.0203	
Market	C1: Market Stability	0.0664	92.37%
	C2: Market Responsiveness	0.0437	
	C3: Return Volatility	0.0460	
	C4: Market Regulation Intensity	0.0173	

4. Empirical Study

4.1. Theoretical Model and Research Hypotheses

Structural equation modeling (SEM) is a widely used multivariate statistical analysis technique in fields such as social sciences, behavioral sciences, and management sciences. It can evaluate complex relationships between variables and is suitable for studying latent variables that cannot be observed directly but can be indirectly measured through multiple indicators. Through path analysis, SEM can explore causal relationships between variables. In addition, this method can assess the fit of the entire model as well as the importance and strength of each path. Therefore, SEM is an ideal tool to empirically test the effectiveness of indicator systems. This method not only allows for in-depth analysis of interactions between indicators but also provides a comprehensive perspective on the effectiveness and consistency of the entire risk assessment indicator system, thereby examining the effectiveness of the indicator system. Based on the structure of the Risk Assessment Indicator System constructed in Section 3, economic risk, technical risk, management risk, social–environmental risk, policy risk, and market risk are considered first-order latent variables in the structural equation model, while transportation infrastructure investment risk is considered as a second-order latent variable, and the risk assessment indicators under each risk dimension are considered as measurement variables in the model.

Based on the theoretical model and the measurement model of the risk assessment indicator system for investment in the transportation infrastructure investment discussed above, the research hypotheses for latent variables are set as follows:

H1: *Economic risk has explanatory power for investment risk in transportation infrastructure.*

H2: *Technical risk has explanatory power over investment risk in transportation infrastructure.*

H3: *Management risk has explanatory power over the risk of investment in transportation infrastructure.*

H4: *Social–environmental risk has explanatory power over the risk of investment in transportation infrastructure.*

H5: *The policy risk has explanatory power over the risk of investment in transportation infrastructure.*

H6: *Market risk has explanatory power over the risk of investment in transportation infrastructure.*

4.2. Data Source and Reliability and Validity Test

4.2.1. Data Source

This study takes economic risk, technical risk, management risk, social environment risk, policy risk, and market risk as exogenous potential variables to analyze their impact on the risk of investment in the transportation infrastructure investment process. Since these exogenous potential variables cannot be directly measured, these potential variables must be evaluated by the measurement model corresponding to each risk dimension. Therefore, it is necessary to design the research questionnaire and collect data on the measurement variables. Therefore, it is necessary to design a survey questionnaire and collect data on measurement variables. When designing the survey questionnaire, we first design a preliminary questionnaire based on existing research findings and expert opinions. Then, a small number of samples are selected for pre-survey to assess the reliability and validity of the scales. Finally, the questionnaire is modified further based on any issues identified during the survey process, forming the formal survey questionnaire. The questionnaire is divided into two parts: the first part consists of background information on the respondents to ensure a deep understanding of the industry and the effectiveness of the survey. The second part of the questionnaire is the main part of the survey, which mainly includes the measurement indicators corresponding to economic risk, technical risk, management risk, social–environmental risk, policy risk, and market risk. Likert five-point scale items are used for each measurement variable in the survey. After the initial questionnaire was completed, a pre-survey was conducted from 1 November to 10 December 2023. A total of 30 questionnaires were distributed, and 21 were collected. Modifications were made based on the issues identified during the presurvey and the shortcomings of the research. The formal survey was conducted from 1 December to 30 December 2023. A total of 350 questionnaires were distributed, and 314 valid questionnaires were collected, with an effective rate of 89.7%. Among the valid questionnaires collected, 259 respondents had intermediate or higher professional titles, representing approximately 82.48% of the total sample. In terms of age distribution, the highest proportion falls between 35 and 45 years of age, with 134 respondents representing 42.68% of the total sample. In terms of years of service, most have worked for 6–15 years, with 175 respondents representing 55.73% of the total sample. Detailed information on the survey respondents is shown in Table 10.

Table 10. Basic information of the questionnaire.

Information	Background	Sample Size	Percentage
Age	Under 25	22	7.01%
	26–34	68	21.66%
	35–45	134	42.68%
	Over 45	90	28.66%
Title	Junior	55	17.52%
	Intermediate	72	22.93%
	Associate senior	104	33.12%
	Senior	83	26.43%
Experience	Under 5	68	21.66%
	6–10	82	26.11%
	11–15	93	29.62%
	Over 15	71	22.61%

Table 10. *Cont.*

Information	Background	Sample Size	Percentage
Education	Associate	64	20.38%
	Bachelor	139	44.27%
	Master	99	31.53%
	Doctorate	12	3.82%

4.2.2. Reliability Test

The reliability testing of the variables refers to the stability and consistency of the results obtained when the same questionnaire is repeatedly administered to measure the variables. Assesses the consistency and reliability of the questionnaire by calculating the internal consistency among various indicators of the measurement tool. The commonly used method to test reliability is Cronbach's α coefficient method. When the α coefficient value is greater than or equal to the threshold of 0.6, the scale is considered to be highly reliable. In this study, the reliability analysis was performed using SPSS 16.0 software. The results are shown in Table 11.

Table 11. Results of the reliability test.

Latent Variable	Measured Variable	Cronbach's α Coefficient		
Economic	E1: Financing Efficiency	0.9268	0.8271	0.9311
	E2: Uncontrollable Investment Costs	0.9286		
	E3: Investment Benefit	0.9276		
	E4: Budget Overrun Rate	0.9269		
Technological	T1: Technical Reliability	0.9272	0.8112	
	T2: Technical Implementation Complexity	0.9274		
	T3: Engineering Quality Compliance Rate	0.9292		
	T4: Technical Compatibility Rate	0.9282		
Management	M1: Decision Execution Efficiency	0.9272	0.7590	
	M2: Management Efficiency	0.9287		
	M3: Stability of Core Team	0.9288		
Political	P1: Policy Environment Stability	0.9289	0.7738	
	P2: Policy Effectiveness	0.9274		
	P3: Adaptability to Policies and Regulations	0.9280		
Social-environmental	S1: Social Stability Risk	0.9276	0.8174	
	S2: Social Acceptance	0.9277		
	S3: Environmental Pressure Adaptability	0.9279		
Market	C1: Market Stability	0.9281	0.7749	
	C2: Market Responsiveness	0.9275		
	C3: Return Volatility	0.9279		
	C4: Market Regulation Intensity	0.9281		

From Table 11, it can be observed that Cronbach's α coefficients for all variables in the sample data were greater than 0.7, with some reliability coefficients exceeding 0.9. This indicates that the scale had good reliability and that the data obtained were highly reliable.

4.2.3. Validity Test

Validity testing refers to the extent to which the results obtained by using a scale or other assessment methods meet the expected goals. There are three types of validity: content validity, criterion validity, and construct validity. In this study, factor analysis was used to analyze the structural validity of the survey questionnaire. Generally, the Kaiser–Meyer–Olkin (KMO) measure should be greater than or equal to 0.5, and the Bartlett

test of sphericity should be significant for the sample data. The results of the KMO and Bartlett's sphericity test are shown in Table 12.

Table 12. Results of the validity test.

Latent Variable	KMO	Bartlett's Sphericity Test		
		Chi-Square	DF	*p*
Economic	0.870	1141.45	6	0.000
Technological	0.862	1126.65	6	0.000
Management	0.761	673.72	3	0.001
Political	0.760	687.35	3	0.000
Social–environmental	0.763	699.53	3	0.000
Market	0.848	991.09	6	0.000
Overall	0.955	6596.81	210	0.000

From Table 12, the total KMO value of the sample data was 0.955, which was greater than 0.8. The latent variables and the general significance test had significant *p*-values, indicating that the scale had a good general validity of the construct, and further research can be carried out.

4.3. Model Construction and Hypothesis Testing

4.3.1. Model Construction

On the basis of the research presented earlier, it can be observed that the data collected through surveys have undergone reliability and validity tests, indicating high reliability of the data, which meets the requirements for constructing a structural equation model. Building on the theoretical model and the measurement model constructed earlier, the structural equation model for this study is preliminarily constructed, as shown in Figure 3.

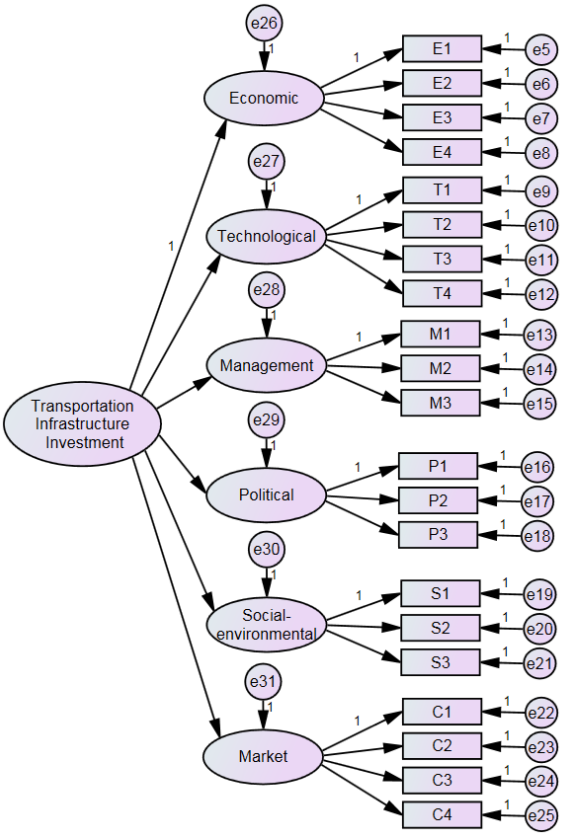

Figure 3. Model of structural equations.

4.3.2. Fitting of the First-Order Structural Equation Model

Building upon the structural equation model constructed earlier, this section will focus on studying the fitting of the first-order structural equation model to verify whether each measurement indicator can effectively explain its corresponding risk dimension. The first-order structural equation model for this study was drawn using AMOS 24.0 software. The data obtained from the questionnaire survey, consisting of 314 sets of data, were imported into the software for model fitting, and the coefficients of each path in the first-order structural equation model were obtained. The fitting results are shown in Figure 4.

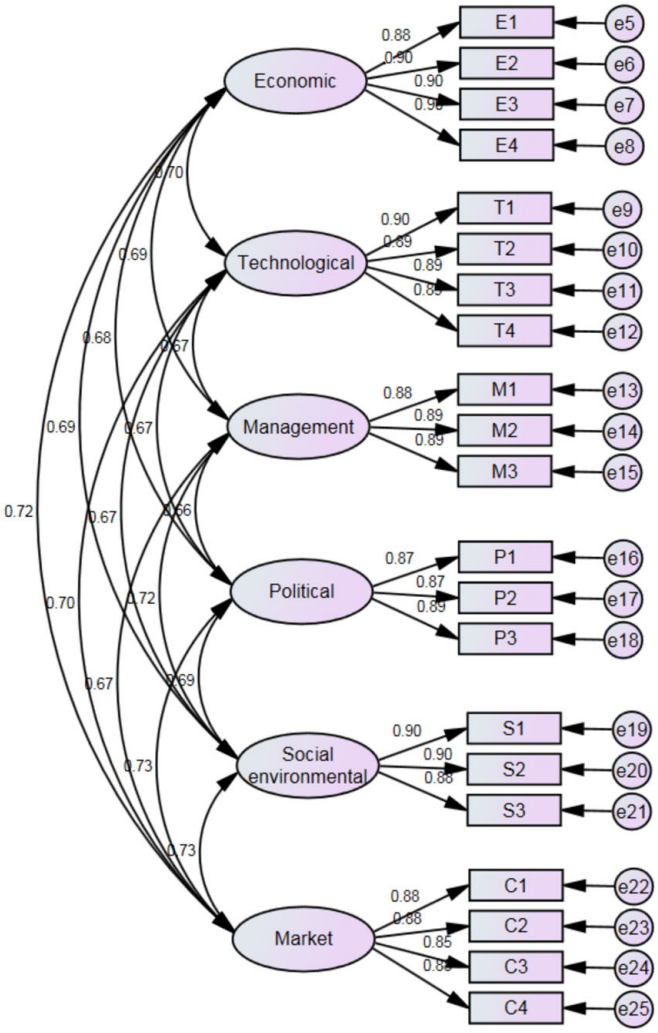

Figure 4. First-order structural equation model fitting result.

Figure 4 shows that the path coefficients between the error variables and the observed variables in the first-order structural equation model were not negative, and the error terms also did not have negative values, indicating compliance with the assumption of proper estimation. The covariance results of the latent variables in the first-order structural equation model are shown in Table 13.

In Table 13, it can be observed that the fit results for the standard error (SE) ranged from 0.124 to 0.141. The significance level (*p*-value) for the standard error was less than 0.001 for all variables. The factor loading coefficients between latent variables ranged from 0.656 to 0.734, indicating that the basic fit of the first-order structural equation model had passed the test. The general results of the fit of the first-order structural equation model are shown in Table 14.

Table 13. Covariance results of latent variables in the first-order structural equation model.

Path	Estimate	S.E	C.R.	*p*
Economic ↔ Technical	0.701	0.125	9.135	***
Economic ↔ Management	0.688	0.130	8.966	***
Economic ↔ Policy	0.681	0.125	8.842	***
Economic ↔ Social–Environmental	0.693	0.134	9.054	***
Economic ↔ Market	0.719	0.128	9.195	***
Technical ↔ Management	0.670	0.128	8.856	***
Technical ↔ Policy	0.672	0.124	8.799	***
Technical ↔ Social–Environmental	0.669	0.131	8.887	***
Technical ↔ Market	0.700	0.126	9.086	***
Management ↔ Policy	0.656	0.128	8.604	***
Management ↔ Social–Environmental	0.722	0.141	9.269	***
Management ↔ Market	0.674	0.130	8.817	***
Policy ↔ Social–Environmental	0.687	0.134	8.905	***
Policy ↔ Market	0.730	0.129	9.186	***
Social Environmental ↔ Market	0.734	0.138	9.34	***

***: $p < 0.001$.

Table 14. The first-order structural equation model fitness.

Indicator	Reference Range	Fitting Result	Model Fitness
X2/DF	≤3.00	1.311	Fit
GFI	≥0.90	0.938	Fit
RMR	≤0.05	0.047	Fit
RMSEA	≤0.08	0.032	Fit
AGFI	≥0.90	0.918	Fit
NFI	≥0.90	0.966	Fit
CFI	≥0.90	0.992	Fit
IFI	≥0.90	0.992	Fit
RFI	≥0.90	0.959	Fit
TLI	≥0.90	0.990	Fit

From Table 14, it can be concluded that all the fit indices of the first-order structural equation model met the requirements, indicating that the first-order structural equation model had passed the test and is the optimal model. Therefore, based on the first-order structural equation model, a second-order structural equation model can be constructed to further investigate the relationship between the first- and second-order latent variables.

4.3.3. Fitting of the Second-Order Structural Equation Model

To examine the relationships between the first-order latent variables and second-order latent variables, the second-order structural equation model was fitted. The results of the fitting of the second order structural equation model are shown in Figure 5.

The parameter estimation results of the second-order structural equation model are presented in Table 15.

Table 15. Parameter estimation results of the second-order structural equation model.

Path	Estimate	S.E	C.R.	*p*
Economic ← Transportation Infrastructure Investment	0.837			
Technical ← Transportation Infrastructure Investment	0.816	0.072	13.494	***
Market ← Transportation Infrastructure Investment	0.861	0.074	13.98	***
Social-environmental ← Transportation Infrastructure Investment	0.844	0.077	13.95	***
Policy ← Transportation Infrastructure Investment	0.822	0.074	13.2	***
Management ← Transportation Infrastructure Investment	0.815	0.075	13.348	***

Table 15. *Cont.*

Path	Estimate	S.E	C.R.	*p*
E1 ← Economic	0.881			
E2 ← Economic	0.899	0.043	23.31	***
E3 ← Economic	0.902	0.042	23.464	***
E4 ← Economic	0.905	0.045	23.671	***
T1 ← Technicalsssssssssss	0.893			
T2 ← Technical	0.881	0.044	22.925	***
T3 ← Technical	0.888	0.043	23.347	***
T4 ← Technical	0.913	0.043	24.907	***
M1 ← Management	0.892			
M2 ← Management	0.892	0.043	22.49	***
M3 ← Management	0.881	0.046	21.993	***
P1 ← Policy	0.869			
P2 ← Policy	0.914	0.047	22.516	***
P3 ← Policy	0.887	0.049	21.391	***
S1 ← Social-environmental	0.900			
S2 ← Social-environmental	0.897	0.042	23.497	***
S3 ← Social-environmental	0.883	0.042	22.754	***
C1 ← Market	0.879			
C2 ← Market	0.884	0.045	22.046	***
C3 ← Market	0.851	0.046	20.439	***
C4 ← Market	0.882	0.045	21.935	***

***: $p < 0.001$.

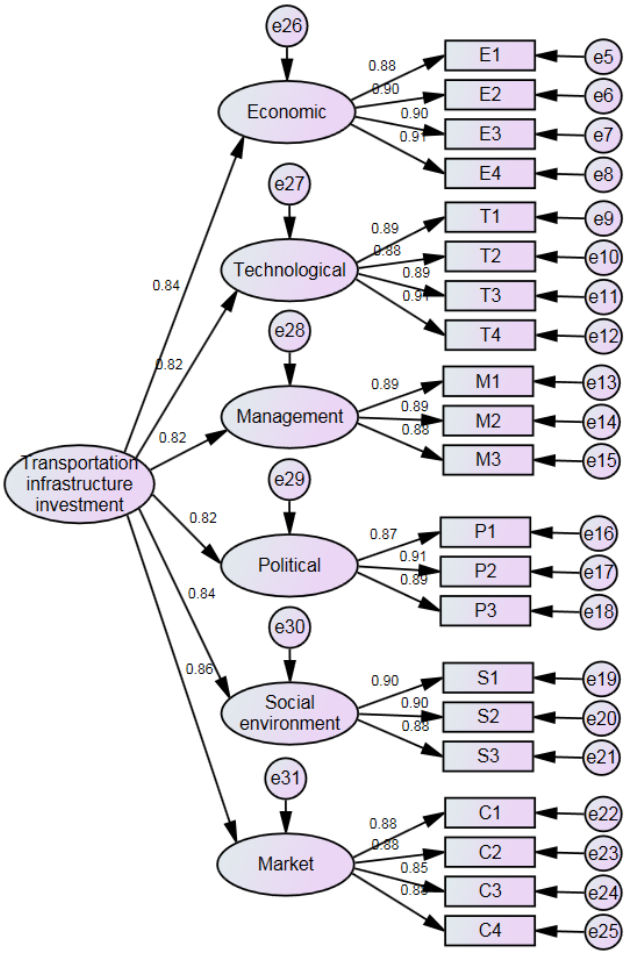

Figure 5. Fitting results of the second-order structural equation model.

From Table 15, it can be observed that all the first-order latent variables had significant positive effects on the second-order latent variable, with path coefficients exceeding 0.8. This indicates that these six risk dimensions had a strong explanatory power for infrastructure investment risk in transportation. The overall fit indices of the second-order model are presented in Table 16.

Table 16. Results of the second-order structural equation model fitness results.

Indicator	Reference Range	Fitting Result	Model Fitness
X2/DF	≤3.00	1.290	Fit
GFI	≥0.90	0.937	Fit
RMR	≤0.05	0.053	Fit
RMSEA	≤0.08	0.030	Fit
AGFI	≥0.90	0.920	Fit
NFI	≥0.90	0.965	Fit
CFI	≥0.90	0.992	Fit
IFI	≥0.90	0.992	Fit
RFI	≥0.90	0.960	Fit
TLI	≥0.90	0.991	Fit

From Table 16, it can be observed that the fit indices of the second-order structural equation model all met the standard criteria, indicating the significance of the model parameters. In general, these fit indices demonstrated a good fit between the model and the data, indicating that this study's transportation infrastructure investment risk assessment indicator system effectively reflects the actual situation of transportation infrastructure investment risk.

4.3.4. Hypothesis Testing

Based on the above research, it can be inferred that the research hypotheses proposed prior to model construction have been validated. The results of the hypothesis testing are shown in Table 17.

Table 17. The results of the hypothesis testing.

No.	Hypothesis	Result
H1	Economic risk has explanatory power over the risk of investment in transportation infrastructure investment risk	Pass
H2	Technical risk has explanatory power over the risk of investment in transportation infrastructure	Pass
H3	Management risk has explanatory power over the risk of investment in transportation infrastructure	Pass

Table 17. *Cont.*

No.	Hypothesis	Result
H4	Social–environmental risk has explanatory power over the risk of investment in transportation infrastructure	Pass
H5	Policy risk has explanatory power over the risk of investment in transportation infrastructure	Pass
H6	Market risk has explanatory power over the risk of investment in transportation infrastructure	Pass

5. Conclusions

This study constructs a risk assessment indicator system for investment in the transportation infrastructure investment projects in the public–private partnership (PPP) mode

employing principal component analysis (PCA) and the CRITIC-EWM method. Addresses the shortcomings of existing research in terms of dynamism, systematicity, and methodological application. Research findings demonstrate that the comprehensive use of the PCA and CRITIC-EWM methods can effectively reduce the dimensions of risk indicators and calculate the weights of each indicator, providing a scientific and systematic assessment tool for the management of risk of transportation infrastructure projects. Through empirical testing, the effectiveness and reliability of the constructed indicator system are validated, providing new theoretical and practical guidance for the risk assessment of transportation infrastructure investment projects in the PPP mode. The conclusions of this study are as follows:

1. This study successfully constructs an assessment indicator system containing multidimensional risk factors that can comprehensively reflect the risk status of transportation infrastructure investment projects in the PPP mode;
2. By integrating the PCA and CRITIC-EWM methods, this study proposes a new method to build a risk assessment indicator system, improving the precision and practicality of risk assessment;
3. The effectiveness of the constructed indicator system is tested using empirical data, verifying its application value in practical PPP project risk assessment.

Based on the above research results, this study proposes the following practical application recommendations for risk management in transportation infrastructure investment projects:

1. The risk assessment indicator system constructed in this study can serve as a reference tool for both government and private sectors in project decision-making and risk management, optimizing resource allocation and risk-sharing strategies;
2. Establish a dynamic risk monitoring and assessment mechanism, regularly updating risk assessment indicators and their weights to adapt to changes during the project implementation process and in the external environment;
3. Establish effective communication and coordination mechanisms among stakeholders to share risk information and collaboratively manage risks, enhancing project management transparency and synergy, thereby increasing the success rate of PPP projects.

Although this study has made certain achievements in constructing a risk assessment indicator system for transportation infrastructure investment projects under the PPP model, there are still some limitations:

1. The empirical analysis in this study primarily relies on historical data from completed projects. The availability and quality of these data may affect the accuracy and generalizability of the research conclusions;
2. While the PCA and CRITIC-EWM methods performed well in this study, their applicability may vary across different types of PPP projects, requiring further validation and optimization in the future;
3. Although efforts were made to ensure the representativeness of the sample, the sample may still not fully represent all types and regions of transportation infrastructure investment projects due to limitations in data sources.

To further enhance the depth and breadth of the research, future studies can focus on the following areas:

1. Future research can further explore the applicability and reliability of the indicator system across different types and regions of the PPP projects.
2. Investigate how to integrate other methods (such as Bayesian networks and machine learning) to optimize the risk assessment indicator system, improving the accuracy and flexibility of risk prediction.
3. Consider the real-time and dynamic nature of data, further studying how to achieve real-time monitoring and dynamic adjustment of risk assessment through big data and artificial intelligence technologies.

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Riesgo: A Knowledge-Based Qualitative Risk Assessment System for PPP Projects

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Abstract: A successful public-private partnership (PPP) relies heavily on effective risk assessment, given the intricate risk factors and contractual arrangements involved. While quantitative risk assessment methods have received significant attention in the PPP literature, qualitative risk assessment, the sector's predominant preference, remains underexplored, causing a low level of applicability of academic studies and indicating a noticeable research gap. A qualitative risk assessment tool prototype, Riesgo, is developed in this paper as a customizable, knowledge-based digital risk register incorporating a pre-defined template that guides users using PPP risk factors, compensation and mitigation options, project information requirements, and risk register items. This paper presents the proposed system architecture, explains the research steps adopted in determining the system elements, and delineates the system functions through a use case developed to illustrate the process and information flows. The prototype was verified by 13 PPP experts who employed it for risk assessment, and their feedback was utilized for further development. A validation survey of 21 professionals affirmed Riesgo's usability and applicability in the industry. The customizable and knowledge-based prototype has the potential to streamline effective risk assessment and guide the users across various PPP phases, such as early risk assessment, feasibility studies, contract preparation, and monitoring.

Keywords: public-private partnership; PPP; risk assessment; risk management; risk factors; risk register

1. Introduction

A public-private partnership (PPP) is a contract established between public and private parties, wherein the project is financed and delivered for public services through a capital asset by the private party (OECD, 2022) [1]. The public party can be a government entity such as a ministry, municipality, or state-owned enterprise, and the private party may be a company possessing technical expertise and investment capacity to achieve project execution (Felsinger, 2008) [2]. Common features of PPP projects, such as including many stakeholders with different goals, complicated contracts between parties, long project durations, and broad project scopes, increase the risks in PPP projects (Kuru and Artan, 2020) [3]. For the successful completion of PPPs, the crucial task is to ensure that these risks are adequately assessed and transferred to the party capable of managing them most effectively (OECD, 2012) [4]. The risk management standard ISO 31000 (2009) [5] depicts risk assessment as the combination of processes involving risk identification, analysis, and evaluation, which is a frequently examined topic in the PPP literature (Osei-Kyei, 2023) [6]. The academic interest in this area arises from the industry's experiences with negative impacts of risks. The Suez Canal Project, recognized as the first build–operate–transfer PPP project in the modern world (Levy, 1996) [7], encountered a substantial cost overrun of 1900%, and factors such as the inherently risky structure of the PPP and misinformation about the risks were cited as causes of this adverse impact (Flyvbjerg, 2014) [8]. Similar issues are extensively reported in the literature, for instance, Li and Wang (2023) [9] empirically demonstrated that inflation risk significantly influences project failures. Castelblanco et al.

(2023) [10] highlighted the intricate correlation between the project risk profile and the concession period, revealing that risk assessment is critical for PPPs.

Following the identification of risks, qualitative or quantitative tools and techniques are employed for risk assessment in PPP projects. Various models have been proposed in prior studies, the majority of which predominantly incorporate quantitative methods. A risk assessment framework for PPP megaprojects using structural equation modeling was developed by Ahmadabadi and Heravi (2019) [11]. Liu and Sun (2020) [12] presented a PPP risk assessment method based on the improved matter element model. Moradi Shahdadi et al. (2023) [13] utilized the measurement alternatives and ranking according to the compromise solution (MARCOS) technique to evaluate risk factors in water and wastewater PPPs in Iran. Wang et al. (2023) [14] established a best–worst multi-criteria decision-making and comprehensive fuzzy evaluation model for optimizing risk assessment in waste recycling PPPs. Nevertheless, it is expressed by the World Bank (2017) [15] that implementing agencies typically prefer to apply qualitative techniques and tools for risk assessment during PPP appraisal in the industry. For this purpose, risk matrices and risk registers are utilized to assess and allocate PPP risks (World Bank, 2008; Global Infrastructure Hub, 2019) [16,17]. Qualitative risk assessment requires an extensive collection of information regarding PPP project risks. However, as the risk matrices and risk registers used in the current practice utilize limited information as input, misinterpretation issues and improper risk allocation are very common due to insufficient information or unavailable critical details regarding PPP projects (Tariq and Zhang, 2020) [18]. Hence, for adequate risk management, it is necessary to determine the critical information items and assessment requirements for PPP risks and incorporate these into a more comprehensive risk register model. Moreover, the current risk matrices and registers are standardized documents that are unsuitable for customization based on project requirements. The customization of risk assessment to the specific attributes of projects in the PPP sector is recommended by the Global Infrastructure Hub (2019) [16]. However, the risk matrix provided by the Global Infrastructure Hub (2019) [16] also adheres to a standard structure, and practical revision of this matrix according to the needs of a particular PPP project is not feasible. The PPP risk assessment process in different project phases can be enriched by a customizable risk register, offering users additional functions and more comprehensive utilization of project information.

The relationship between risk registers, risk matrices, and contracts is emphasized in the literature. Farquharson et al. (2011) [19] express that the recording of risk assignments, which will be implemented in the PPP contract, can be accomplished using risk registers and matrices. This contributes to clarifying any aspect related to risks in the contract, and an agreement is reached among the parties regarding actions to be taken for the risks. The connection between the contract and risks is also underscored by the World Bank (2017) [15] suggesting that the determined risk allocation should be incorporated into the PPP contract by enhancing it with additional information. The importance of practical risk assessment models for successful PPP contract formation and implementations is also emphasized by previous researchers (Xu et al., 2010; Chan et al., 2011) [20,21]. However, despite the sector's predominant preference for qualitative and expedient solutions, the tools and techniques explored in prior studies are mostly quantitative, and a comprehensive digital risk register tool for PPP risk assessment is lacking in the literature. As a result of this neglect in the current studies of the needs of the PPP sector, the level of transition of academic studies to the industry is deemed low. Bruneel et al. (2010) [22] state that a lack of understanding of working practices and sectoral expectations acts as a barrier to the practical applicability of academic research. Furthermore, the complexity of the quantitative risk assessment models developed in the literature hinders their usability by PPP professionals (Chan et al., 2011) [20]. As the result of their systematic literature review, Rasheed et al. (2022) [23] stated that despite the proliferation of quantitative risk management models in the PPP literature, qualitative methods are preferred in practice, and that the development of practical knowledge-based models that can guide users through the

PPP risk assessment process is essential to overcome this problem. Jiang et al. (2023) [24] also underlined the need for adequate information management for the assessment of PPP risks. The main shortcomings in PPP risk assessment identified as a result of the presented review include (1) the current tools utilize very limited information and lack customization, (2) the complexity of the existing risk assessment models lack a knowledge base and practical guidance, and (3) academic studies are mainly grounded in quantitative or semi-quantitative approaches, despite the sector's needs for qualitative tools.

This study aims to present a qualitative risk assessment tool prototype, Riesgo, which is a digital model designed to advance the risk assessment practices in PPP projects. Addressing critical deficiencies highlighted in the current models, Riesgo offers a customizable, knowledge-based qualitative risk assessment system explicitly tailored for PPPs. By rectifying shortcomings such as limited information utilization, lack of customization, and the absence of practical solutions based on sectoral needs, Riesgo aims to bridge the gap between theoretical PPP risk assessment models and real-world applications. By guiding PPP professionals in the utilization of the required PPP information and risk register items, the proposed prototype enhances information management in PPP projects. Moreover, by providing knowledge of PPP risk factors, as well as compensation and mitigation options to manage these risks, Riesgo offers the users practical solutions to support the risk assessment process. Riesgo is developed to be used by the public party and its consultants in various project phases, with the objectives of (1) assessing project risks during the early phases of the project, (2) assessing the risks that will be addressed in the contract, (3) assessing the risks inherent the contracts before project commencement, and (4) monitoring project risks throughout the construction and operation stages in ongoing projects. As the model includes information items applicable to all types of PPPs, regardless of project location, it was developed with a generic approach targeting all PPP projects. The processes detailed in this paper include (1) identifying risk register items and system requirements for the prototype, (2) developing of the system architecture by incorporating PPP risk factors, PPP information requirements, risk register items, and system functions into the model, and (3) conducting verification and validation processes for the prototype.

2. Literature Review

2.1. Previous Studies on PPP Risk Assessment and the Literature Gap

The bibliometric analysis of the PPP literature reveals that risk assessment ranks among the top ten keywords noted, based on occurrence frequency (Azarian et al., 2023) [25]. Numerous studies focus on PPP risk assessment using diverse scopes and techniques. Regarding scope, some studies concentrate solely on assessing specific risk factors, without presenting a model encompassing the entirety of the project's risks. Liu et al. (2017) [26] presented a framework for the assessment of revenue risk in PPPs. The performance risk of PPPs was the focus of Chen et al. (2020) [27], who integrated structural equation modeling and fuzzy cognitive mapping. Liu et al. (2021) [28] utilized Bayesian Network calculations to assess the construction risks in urban rail transit PPPs in China. Alasad and Motawa (2015) [29] developed a system dynamics model for assessing demand risk in PPP road projects. Sun et al. (2023) [30] assessed the investment risk of urban rail transit PPPs using the system dynamics approach. On the other hand, the three types of techniques used in the risk assessment literature include qualitative, quantitative, or semi-quantitative approaches (Chinyio, 2003) [31], and numerous models have been developed in the literature using these approaches. Monte Carlo simulation is often employed as a quantitative approach in financial risk assessment models (Kumar et al., 2018) [32]. Quantitative risk assessment models are widely utilized in the calculation and assessment of various values or formulas (e.g., demand guarantees/volume thresholds, tariff indexation) included in the PPP contracts (ADB et al., 2016) [33]. However, PPP contracts also contain complicated verbal details concerning the qualitative aspects of the projects, which may be overlooked in the quantitative models. Therefore, using solely quantitative models may not be sufficient to conduct a comprehensive risk assessment and comprehend generic

project risks, and they are better suited as contributory tools. As the second approach, semi-quantitative studies incorporate linguistic statements, yet they lean towards a more mathematical perspective (Xu et al., 2012, Wu et al., 2018, Niazmandi et al. 2024) [34–36]. Niazmandi et al. (2024) [34] proposed a PPP risk and productivity assessment model by using a fuzzy interference system. Another example is the risk assessment model developed by Xu et al. (2012) [36]. The Delphi survey and the fuzzy set theory were preferred for the weighting and membership functions of the risk factors, and fuzzy synthetic evaluation was then applied. Thus, both the qualitative and quantitative steps are encompassed. However, PPP professionals' unfamiliarity with the techniques employed in semi-quantitative studies hinders the practical application of these models in the industry (Chan et al., 2011) [20].

The third and final approach involves the qualitative technique. The recent studies employing qualitative research primarily involve probability and impact-based risk assessment and ranking studies (Ameyaw and Chan, 2015; Osei-Kyei and Chan, 2017; Kukah et al., 2024) [37–39]. Ranking the risks aids in identifying the most significant project risks, allowing PPP professionals to focus more on these critical areas. However, conducting risk analysis using solely probability and impact assessment may result in overlooking noteworthy information regarding risks in PPPs. For instance, the unprecedented stress of the COVID-19 pandemic on PPPs presented challenges. While it was anticipated that contractual provisions related to force majeure could be linked to the pandemic risk, further uncertainties concerning the applicability of this provision were encountered in practice (Casady and Baxter, 2020) [40]. In such circumstances, the assessment remains incomplete if the force majeure risk is evaluated solely through probability-impact assessment and lacks enrichment with more qualitative information. Further qualitative analysis is needed to assess the conditions required for the pandemic risk to fall within the scope of the force majeure risk and to determine the compensation mechanisms that can be applied in the case of a pandemic. Ward (1999) [41] and Taroun, (2014) [42] also underlined the inadequacy of probability and impact-based assessment processes for a comprehensive qualitative risk evaluation.

In addition to academic studies; various models, tools, and techniques are also developed for risk assessment in the industry. For example, a quantitative fiscal risk assessment model known as PFRAM was presented by the IMF and World Bank Group (2022) [43]. PFRAM is an Excel-based fiscal model designed for use by public authorities, such as PPP units and public corporations. The World Bank (2008) [17] offers a qualitative tool in the form of a risk matrix, serving as a risk assessment and allocation tool. This matrix encompasses information on risk groups, risk descriptions, cost drivers, risk allocation, and treatment recommendations. Similarly, the Global Infrastructure Hub (2019) [16] developed risk matrices for PPPs that include risk factors, preferred risk allocation, mitigation measures, actions, and recommendations based on the type of market in which the project is conducted. Omurzakova (2022) [44] suggests that a risk matrix can be employed during project assessment to determine risk significance, relationship, and priority. Another qualitative tool is the risk register, as emphasized by Williams (1994) [45], who states that the risk register functions as an information repository and usually contains more fields for recording information when compared to a risk matrix. Due to its simplicity, the risk register is often preferred in various sectors. For instance, the risk register used by the U.S. Department of Transportation is the agency's most commonly employed risk management tool (Curtis and FHWA, 2012) [46]. Farquharson et al. (2011) [19] recommend continuous review and monitoring of PPP risks with the assistance of risk registers and risk matrices developed during the project preparation. Since PPPs typically have long durations, the risk registers and matrices allow for their ongoing review and update during the project (O'Har et al., 2017) [47].

Despite their suitability for PPPs, there are crucial areas for improvement in PPP risk registers and matrices. Firstly, these tools often include only standard items (e.g., risk description, compensation, mitigation). There is a potential to enhance the items regarding risk registers and collect more detailed information about the risks. Secondly, despite the need to develop such tools for PPPs, the topic has not been extensively studied in academic literature. A search on the Scopus database for "Search Within the Article Title: public-private partnership" and "Search Within All Fields: register" and "Search Within the Abstract: risk assessment" returns only one study for PPPs (Mazher et al., 2018) [48]. Moreover, in this study, the term "register" refers only to the "list of risk factors" and does not include a qualitative assessment tool. It is evident that PPP risk assessment based on the risk register approach has been neglected. This identified gap in both the literature and industry emphasizes the need for a comprehensive qualitative risk assessment tool based on the detailed risk register approach. Therefore, there is a need for a (1) qualitative, (2) knowledge-based, and (3) customizable risk assessment tool developed with the risk register/matrix approach. It is anticipated that a model developed in line with this approach would exhibit greater industry applicability compared to those found in other studies in the literature.

2.2. Risk Register Items in the Literature and System Functions Used in the Previous Tools

In the scope of developing a digital qualitative risk assessment system prototype, the risk register items and system functions were determined. The term "risk register item" is used to describe the information that can be held and stored in a risk register (Ward, 1999; Patterson and Neailey, 2002) [41,49]. A literature review was undertaken to identify the risk register items to be used in the prototype. System functions were determined based on the analysis of previous tools developed for risk assessment in various domains.

During the determination of risk register items, a query was executed for the term "risk register" and "public-private partnership" in the abstract, resulting in only three relevant results (Ke et al., 2010; Mazher et al., 2018; Erfani et al., 2021) [48,50,51] in the Scopus database. In these studies, the term was used to refer to a list of risk factors, but they did not provide detailed sample risk registers or typical items found in registers, rendering them unsuitable for this research. Subsequently, the search was broadened to include sources regarding risk registers, without specifying the "public-private partnership" keyword. This choice was made on the premise that items in risk registers used in other sectors can also be applicable in PPP registers. A query was also made for the risk matrix term. Filtering "risk matrix" and "public-private partnership" in the abstract resulted in eight articles meeting these criteria. While half of these studies used the term "risk matrix" in the context of this paper, they did not provide sample risk matrices or information about the items in a typical risk matrix. Consequently, instead of academic studies, the review primarily considered sectoral documents from sources such as the NDFA (2007), the World Bank (2008), and the Global Infrastructure Hub (2019) for insights into risk matrices [16,17,52]. Since risk matrices generally contain fewer items than risk registers, and their items are more standardized, the number of references for determining risk matrices was relatively low compared to the references reviewed for risk register items. The risk register items and their references are presented in Table 1. References 1 to 13 come from studies related to risk registers, while the remaining references (14 to 18) pertain to risk matrices. The references included in the table contain a risk register/risk matrix or comprise the items that can be seen in a risk register or risk matrix. The table contains both PPP-related references and references from outside the PPP literature. This is due to the scarcity of studies on the risk registers within the PPP field, necessitating the exploration of studies in other construction or project management domains (Dunovic et al., 2013; Patterson and Neailey, 2002) [49,53].

Table 1. Risk register items found in the literature.

	Risk Register-Based Studies													Risk Matrix Based Studies				
Risk Register Items	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Risk ID		■	■	■	■	■	■	■	■			■			■		■	
Risk contract clause ID															■			
Category (Type)						■			■			■		■	■	■	■	■
Project phase			■		■													
Description	■	■	■	■	■	■	■	■	■	■	■	■			■	■		
Probability score	■	■	■	■	■	■	■	■		■		■	■				■	
Impact score	■	■	■	■	■	■	■	■		■		■	■					
Probability x Impact		■	■	■					■	■			■					
Impact type		■	■	■	■	■												
Risk cost impact	■	■	■	■	■												■	
Risk time impact	■	■	■	■	■													
Strategy					■	■						■	■					
Allocation	■	■			■						■	■	■	■	■	■	■	■
Risk owner	■	■	■		■		■					■						
Mitigation/Prevention			■			■	■	■	■		■		■			■		■
Compensation																■		■
Causal risk (cause, source)		■			■	■				■				■				
Consequential risk					■													
Residual risk		■			■													
Secondary risk	■				■													
Author					■							■						
Risk entry date			■		■		■					■						
Risk revision date							■											
Risk status			■		■							■						

(1) Williams (1994) [45]; (2) Ward (1999) [41]; (3) Patterson and Neailey (2002) [49]; (4) Sillars and O'Connor (2009) [54]; (5) Dunovic et al. (2013) [53]; (6) Govan and Damnjanovic (2016) [55]; (7) Leva et al. (2017) [56]; (8) Ou-Yang and Chen (2017) [57]; (9) Ahmad et al. (2018) [58]; (10) Castro-Nova et al. (2018) [59]; (11) Hossain et al. (2018) [60]; (12) Richards (2018) [61]; (13) PMI (2021) [62]; (14) Grimsey and Lewis (2004) [63]; (15) National Development Finance Agency NDFA (2007) [52]; (16) World Bank (2008) [17]; (17) Fantozzi et al. (2014) [64]; (18) Global Infrastructure Hub (2019) [16]. Colored fields represent the presence of the risk register item in the related reference.

Some references listed in Table 1 contain a risk register that aligns with the objectives of the research. Govan and Damnjanovic (2016) [55] conducted a case study on a compressor station and pipeline project, and they presented the risk register used in their research. Ahmad et al. (2018) [58] explored the impact of building information modeling on risk management, providing a post-BIM-based risk register of the project. Ou-Yang and Chen (2017) [57] identified and analyzed risks in a petrochemical plant project in Taiwan, presenting their risk register findings. On the other hand, some of the other studies in Table 1 discussed the concept of risk registers, but did not present a risk register for a specific project. Ward (1999) [41] investigated the role of risk registers in risk assessment. Williams (1994) [45] devised an integrated risk management scheme centered around the register approach. Dunovic et al. (2013) [53], Patterson and Neailey (2002) [49], and O'Har et al. (2017) [34] studied risk register development. In addition to the risk register-based references, Table 1 also consists of risk matrix-related references, and all those references contain risk matrices in varying degrees of detail. While Fantozzi et al. (2014) [64] used a small risk matrix to assess the risks they studied, the Global Infrastructure Hub (2019) [16] presented a more detailed risk matrix that can be used during the risk assessment of PPPs.

All items in Table 1 were incorporated into the risk register in the proposed prototype, without applying a criterion based on the frequency of occurrence, since all these items contain information useful for PPP project risk assessment. Even though "project phase" is mentioned in only two references, it was included in the prototype's register because

it allows users to classify and filter risks based on the project phase. To illustrate, in a PPP project with numerous risk factors, PPP professionals may prefer to view risks in the construction phase, and the inclusion of the project phase item on the risk register can facilitate filtering the related risks. Another example is the "consequential risk". Although it was mentioned in only one reference, it can aid in defining the consequences of a PPP risk factor, facilitating a more efficient interpretation of risk factors, and establishing connections to the contract.

Table 2 presents the system functions utilized in previous risk management software tools. The list of software reviewed for the determination of system functions in the proposed prototype is given in Supplementary Material A. The software systems featured in Table 2 were not chosen from those specifically developed for PPPs, as no specialized software for PPP risk assessment was identified in the academic databases and search engines. Therefore, risk assessment software systems developed in other domains were analyzed to select functions suitable for qualitative risk assessment in PPPs. The software models that featured supporting materials on their websites and possessed at least three functions suitable for risk assessment were added to Table 2, and the system functions requirements table was compiled using 28 software systems. These software systems encompass various scopes and functions, all focused on the management and assessment of risks. The table highlights that heat maps, registers, and visualization features are commonly integrated into most risk management systems. While certain systems like A1 Tracker [65] and Execview [66] primarily offer basic risk assessment functions, others include additional features such as the Risk Hierarchy function in the Apertisoft [67] and SAP Risk Management [68], or the Filters function in Project Risk Manager [69]. Apart from system functions that can be comprehended easily by many users, some systems also incorporate advanced features that may necessitate greater user expertise and knowledge. For instance, Palisade @Risk [70] and Risky Project Professional [71] include functions like Monte Carlo simulation and sensitivity analysis.

Table 2. System functions used in the previous tools.

System Functions	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12	S 13	S 14	S 15	S 16	S 17	S 18	S 19	S 20	S 21	S 22	S 23	S 24	S 25	S 26	S 27	S 28
Templates *													■					■										
Risk Hierarchy *				■											■										■			
Risk Search *						■	■									■		■					■					
Filters *						■	■		■	■			■							■		■		■				■
Risk Register *	■		■	■			■	■		■			■	■	■	■		■	■		■	■	■	■		■		■
Risk Matrix (Heat Map) *	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■		■	■	■	■
Risk Visualization *	■	■	■	■			■	■			■		■			■	■	■			■	■		■	■		■	
Risk Ranking *				■			■				■									■				■				
Relationship Diagram *																											■	
Document Library *					■					■						■			■	■								
Export Options *			■	■		■				■			■			■		■	■	■	■					■	■	
Bow-Tie Method			■								■											■			■			
Monte Carlo Simulation	■		■	■											■										■			
Sensitivity Analysis	■														■													
Scenario Analysis	■																				■				■			
Stress Test	■																											
Efficient Frontier Analysis	■																											
Genetich Algorithm	■																											
MS Project Integration															■													
Reviewed systems	(S1) Palisade @Risk [70]; (S2) A1 Tracker [65]; (S3) Active Risk Manager [72]; (S4) Aperitisoft [67]; (S5) Aptien [73]; (S6) Auditboard [74]; (S7) Auditcomply [75]; (S8) Barnowl [76]; (S9) Corporater [77]; (S10) Decision Time [78]; (S11) ERM Essential [79]; (S12) Execview [66]; (S13) Goat [16]; (S14) Hyperproof [80]; (S15) Risky Project Professional [71]; (S16) iRisk [81]; (S17) JCAD Core [82]; (S18) Logic Manager [83]; (S19) Mango [84]; (S20) nTask Manager [85]; (S21) Optial Smart [86]; (S22) Omega 365 Pims Risk Management [87]; (S23) Pirani Riskment Suite [88]; (S24) Project Risk Manager [69]; (S25) SAP Risk Management [68]; (S26) Sectera [89]; (S27) Symbiant [90]; (S28) Dmaze [91].																											

* System functions that are integrated into the proposed prototype. Colored fields represent the presence of the system function in the reviewed system

The system functions selected for the proposed model are highlighted in bold in Table 2. The selection of these functions is based on their expected contributions to the model. The integration of the "templates" feature allows users to utilize a specific pre-established PPP template with predefined risk factors. The "risk hierarchy" facilitates

the easy visualization of project risks within distinct risk groups through a structured hierarchical format. The inclusion of "risk search" and "filters" aims to simplify the finding of searched risks within PPP projects that involve numerous intricate risk factors. Given that the primary objective of the model is to assess project risks, the "risk register" function is chosen to retain the risk information. The "risk matrix (heat map)" and "risk ranking" functions demonstrate the distribution and ranking of risks based on their importance. A "relationship diagram" is integrated into the prototype to aid in understanding risk relations. A "document library" is included to store documents related to the project, and "export options" are added to provide users with Excel and PDF outputs based on the data entered into the model. All these functions are suitable for the qualitative assessment of PPP risks, given that PPP risks often involve many details, and these functions empower users to define and manage those details with ease. Hence, these functions are integrated into the developed qualitative risk assessment prototype. While the bow-tie method is also ideal for qualitative assessment, it was omitted from the prototype since the relationship diagram serves a similar function. The remaining system functions in Table 2, such as Monte Carlo simulation and sensitivity analysis, are suitable for quantitative analysis; hence, they were not included in the prototype. The selection of system functions was validated via interviews conducted with PPP experts, and the validation process is detailed in Section 6.

3. Methodology

The risk assessment prototype system was developed through a research process comprising three steps: (1) the determination of PPP risk factors that must be analyzed by the public party, (2) the determination of the information requirements for risk assessment by the public party in PPPs, and (3) the determination of risk register items and system functions, the development of the prototype, and validation and verification (Table 3).

In the first step of the research, which was previously presented by Authors [92], PPP risk factors that must be analyzed by the public party in PPPs were identified. Initially, the literature was reviewed by examining academic journals, books, and sectoral documents [16,21,37,39,94–104]. The risks were categorized in the PPP risk factors draft list, and a Delphi study was conducted involving 13 experts from the PPP sector for validation. The experts, specializing in assessing PPP risks for the public party, were lawyers, each possessing at least five years of experience regarding PPPs, with a minimum of three PPP project experiences. The group's average PPP experience duration exceeded 12 years, and the average PPP project count per person surpassed 17 projects (Supplementary Material E). Based on the Delphi results, certain risk factors were excluded from the draft list, and the remaining components were consolidated under the validated risk factors list as the outcome of the first step (Supplementary Material B). The identified PPP risk factors are utilized in the proposed prototype in this paper.

Table 3. Methodology.

Research Step	Activity	Method	Input	Output
Step 1—Presented by Authors [92]	Determination of PPP risk factors that must be analyzed by the public party	Structured literature review	Academic journals, books, sectoral documents	Validated PPP Risk Factors List (Supplementary Material B)
		Validation of the risk factors by the Delphi method using 13 experts	Expert input	
Step 2—Presented by Authors [93]	Determination of PPP information requirements for the public party	Literature review	Academic journals, books, sectoral documents	Validated PPP Project Information Requirements List (Supplementary Material C) Validated PPP Financial Information Requirements List (Supplementary Material D)
		Validation of the requirements by Delphi method using 12 experts	Expert input	
Step 3 (Current paper)	Determination of the risk register items	Literature review	Academic journals, books, sectoral documents	Risk Register Items Table (Table 1)
	Determination of the risk software functions	Review of the risk software used in the industry	Sectoral software	Risk Software's Functions Table (Table 2)
	Development of the system architecture and GUI design	Use case	Validated PPP Risk Factors List Validated Project Information Requirements List Validated PPP Financial Information Requirements List Risk Register Items Table Risk Software's Functions Table	Draft GUI design
	Development of the prototype	Microsoft Winform App, C# Language, Devexpress component	Draft GUI design	Prototype
	Testing the prototype	User acceptance tests	Prototype	Bug reports
	Verification	Use of the software by 13 PPP professionals and subsequent feedback collection	Semi-structured interviews	User feedback
	Validation	Via usability questionnaire administered to 21 users	1–5 Likert usability survey	Average usability scores

The second step, as presented by Authors [93], involved determining PPP information requirements for the public party. The term "requirements", described by PMI (2016) [105] as "conditions or capabilities necessary in a product, service, or result", was used to emphasize the role of requirements in meeting contractual obligations. In this context, information requirements refer to the information that can be recorded or collected regarding the project, contract, and project risks, and that can be used in assessing and monitoring project details and risks. A methodology similar to Step 1 was employed. Initially, a literature review was conducted to identify PPP information requirements, which were then categorized into two groups. The qualitative requirements acquired from the literature [33,61,62,103,106–114] were labeled "project information requirements", while the quantitative factors obtained from [43,63,107,115–117], focusing on the project finance aspect of PPPs, were named "financial information requirements". Subsequently, a Delphi study, involving 12 experts from the PPP sector, was conducted to validate these draft requirements. These experts were different from those in Step 1, but the criteria for selecting them remained the same. The experts were lawyers specializing in assessing PPP risks for the public party, each with a minimum of five years of experience in PPPs and at least three PPP project experiences. The average PPP experience within this group exceeded 11 years, and the average PPP project count per person surpassed 14 projects (Supplementary Material F). Following the Delphi process, some project information requirements and financial information requirements were excluded from the draft lists and the remaining were consolidated into the validated information requirements and financial information requirements list as the outcome of the second step (Supplementary Material C and D). In this paper, the identified project and financial information requirements are utilized in the proposed prototype.

The third step presented in this paper involves the development of the system architecture, as well as the research steps adopted in determining the system elements (i.e., risk register items, system functions, and graphical user interfaces (GUIs)) and delineates the proposed risk assessment process through a use case developed to illustrate the utilization of the prototype. Verification and validation of the proposed prototype by the PPP experts were also undertaken in this step.

Qualitative risk assessment methodology is adopted in the development of the proposed risk assessment process. Academic studies often employ quantitative or semi-quantitative methodologies for PPP risk assessment. Qualitative risk assessment, the sector's predominant preference (World Bank, 2017) [15], remains underexplored, causing a low level of applicability of academic studies and indicating a noticeable research gap (Rasheed et al., 2022; Jiang et al., 2023) [23,24]. On the other hand, tools used in practice encompass both qualitative and quantitative methods, yet none have been tailored to meet the needs of PPP projects. The proposed prototype, Riesgo, stands out not only by responding to the specific needs of PPPs through its qualitative risk assessment methodology but also by utilizing a knowledge-based approach. The risk register featured in the proposed prototype offers comprehensive information for PPP practitioners. The pre-populated template encompasses PPP risk factors, required information items for risk assessment, comprehensive risk explanations, compensation details, and mitigation recommendations for the identified risks. Moreover, Riesgo is suitable for all PPPs, regardless of contract type, location, or other variables via the customizable structure adopted in its development.

The third step commenced with identifying items typically found in a risk register. A comprehensive literature review was conducted to define the risk register items. Initially, studies related to risk registers and risk matrices for PPPs were reviewed. However, due to the lack of studies for risk registers in the PPP field, studies on the risk registers in the construction and project management field were also reviewed. The identified items for both risk matrices and risk registers are presented in Table 1.

After the identification of risk register items, the next step was the identification of system functions. The prototype's system functions were determined based on a review conducted on a sectoral software website called Capterra (Capterra, 2023) [118]. Capterra is a digital platform that compiles software listings across various fields and facilitates

connections between software vendors and users. The platform offers numerous software options based on selected expertise fields, and filter options are available to find suitable software for various domains. Employing risk management and risk assessment filters, over 300 software options were initially listed. In the process of determining system functions, the websites of the software models were scrutinized. Software models lacking explanatory documents or demo videos showcasing system functions on their websites were excluded. The system functions integrated into the prototype can be seen in Table 2.

After the determination of risk register items and software functions, the subsequent step involved the design of system architecture and graphical user interfaces (GUIs). A use case was developed to illustrate the proposed PPP risk assessment process, and accordingly, digital design software was employed for creating the GUIs (Section 5.2). The validated PPP risk factors list (Supplementary Material B), project information requirements list (Supplementary Material C), financial information requirement list (Supplementary Material D), risk register items (Table 1), and system functions (Table 2) were utilized in designing the algorithm and GUIs. Draft designs were generated, and consequently, the prototype development process was initiated. The prototype was developed as desktop software using the C# language and incorporating Devexpress components.

Upon the completion of the development phase, the researchers conducted user acceptance tests (UAT) to identify any encountered system bugs. These bugs were categorized based on their priority levels. While some bugs were straightforward and related to design aspects, others pertained to the technical facets of the prototype. Bugs influencing more than one prototype module were deemed more critical and were addressed with high priority. After resolving all reported bugs, the system underwent further scrutiny, signifying the comprehensive completion of both the development and testing phases.

For the verification of the developed prototype, semi-structured interviews were conducted with professionals possessing expertise in PPPs, contracts, and project risks. During these interviews, a detailed presentation elucidating the software's functions was delivered to the professionals. The professionals were also allowed to use the software. Feedback from the professionals was collected through open-ended questions. The interviews incorporated additional questions based on the users' responses, in addition to pre-defined inquiries. While there is no stringent criterion for determining the sample size in qualitative studies, Boddy (2016) [119] asserts that a sample size of 12 in qualitative research design is adequate for achieving theoretical saturation. A similar sample size is also indicated in various studies (Guest et al., 2006; Hennink and Kaiser, 2022) [120,121]. Data saturation is realized when no novel information or themes emerge in the data after conducting further interviews or case evaluations (Boddy, 2016) [119]. In this study, saturation was achieved after the ninth interview, as the professionals' responses and recommendations began to replicate. The interviews concluded after the 13th session, given the absence of new feedback for the questions addressing the prototype's contribution, challenges encountered with the prototype, and recommendations for future developments.

Upon the completion of the verification process, the validation phase was initiated. An online survey form was dispatched to the previous 13 participants and 8 additional participants to validate the prototype. In total, 21 professionals replied to the validation questions. The participant profile is presented in Supplementary Material G. The survey encompassed inquiries regarding the model's usability and its application in regards to PPPs. The usability questions were derived from the system usability scale (SUS) (Brooke, 1996) [122]. In addition to the usability queries, ten questions about the model's utilization in PPP projects were incorporated. All questions related to usability and the model's practicality and applicability were presented on a 1–5 Likert scale, ranging from strongly disagree to strongly agree. A similar sample size was employed in the validation of the prototypes developed within the construction management field in previous studies (Artan et al., 2022) [123]. The results of the validation process are detailed in Table 4.

4. System Architecture and Elements

4.1. System Architecture

The Riesgo prototype is developed as a desktop application. PPP experts utilize project documents and project-related data to complete the pertinent fields within Riesgo (Figure 1). Some menus within the prototype serve primarily as information repositories, aiding users in documenting and monitoring vital project details. Other menus have connections to each other to facilitate an exchange of information among them. These connections will be further elaborated in the information flow section. Based on the user inputs entered into Riesgo during risk assessment, the prototype generates outcomes such as rankings, graphs, pie charts, and visualizations. The information about the risks assessed in Riesgo can be saved, stored in a database, and exported to Microsoft Excel.

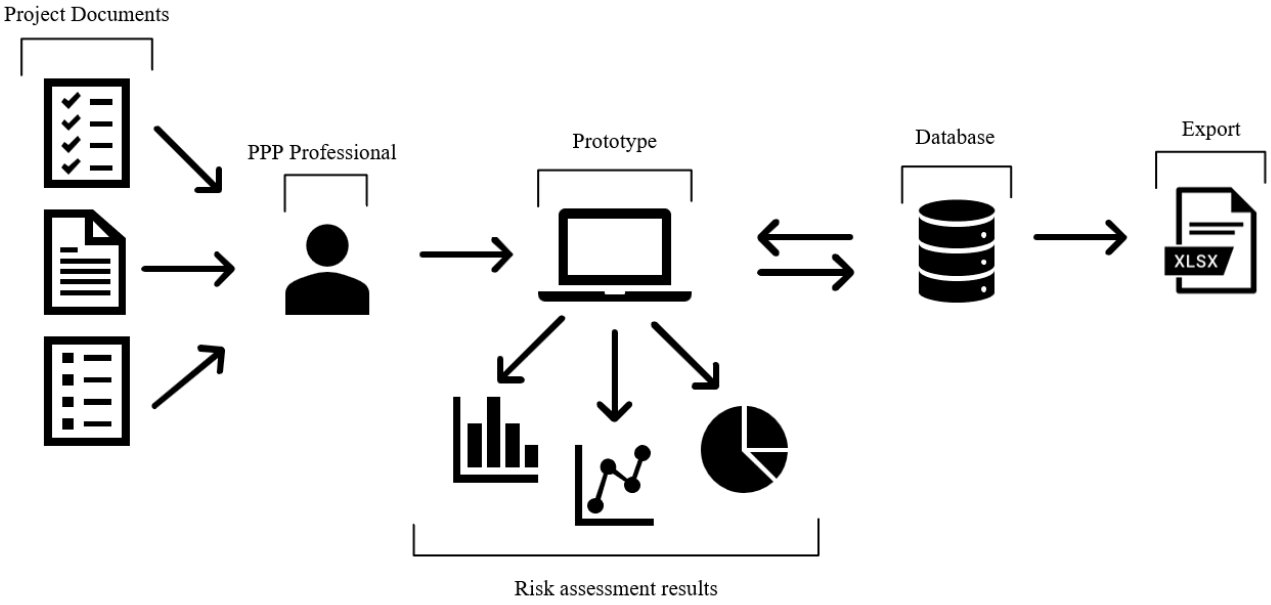

Figure 1. System architecture.

4.2. Risk Factors

The Delphi technique was employed to determine the PPP risk factors that must be analyzed by the public party while using the proposed prototype. A total of 83 risk factors were identified and grouped into Land Risks, Financial Risks, Legal and Contractual Risks, Governance Risks, Political Risks, Social Risks, Design Risks, Environmental and Force Majeure Risks, Construction Risks, and Operation and Transfer Risks. The details and methods adopted in the determination of the risk factors using the Delphi technique were presented by Authors [92]. These risks were integrated into the prototype's template under the Risk Hierarchy menu. Embedded risk factors in the Risk Hierarchy menu are presented in Supplementary Material B. Various implementation modes (e.g., BOT, BOOT, BLT) can be employed for PPPs, each encompassing certain common generic risks. Nonetheless, these modes also entail distinct risks (Akhtar et al., 2023) [124]. Furthermore, the project risk profile can be influenced by the nature and location of the project, and new risks can occur. Hence, "add", "edit", and "delete" functions are incorporated into the Riesgo prototype to enable modifications to the predefined risk factors. Thus, risk factors can be updated based on the project characteristics. These features make the prototype dynamic and set it apart from previously described tools, such as risk registers and matrices, providing a distinct advantage.

4.3. Project Information Requirements and Financial Information Requirements

Project information requirements are the information items that need to be collected and entered into the proposed prototype by the users. Since the utilization of limited information was determined as a major drawback of the previous studies, information items required for a comprehensive PPP risk assessment were identified by a detailed process involving the Delphi technique. The details and methods adopted in the determination of the project information requirements using the Delphi technique were presented by Authors [93].

The qualitative information requirements, designated as "Project Information Requirements", were categorized under Project General Information, Contract General Information, Financial Details, Legal and Technical, Mechanisms and Provisions, and Project General Analysis. Project General Information requirements encompass aspects such as PPP types, scope, description, and stakeholders. Contract General Information pertains to crucial dates for tender and contract, concession period, and expiry date. Financial details address topics like shareholder percentages, loan financing structure, and guarantees. Legal and Technical requirements involve laws, regulations, permits, guideline details, and specifications. Mechanisms and Provisions focus on the types of mechanisms applicable to the contract, such as tariff adjustment mechanisms, revenue sharing mechanisms, dispute resolution mechanisms, and early termination provisions. Finally, Project General Analysis includes requirements like milestones, success criteria, and boundaries. The complete list of project information requirements is presented in Supplementary Material C.

Alongside the provided examples, the quantitative requirements employed to analyze the financial aspect of PPPs were identified as "Financial Information Requirements". The monitoring of the project's financial aspect relies on these specific financial values. These requirements have the potential to be incorporated into contracts using threshold values, establishing guidelines for implementing compensation mechanisms and as a result, being linked to project risks. Examples of financial information requirements include demand projection, inflation, net present value, and debt service coverage ratio. The complete list of financial information requirements is presented in Supplementary Material D.

4.4. Risk Register Items

Risk register items were identified through a literature review and are presented in Table 1. These items have been integrated into the Risk Register menu of the prototype. The goal is to facilitate the gathering of diverse information related to the risk factors. Consequently, users can conduct risk assessments by examining numerous risk items. A detailed list of the items featured in the Risk Register, along with their explanations, is provided in Supplementary Material H.

5. Prototype Information Flow and Graphical User Interfaces

5.1. Prototype Information Flow

The illustration in Figure 2 shows the main functions, information flow, and outputs of the prototype. The initial menu of the prototype, All Projects (a), allows users to either create a new project or choose one that was previously created. When initiating a new project, users are presented with two options: generating a project from a pre-populated PPP template or an empty template. While the empty template lacks pre-defined information, the pre-populated template includes predetermined elements for PPPs, such as risk factors, compensation, and mitigation actions.

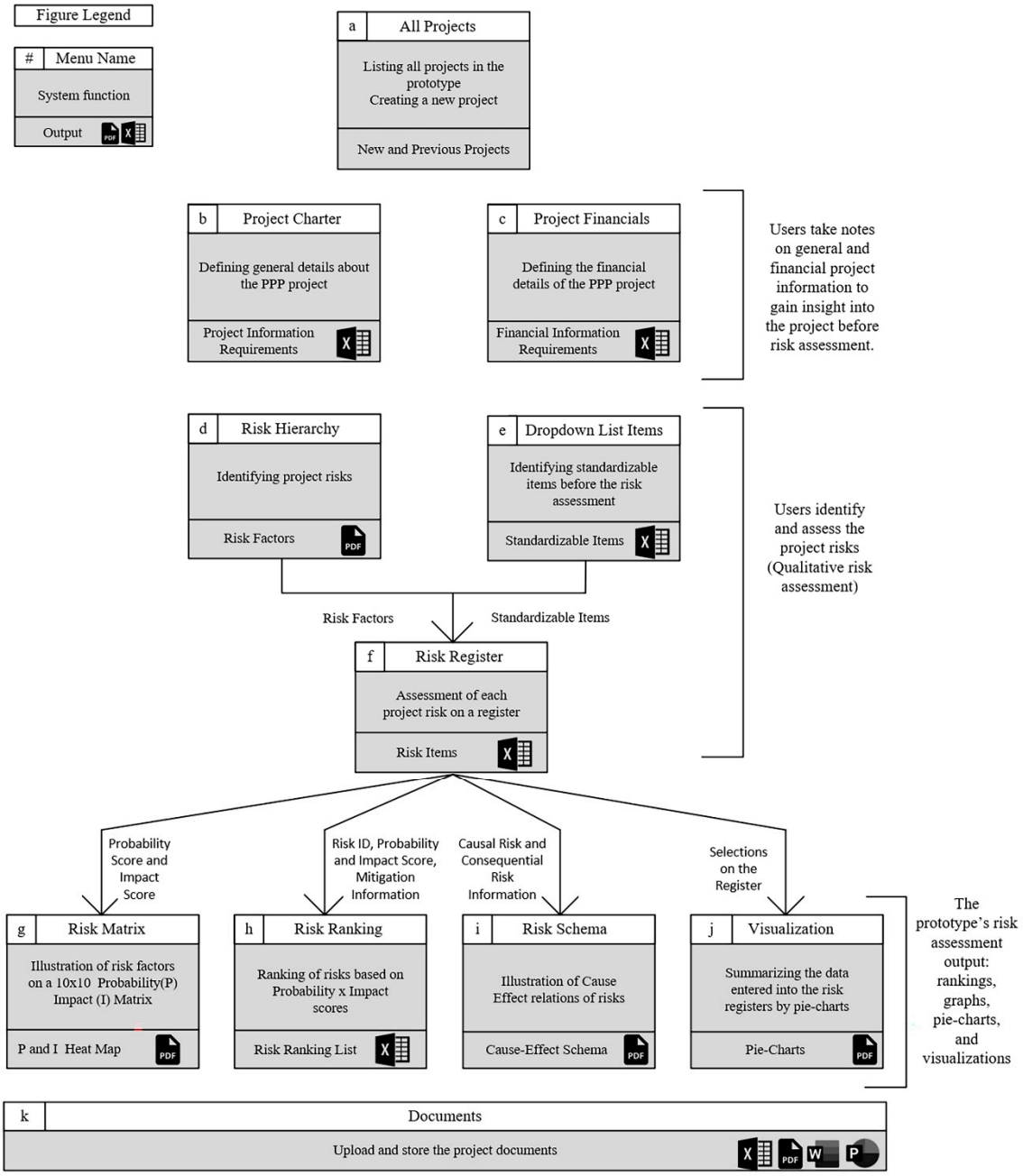

Figure 2. Menu functions and information flow in the prototype.

Upon the creation of a new project, the Project Charter menu (b) is activated. This menu encompasses fields for the PPP information requirements listed in Supplementary Material C (e.g., project description and scope, laws related to the project, milestones of the project) to delineate the general characteristics of the PPP. Subsequently, as the user fills out the Project Charter, the Project Financials menu (c) is opened. This menu facilitates the input of data for the Financial Information Requirements listed in Supplementary Material D (e.g., demand projection, interest rate, project costs). Filling out the fields in these two menus with comprehensive notes and data provides users with a thorough understanding of the project before initiating the risk assessment. Data in both menus can be exported to Excel. In the Risk Hierarchy menu (d), risks are identified. The Pre-Populated Template includes 83 validated risk factors (listed in Supplementary Material B), and users can either use these risks or make modifications, delete existing ones, and add new risks and risk groups. After identifying the risks pertaining to the project being assessed, the Dropdown List

Items menu (e) is accessed, where project specific risk details (e.g., project phases, risk management strategies, risk owners) are identified. Subsequently, the risk factors in the Risk Hierarchy menu (d) and the project specific risk details identified in the Dropdown List Items menu (e) contribute to the Risk Register menu (f). The user performs a qualitative risk assessment on the Risk Register menu (f) using the risk factors and project specific risk details. When the user enters information for the risk items in the Risk Register, the information is analyzed and fed to the other menus (g-h-i-j), creating the prototype's risk assessment output as rankings, graphs, pie charts, and visualizations. For instance, the Probability and Impact Score feed the Risk Matrix menu (g), displaying risks on a risk heat map. Risk ID, Probability and Impact Score, and Mitigation information feed the Risk Ranking menu (h), ranking risks based on Probability x Impact scores. Causal Risk and Consequential Risk information in the Risk Register (f) menu feeds the Risk Schema (i), creating a cause–effect schema illustrating the relationship between occurring risks. Finally, the user's selections on the Risk Register menu (f) feed the Visualization menu (j), generating pie charts summarizing the entered data. The Documents (k) menu can be employed to upload and store project documents.

5.2. Development of the Use Case and the Graphical User Interfaces (GUIs)

This section delineates the system functions through a use case developed to illustrate the information and process flows in the proposed prototype. Steve, a PPP professional, intends to perform a comprehensive risk assessment on Riesgo. Initially, he generates a new project within the All Projects menu by choosing the PPP Risk Template (pre-populated) and assigning it the name Test Project Riesgo (Figure 3).

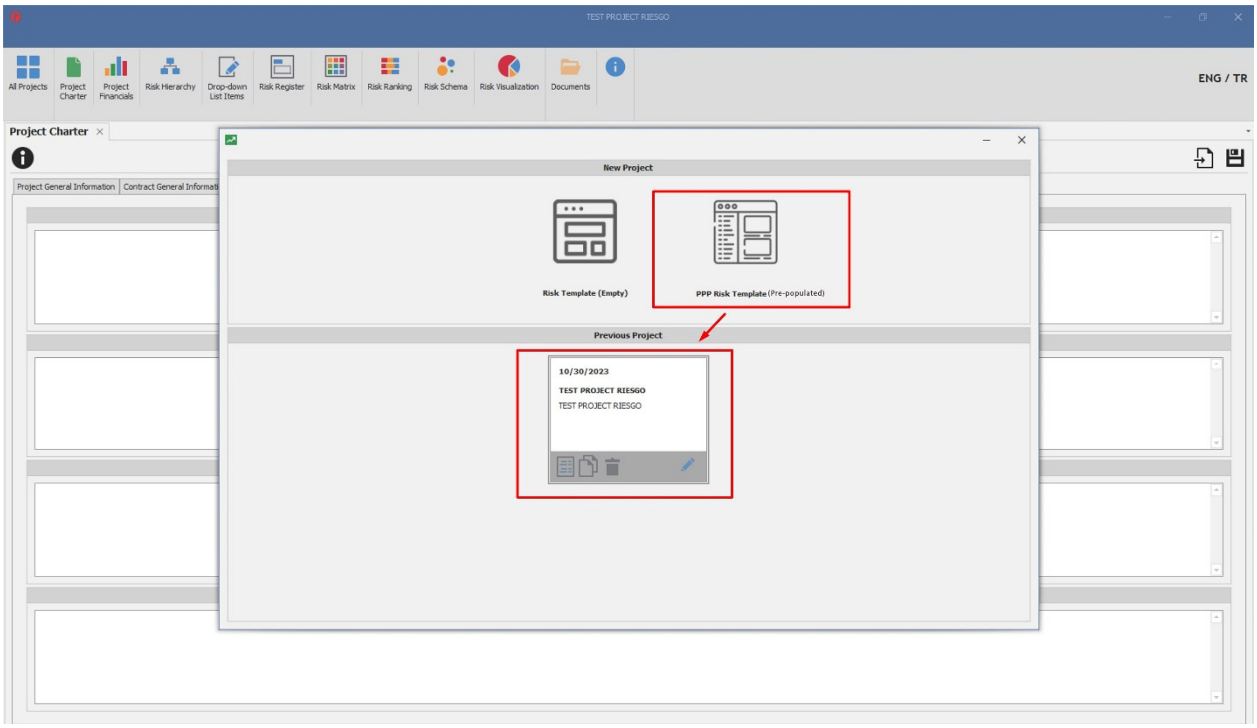

Figure 3. All projects menu.

Upon entering the project, the Project Charter becomes accessible. This menu encompasses multiple tabs and information fields for Steve to complete using the information he possesses. For instance, in Figure 4, he enters some details into the "Loan Financing Structure" information requirement box under the Financial Details Table. The full list of Project Information Requirements can be seen in Supplementary Material C.

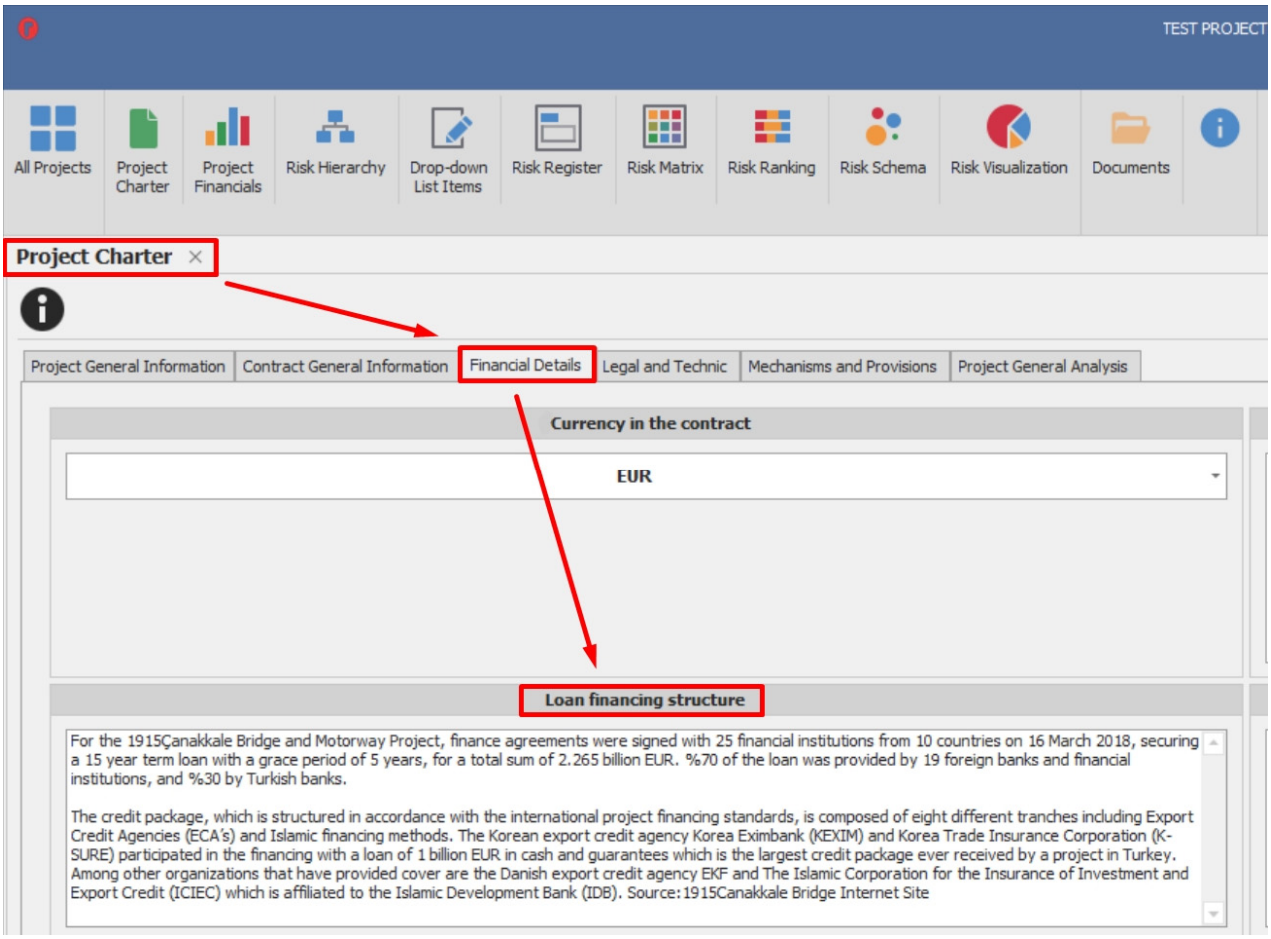

Figure 4. A section from the project charter.

In the following menu, Project Financials (Figure 5), values for project financials are entered by Steve. During his use test, dummy demand projection values are added by Steve, and he observes the trend of the data through graphs (Figure 6). The full list of Financial Information Requirements can be seen in Supplementary Material D.

Upon accessing the Risk Hierarchy menu (Figure 7), all the predefined risk factors within the prototype (Supplementary Material B) are listed. Steve reviews all the predefined risk groups and the predefined risks under these groups. He wants to make sure all potential risks in the PPP project he is working on are listed in the prototype.

For example, he intends to see whether the force majeure risk is listed. Since numerous risks are available in the Risk Hierarchy menu, checking each risk individually can be challenging. Therefore, Steve utilizes the risk search bar for "force majeure" risk (Figure 8). Consequently, he sees a risk group titled Environmental Risks and Force Majeure, and within this group, the force majeure risk is listed.

Subsequently, Steve recalls the significant global impacts of the COVID-19 pandemic on various PPP projects. Consequently, he contemplates including "pandemic risk" as a new risk within the Environmental Risks and Force Majeure group. The prototype facilitates this process by allowing users to add, edit, and delete risks effortlessly. To introduce the new risk, Steve opts for the risk group, utilizes the "Add Risk" function, enters "pandemic risk", and successfully incorporates the new risk (Figure 9). Also, risks are listed on the left side of the menu, so he can alternatively use add, edit, and delete functions by pressing the icons near these risks.

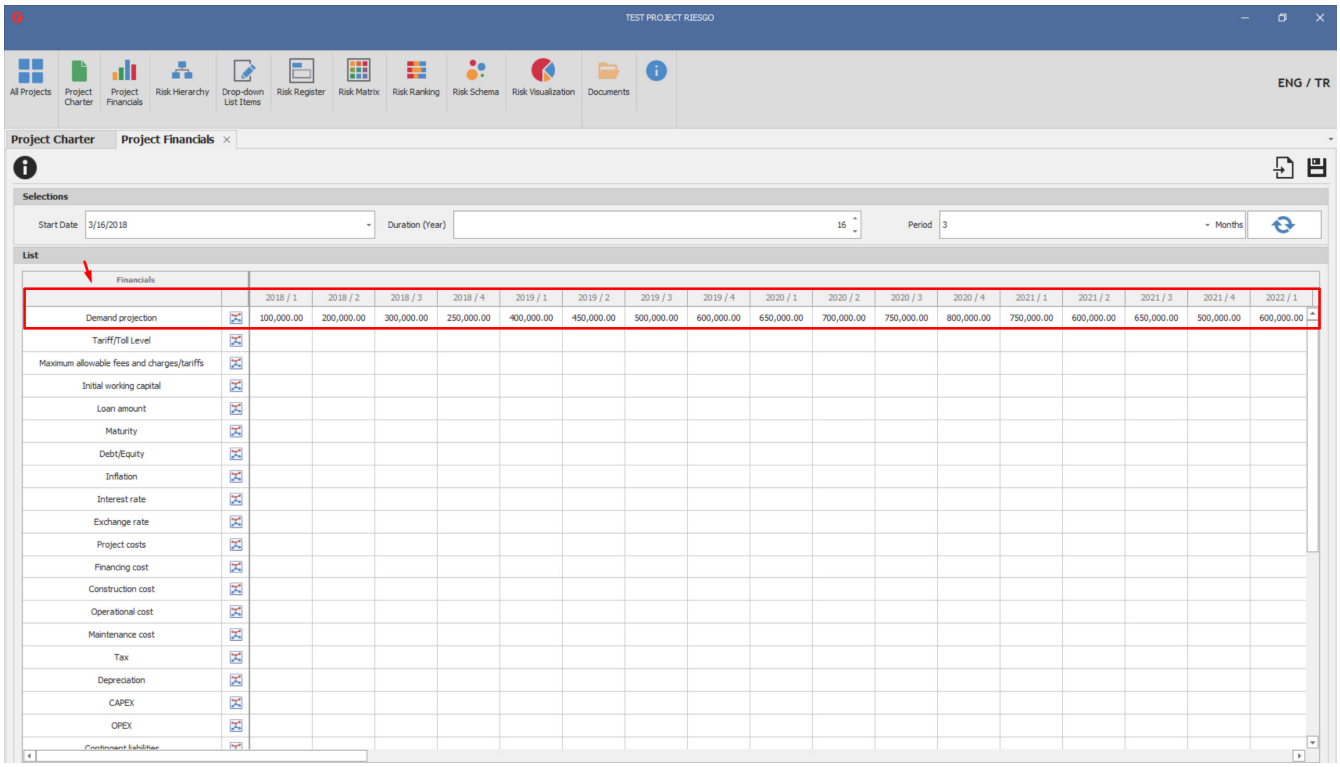

Figure 5. Project financials menu.

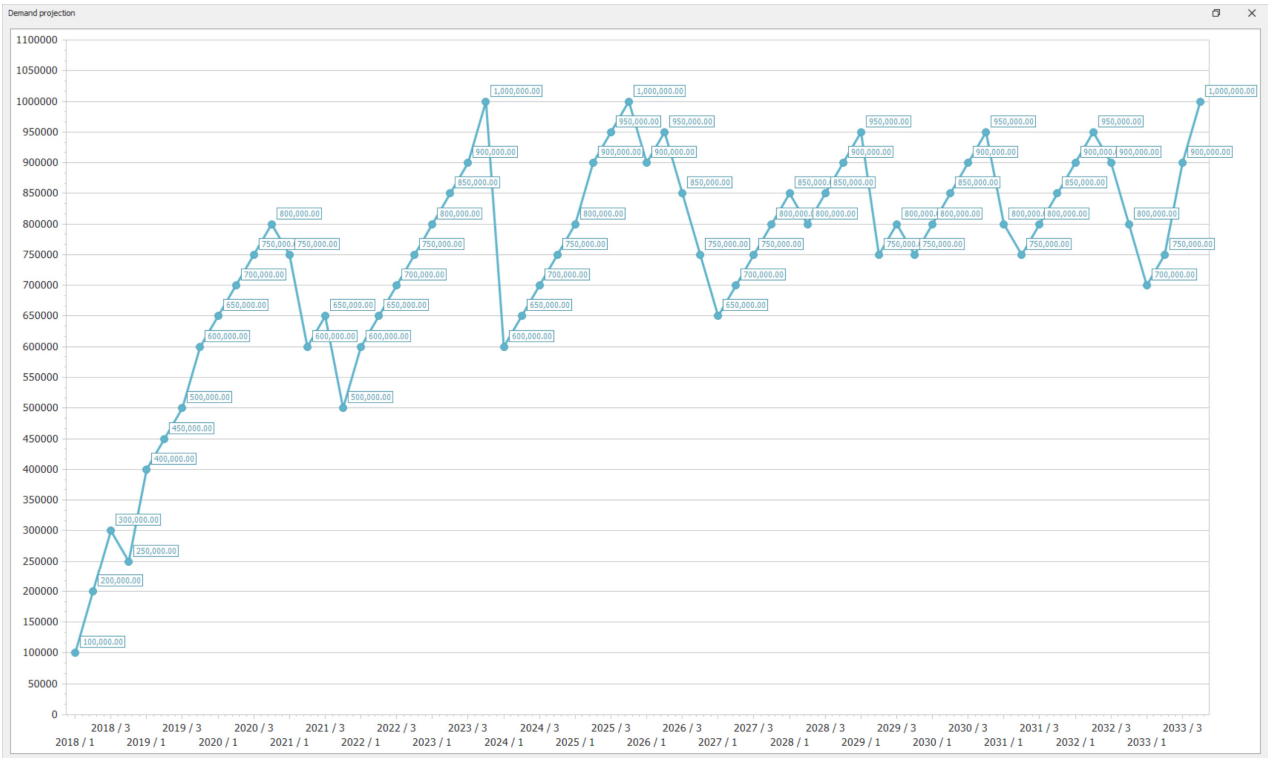

Figure 6. Graph for demand projection based on dummy data.

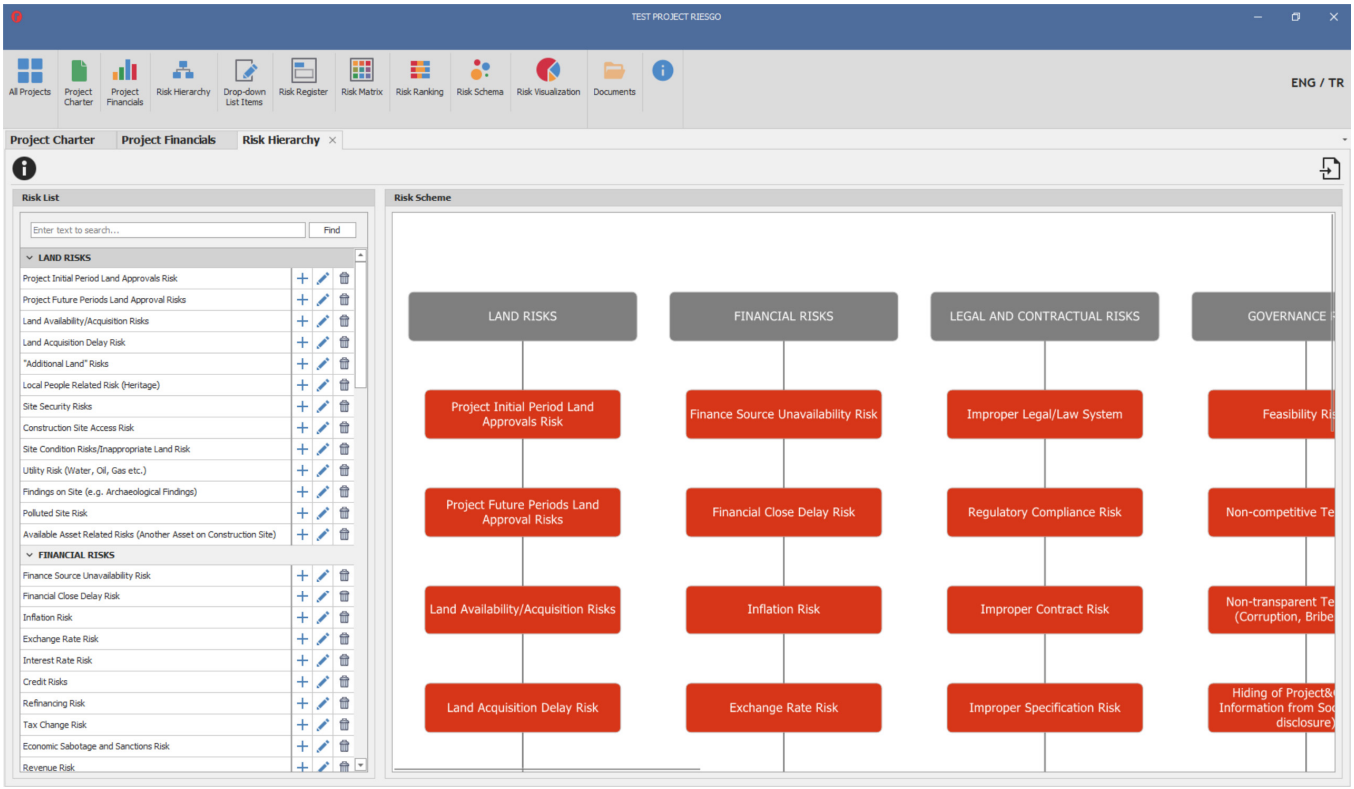

Figure 7. A section of Risk Hierarchy menu.

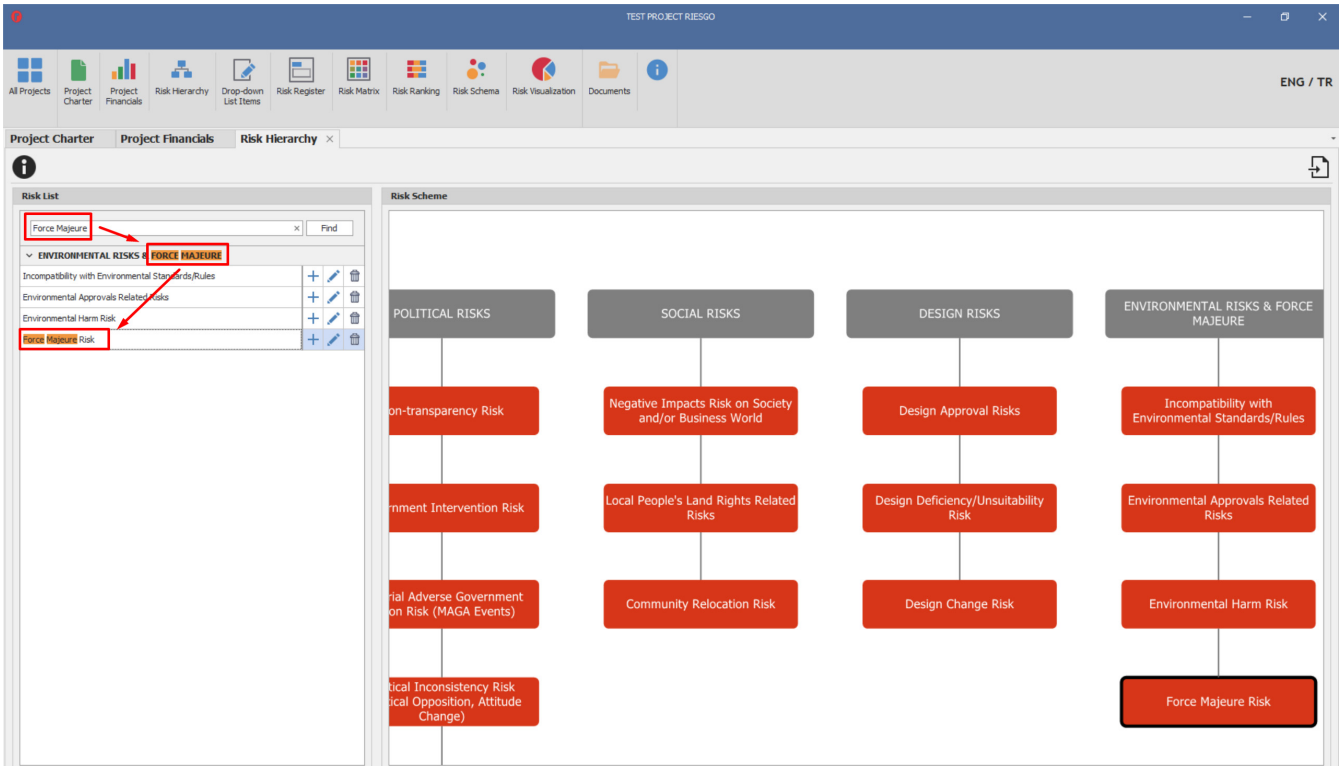

Figure 8. Risk search.

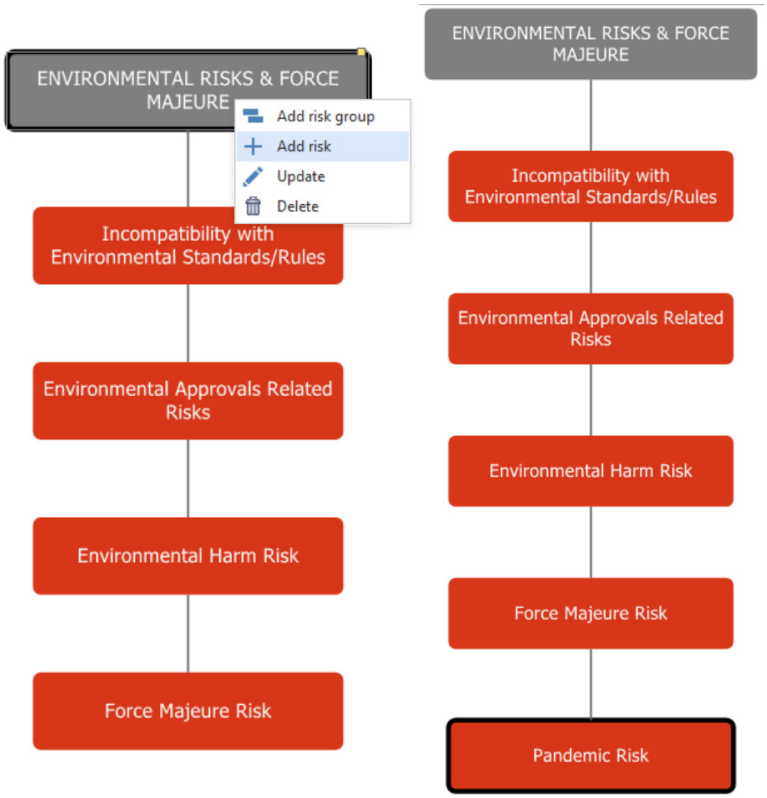

Figure 9. Adding new risk (before–after).

Next, Steve assesses the risks on the Risk Register menu. During the assessment, he can also utilize the Dropdown List Items menu to expedite the assessment process. Steve establishes project specific risk details using the Dropdown List Items menu. These items are categorized under Project Phases, Impact Types, Risk Strategy, Risk Allocation, Risk Owners, Mitigation Mechanism, Compensation Mechanisms, and Risk Status and are listed in the dropdown lists in the Risk Register menu. Steve retains control over these items, with the ability to delete those unsuitable for his project and add new items under each heading. For example, he adds new project phases named "Phase 1", "Phase 2", and "Phase 3". Similar customizability exists for adding new items under the other headings (Figure 10).

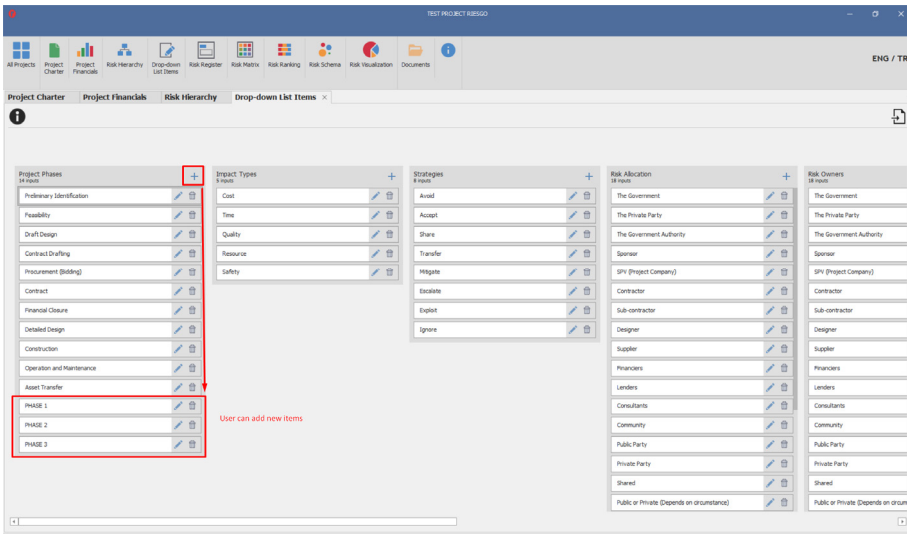

Figure 10. Dropdown List Items menu and adding new items.

Once all the necessary items have been included in the Dropdown List Items menu, Steve can proceed to the Risk Register menu. The risk list previously established in the Risk Hierarchy menu is visible on the left side of the Risk Register menu. Here, he can choose the risk he intends to assess, prompting the display of a register for the selected risk on the screen. For instance, when Steve opts for the "Changes in the Law" risk, the risk register for this specific risk becomes visible. Knowledge embedded in the prototype pertaining to this risk factor, including information such as Explanation, Compensation, and Mitigation actions, are presented to Steve. He can revise this information, if he chooses (Figures 11 and 12).

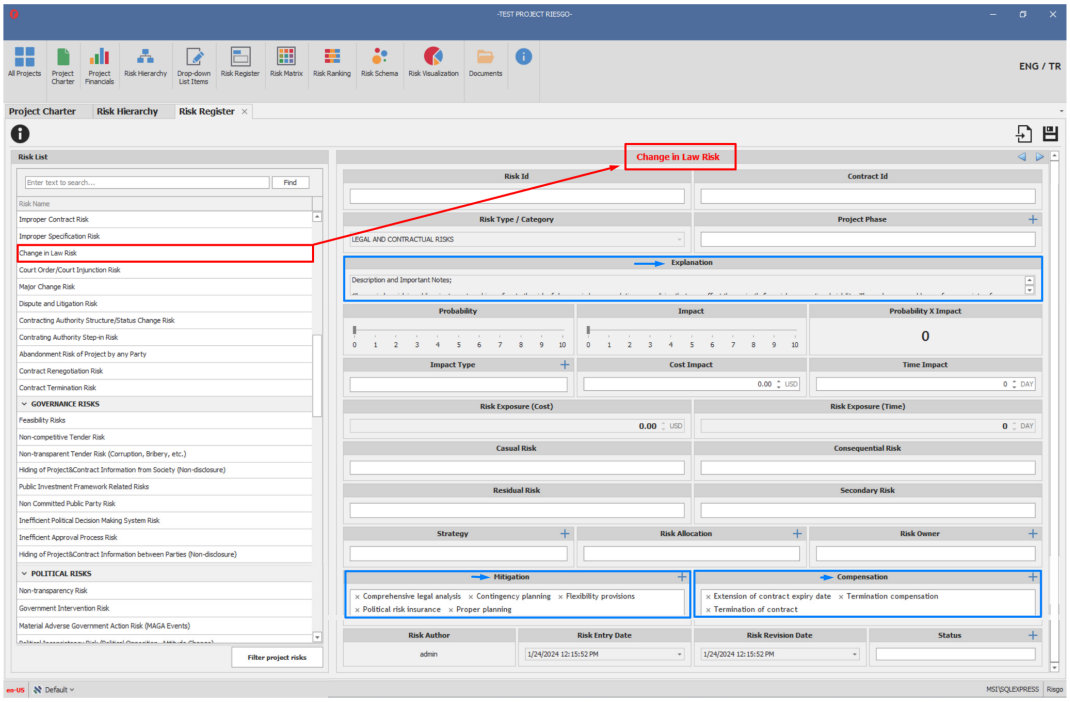

Figure 11. Risk register menu.

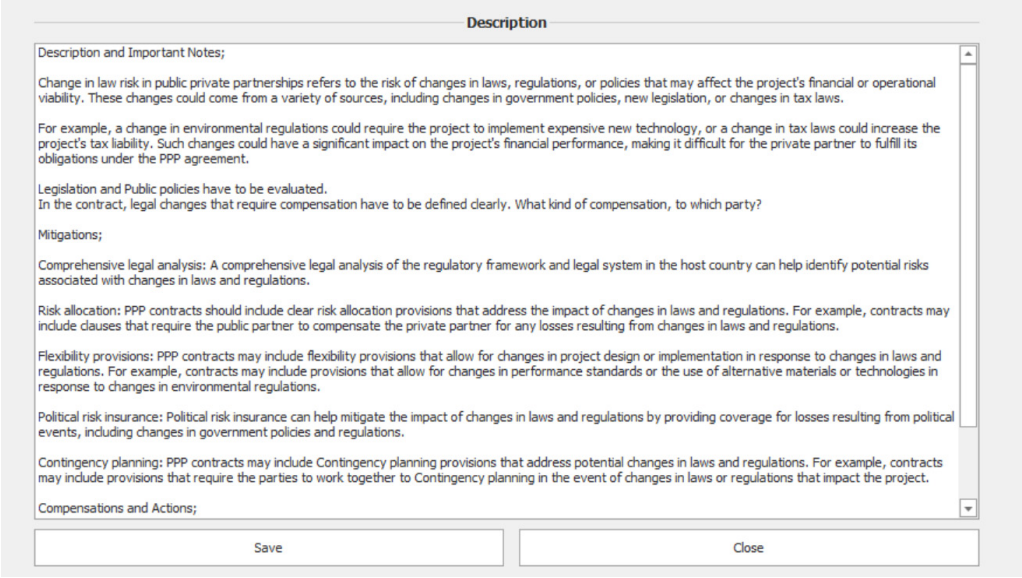

Figure 12. An example of the Explanation (description) field in the Risk Register menu.

Steve fills out the remaining fields based on the project (Figure 13). He manually enters the Risk ID and Contract ID. He provides a Probability and Impact value, based on his subjective judgement. Project Phase, Strategy, Risk Allocation, Risk Owner, Mitigation, Compensation, and Status are completed with the selections from the Dropdown lists. For example, when Steve clicks on the field under Project Phase, a dropdown list containing previously defined project phases from the Dropdown List Items menu pops up. Then, Steve assigns the Construction, Operation, and Maintenance phases to the Changes in the Law risk (Figure 14). Causal Risk, Consequential Risk, Residual Risk, and Secondary Risk are also determined by Steve using dropdown menus. For instance, by clicking the field under Consequential Risk, all risks outlined in the Risk Register menu are displayed in a dropdown menu. Then, Steve designates Regulatory Compliance risk as a consequential risk for the Changes in the Law risk. The system automatically fills the remaining fields, such as risk author, revision date, and risk entry date. The risk status is also assigned by Steve.

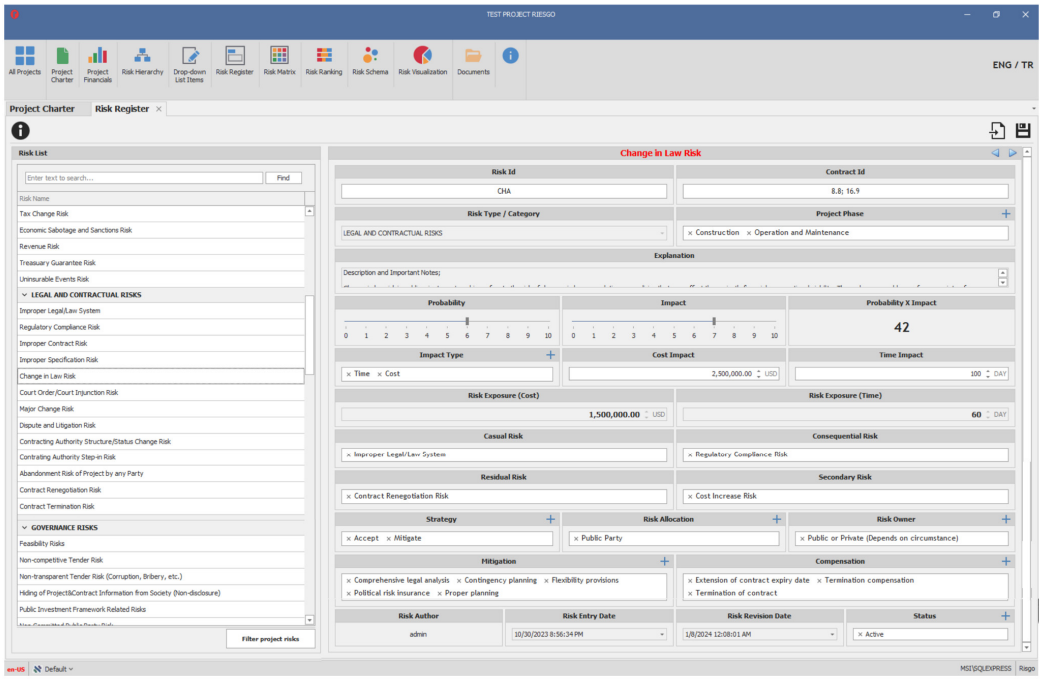

Figure 13. Risk Register menu (after the Changes in the Law risk is assessed).

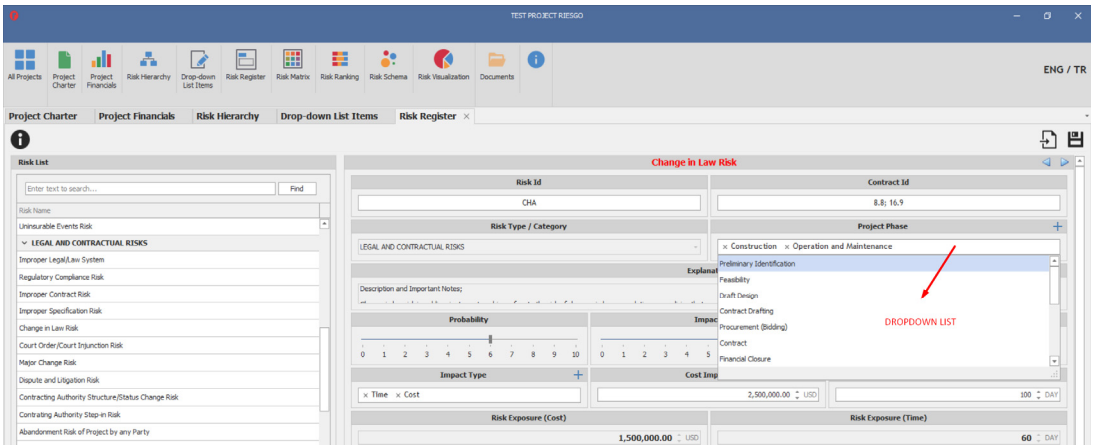

Figure 14. An example of Dropdown lists in the Risk Register menu.

Utilizing the explained approach, Steve assesses ten risks. Then, he opens the Risk Register menu and observes the assessed risks displayed on a 10 × 10 Probability Impact Risk Matrix, depicted in Figure 15. The risks are represented on the risk matrix according to the risk IDs assigned by Steve in the Risk Register. Positions of the risks are also determined based on the Probability and Impact Scores that Steve determined with his subjective assessments in the Risk Register. For example, Changes in the Law risk (Risk ID: CHA) had been rated by Steve with a Probability Score of 6 and an Impact Score of 7, as evident in the Risk Register in Figure 13. Hence, in Figure 15, the representation of CHA is illustrated at the intersection of Probability Score: 6 and Impact Score: 7. Steve can change the bars' position on the right side of the screen and determine red, yellow, and green fields based on his subjective risk perception.

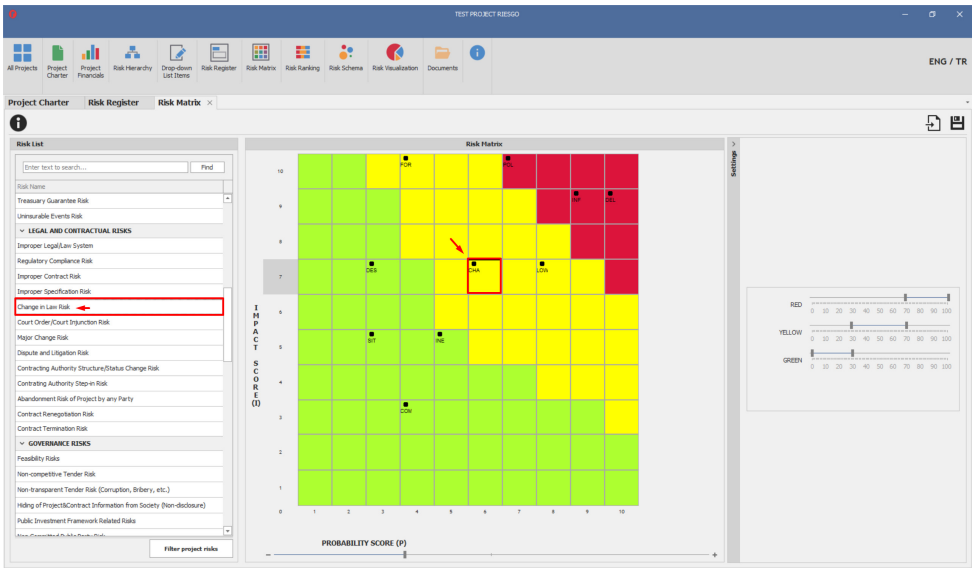

Figure 15. Risk Matrix menu.

In his assessment, Steve opts to maintain the intervals as unchanged and proceeds to the subsequent menu, Risk Ranking (Figure 16). Within this menu, the ten risks assessed by Steve are arranged in a list based on their Probability and Impact Scores. For instance, based on his assessment, the Delay risk is positioned at the top. The Risk ID and Contract ID (i.e., related contract clauses for a specific risk) are also provided to facilitate Steve's understanding of the relationship between the most significant risks and the project contract. The prototype further assesses the Risk Level and the availability of mitigation, presenting Steve with a priority value for each risk based on an "if–then" rule.

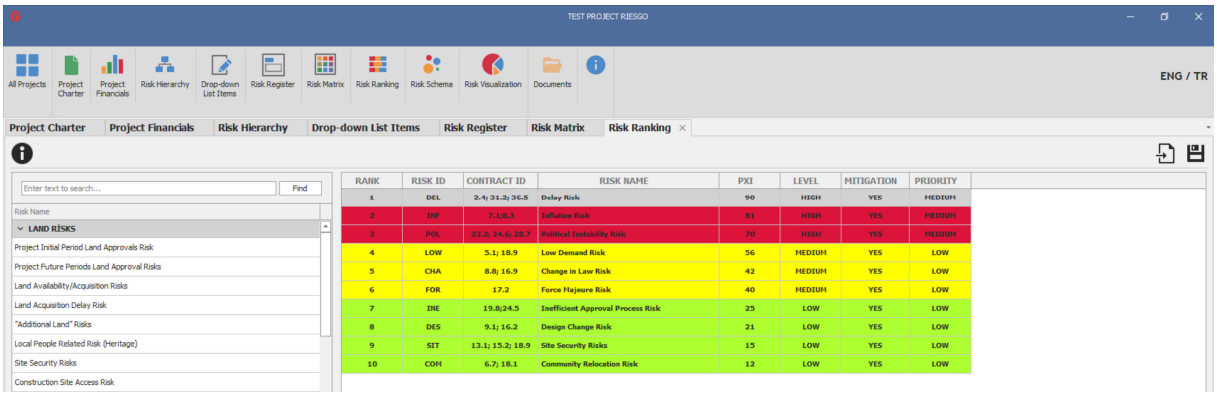

Figure 16. Risk Ranking menu.

In the following menu titled Risk Schema (Figure 17), Steve observes the cause-and-effect connections among the risk factors. Riesgo generates this relationship scheme automatically, relying on Steve's input in the Risk Register menu under the risk items of Causal Risk and Consequential Risk. In the Risk Register, Improper Legal/Law System was designated as a Causal Risk for the Changes in the Law risk by Steve, and the Regulatory Compliance Risk was specified as the Consequential Risk (Figure 13). Analyzing this data, the prototype visually demonstrates the relationships between the risks, and it can be easily inferred that the occurrence of the Changes in the Law risk can be attributed to the Improper Legal/Law System, and the Regulatory Compliance Risk may arise as a consequence of the Changes in the Law (Figure 17). This visualization enhances decision making in risk assessment by enabling a thorough observation of the relationships between risks, which may be particularly insightful in complex PPPs comprising multiple cause–effect relationships among the risks.

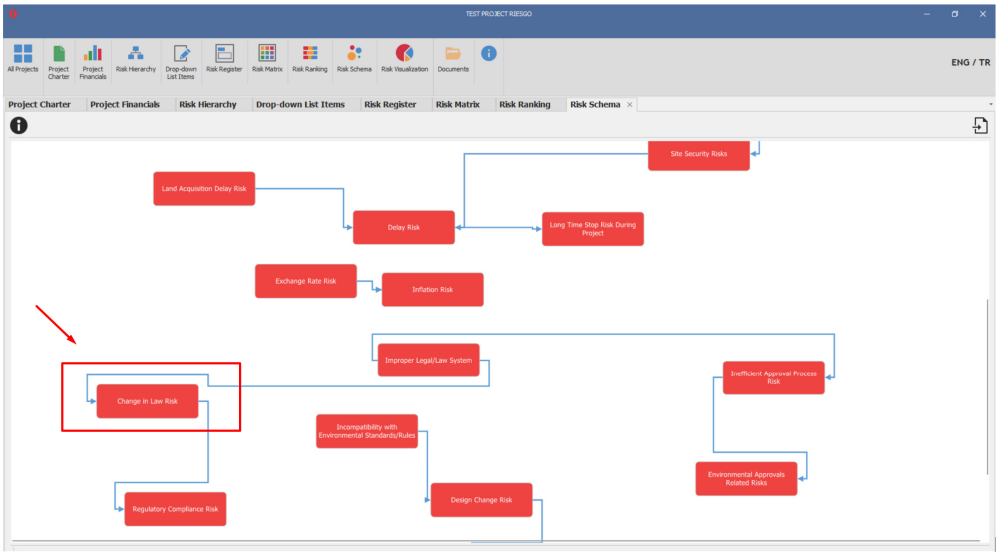

Figure 17. A section of Risk Schema menu.

In the subsequent menu, called Risk Visualization, Steve accesses pie-chart representations derived from the risk data he entered into the Risk Register. Pie charts for Risk Category, Project Phase, Impact Type, Strategy, Risk Allocation, Mitigation, Compensation, Risk Owner, and Risk Level are automatically generated, analyzing the data entered by Steve in the Risk Register. For example, Figure 18 illustrates the distribution of risks based on their categories.

Figure 18. A section from risk Visualization menu.

In the final menu, Documents (Figure 19), Steve can upload project-related files. For example, he can upload an XSLX file containing Exchange Rate projections to examine during the assessment of exchange rates. In this use test, Steve uploads files exported from various menus within the Riesgo prototype. Project Charter, Project Financials, Dropdown List items, Risk Register, and Risk Ranking are suitable for Excel export since they contain a database. Risk Hierarchy, Risk Matrix, Risk Schema, and Risk Visualization are suitable for PDF export since they contain visual output.

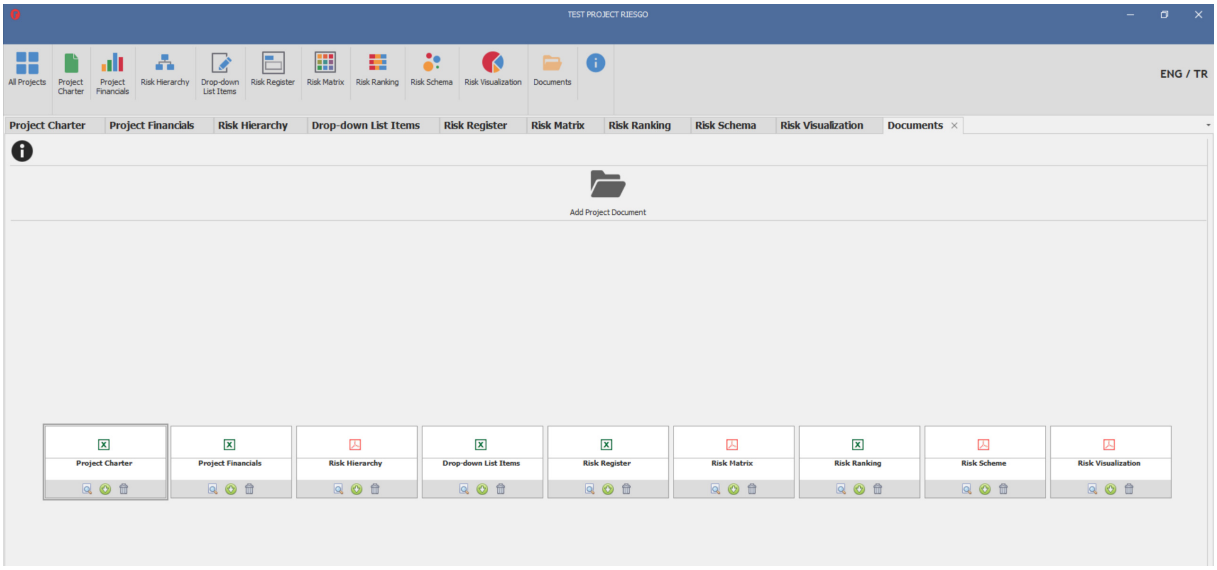

Figure 19. Documents menu.

6. Validation and Verification of Prototype

Verification and validation were conducted in the final step to examine the developed prototype's functionality, as well as its applicability, usability, and practicability in PPP projects. The prototype was verified by 13 PPP experts with experience in the fields of PPP, risk management, and contracts who used it for risk assessment, and their feedback was utilized for further development. The validation process was undertaken with 21 PPP experts through a usability survey. The validation and verification results are explained in this section.

The feedback received from professionals during verification can be summarized as follows: (1) Riesgo is easy to use due to its user-friendly graphical interface. (2) The Pre-Populated PPP Template, containing predefined risk factors, provides a time-saving advantage to the professionals during the risk assessment, and the template also works as a checklist to prevent the oversight of significant risks. (3) Since the PPPs comprise a multitude of risk factors and risk items that can vary from one project to the other, the customizable structure of the prototype is identified as another noteworthy advantage. This structure helps to facilitate the revision of a project in Riesgo based on the needs of a real PPP project. (4) The visualizations provided by Riesgo for the PPP risk assessment deliver easily comprehensible outputs. (5) Riesgo can expedite risk and contract management operations. Its proactive risk assessment approach can prevent significant cost and time losses arising from risk factors. (6) All main PPP stakeholders, including the public party, private party, and financiers, can utilize the prototype for PPP risk assessment (7) The utilization of Riesgo in real PPPs promotes transparency and unity among stakeholders. (8) Considering the absence of dedicated software for PPPs' qualitative risk assessment, this prototype can fill a gap in the PPP sector.

Challenges were also reported by professionals during verification, mainly due to the numerous information fields in the prototype. To overcome the uncertainty regarding which information fields should be completed by the users, it was suggested by professionals

that the model should show the mandatory data entry fields to the users. This way, users can initially focus on the mandatory fields to obtain Riesgo outputs. In addition, a simple diagram illustrating the relationships between information fields in the Riesgo can be added to the model. This clarifies which information fields contribute to which menus. Another difficulty mentioned by some professionals was that, despite the user-friendly graphical interface of the prototype, becoming accustomed to new software in a business process might require a period of adjustment. Concerning the second challenge, professionals recommended the development of additional user documents and the inclusion of a video within Riesgo. These Supplementary Material can facilitate the resolution of issues encountered by new users and promote their adaptation to the new software.

To validate the prototype, as outlined in the methodology section, professionals from the sector completed a survey comprising 20 questions. Ten questions focused on the general usability of the prototype, while the remaining questions assessed its applicability in PPPs. Average scores were computed based on the responses. The statements in questions 1, 3, 5, 7, and 9 incorporated positive language, while those in questions 2, 4, 6, 8, and 10 comprised a negative structure. Hence, higher scores for questions 1, 3, 5, 7, and 9 and lower scores for questions 2, 4, 6, 8, and 10 are expected. The average scores are presented in Table 4.

The average scores for questions 1, 3, 5, 7, and 9 ranged from 3.81 to 4.33. The participants indicated a strong intention to use the system frequently (Q1 avg = 4.33), acknowledged its user-friendly nature (Q3 average = 4.29), and praised the integration of functions within the system (Q5 avg = 4.24). Questions 7 and 9 assessed the ease of learning and user confidence, with both averaging 3.81. Despite these scores being lower than the others, they still indicate that the users found the system easy to learn. Furthermore, analyzing the averages of questions with negative statements revealed that the users believed the system could be learned without technical support (Q4, avg = 1.71) and that it did not require extensive learning (Q10, avg = 2.05). Additionally, Q2 (Average = 1.71) suggested that the system was not complex, which was supported by Q6 (avg = 1.43), indicating low system inconsistency. Q8 (avg = 1.95) highlighted the system's efficiency and showed that it is not cumbersome.

For the remaining questions related to the model's applicability and practicability for PPPs, average scores ranged from 4.19 to 4.52. Participants agree that the model facilitates data collection for projects (Q11 avg = 4.19), enables the retention of more information compared to sector tools (Q12 avg = 4.29), and has the potential to prevent the overlooking of critical information during risk assessment (Q13 avg = 4.29). They also affirm the suitability of selected functions for risk assessment (Q14 avg = 4.48), stating that it can facilitate (Q15 avg = 4.48) and expedite (Q16 avg = 4.29) PPP risk assessments. Additionally, they endorse the model's applicability in real PPPs, suggesting its use in the feasibility phase (Q17 avg = 4.48), during PPP contract preparation (Q18 avg = 4.52), for assessing contract risks during contract preparation (Q19 avg = 4.48), and for tracking and monitoring project risks during project implementation (Q20 avg = 4.24).

Table 4. Validation survey results.

	Questions Regarding General Usability	**# 1**	**# 2**	**# 3**	**# 4**	**# 5**	**# 6**	**# 7**	**# 8**	**# 9**	**# 10**	**# 11**	**# 12**	**# 13**	**# 14**	**# 15**	**# 16**	**# 17**	**# 18**	**# 19**	**# 20**	**# 21**	**Avg**
Q1	I think that I would like to use this system frequently.	4	4	4	3	4	5	4	4	5	5	4	5	5	4	5	4	5	4	4	5	4	4.33
Q2	I found the system unnecessarily complex.	1	2	2	2	1	2	3	1	2	1	1	2	2	2	1	2	2	2	1	1	3	1.71
Q3	I thought the system was easy to use.	4	4	4	4	5	5	4	4	4	5	4	5	5	4	5	4	5	4	3	5	3	4.29
Q4	I think that I would need the support of a technical person to be able to use this system.	1	1	2	4	1	2	1	1	1	1	2	1	2	2	2	2	2	2	2	2	2	1.71
Q5	I found the various functions in this system were well integrated.	4	3	4	3	5	5	3	5	5	5	4	5	5	4	5	3	5	4	3	5	4	4.24

Table 4. *Cont.*

	Questions Regarding General Usability	**# 1**	**# 2**	**# 3**	**# 4**	**# 5**	**# 6**	**# 7**	**# 8**	**# 9**	**# 10**	**# 11**	**# 12**	**# 13**	**# 14**	**# 15**	**# 16**	**# 17**	**# 18**	**# 19**	**# 20**	**# 21**	**Avg**
Q6	I thought there was too much inconsistency in this system.	2	1	2	2	1	2	2	1	1	1	1	1	1	2	1	2	1	1	2	1	2	1.43
Q7	I would imagine that most people would learn to use this system very quickly.	4	4	4	4	5	4	3	5	4	4	3	4	4	4	4	2	4	3	3	5	3	3.81
Q8	I found the system very cumbersome to use.	1	2	2	2	1	2	4	1	1	2	1	2	3	2	1	2	2	2	3	1	4	1.95
Q9	I think I will feel confident using the system.	4	4	3	3	5	4	4	4	5	4	3	4	4	4	4	2	4	4	3	5	3	3.81
Q10	I need to learn a lot of things before I get going with this system.	1	1	2	3	2	2	2	1	1	2	2	2	2	2	2	4	2	2	2	2	4	2.05
	Questions regarding the usage of model in PPPs	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9	# 10	# 11	# 12	# 13	# 14	# 15	# 16	# 17	# 18	# 19	# 20	# 21	Avg
Q11	The model facilitates the data collection associated with the project.	4	3	4	4	5	4	4	4	5	5	4	5	5	4	5	3	5	4	2	5	4	4.19
Q12	The model enables the keeping of more data/information related to risks compared to alternative tools commonly used in the industry such as Risk Registers and Risk Matrices.	4	5	3	4	5	4	5	3	4	5	4	4	5	4	5	3	5	5	3	5	5	4.29
Q13	The model may prevent critical points from being overlooked in qualitative risk analysis/assessment processes.	2	4	4	3	5	4	5	5	5	5	4	4	4	4	5	4	5	5	4	5	4	4.29
Q14	The functions of the model can provide a comprehensive/versatile view for qualitative risk analysis/assessment processes.	4	4	4	3	5	4	5	4	5	5	4	5	5	4	5	4	5	5	5	5	4	4.48
Q15	The model has the potential to facilitate qualitative risk analysis/assessment processes.	4	4	4	4	5	4	4	5	5	5	5	5	5	4	5	3	5	5	4	5	4	4.48
Q16	The model has the potential to expedite qualitative risk analysis/assessment processes.	4	2	4	4	5	4	4	4	5	5	4	5	5	4	5	3	5	5	4	5	4	4.29
Q17	The model can be used for general risk assessment in the feasibility processes of PPP projects.	3	4	4	3	5	4	4	5	5	5	4	5	5	4	5	4	5	5	5	5	5	4.48
Q18	The model can contribute to the contract preparation processes of PPP projects.	5	4	4	3	5	4	4	5	5	5	4	5	5	4	5	3	5	5	5	5	5	4.52
Q19	The model can be utilized for conducting risk assessment through PPP project contracts.	4	5	4	4	5	4	4	5	5	5	4	5	5	4	5	3	5	5	3	5	5	4.48
Q20	The model can be used for tracking/monitoring risks in PPP projects.	5	4	3	3	5	4	4	2	5	5	3	5	5	4	5	4	5	5	3	5	5	4.24

7. Discussion

Various risk management models are available in practice, each serving different purposes and providing different functions. Palisade @Risk [70] possesses an approach that focuses on Monte Carlo simulation, decision tree analysis, predictive neural networks, statistical analysis, and forecasting. Both qualitative and quantitative tools for project or program risk assessment are included in Primavera Risk analysis [125], yet quantitative assessment conducted by Monte Carlo simulation is at the forefront. Similarly, Full Monte [126] executes schedule risk analysis in Microsoft Project [127] or Primavera [125] through the Monte Carlo simulation. Riskonnect (formerly Sword Active Risk Manager) [72] incorporates qualitative functions and cost impact analysis, once again using Monte Carlo. Reviewing alternative risk management tools reveals that (1) none were specifically designed for PPP risk assessment, (2) they do not include knowledge-based templates developed to guide the practitioners through various PPP project phases, and (3) the existing tools aim for versatility across multiple sectors, leading to a general approach rather than to a focus on the specific needs of a sector such as PPP.

The proposed Riesgo prototype provides a qualitative assessment process with a knowledge-based approach. Like other risk software models, Riesgo can also be applied to various project types, but it is particularly tailored to meet the needs of PPP projects. Therefore, the pre-populated PPP template within Riesgo sets it apart from other risk software models, making it a unique model for PPP risk assessment. This template, readily available in the software, comprises PPP risk factors, information requirements, descrip-

tions, and explanations regarding the risks, compensation, and mitigation mechanisms for the risk factors. Additionally, users can customize these elements based on their project requirements. While most software models focus on risk management after project commencement, Riesgo can be also utilized before project initiation to understand project risks and develop a comprehensive PPP contract, mapping the project risks and their details. Thus, the key advantages of Riesgo lie in its customizable and knowledge-based structure, which is suitable for use in all project phases by all stakeholders, with a focus on qualitative risk assessment, which is often not prioritized in many software solutions. The contributions and limitations of the proposed prototype are further discussed below, utilizing the findings from the verification and validation processes.

7.1. Contributions

7.1.1. A Customizable and Knowledge-Based System Utilizing Extensive Project Information for Qualitative Risk Assessment in PPPs

Riesgo boasts a wide array of data entry fields that have been validated by PPP experts, ensuring a thorough consideration of crucial aspects and information related to the project, contract, and associated risks. The design of its user-friendly graphical interface, validated based on Brooke's (1996) [122] system usability questions, significantly contributes to facile user comprehension of the system.

The Riesgo prototype offers users a predefined PPP risk template, incorporating validated risk factors and detailed information, such as mitigation and compensation mechanisms. In other words, Riesgo presents its users with predefined knowledge and thereby works with its content as a knowledge-based system. This feature allows users to streamline the risk assessment, saving valuable time. Also, it can help knowledge transfer among the PPP projects, which is one of the significant requirements for capacity-building in PPPs (Chileshe et al., 2023) [128]. In addition to presenting predefined knowledge, Riesgo goes a step further by visualizing data, simplifying the interpretation of risks compared to traditional risk matrices/registers, such as Excel sheets, prevalent in the sector,.

The critical risks employed in the prototype were ascertained through expert validation and are presented in Supplementary Material B. Upon review, it becomes evident that experts deemed most factors related to land, financial, legal and contractual, governance, political, social, design, and environmental risks critical for the public party. Conversely, the proportion of critical risks within the construction and operation categories was comparatively lower. This result may stem from the usual allocation of these risks to the private party. However, it is essential to highlight that certain risk factors typically allocated to the private party, such as inflation, interest rate, revenue risk, finance source unavailability, cost increase, and demand risk (Bing et al., 2005; Ibrahim et al., 2006) [95,99] were also identified by the experts as critical risks and were integrated into the model.

In practical applications, if new critical risks are identified, the project team can add new risk factors to Riesgo with the help of its customizable structure. Users can modify the template according to their project requirements, including creating new risk groups and risk factors within these groups. By default, Riesgo does not categorize risks based on their criticality level, as the criticality of PPP risks can vary from one project to another. For example, financial risks such as inflation and exchange rates may not be considered primary risks in mature markets. In contrast, in less developed markets, these risks could be deemed more critical (Global Infrastructure Hub, 2019) [16]. Therefore, in Riesgo, all risks possess the same criticality level at the project's outset, and users alter this status by determining the level of criticality through the probability and impact scores they assign during their risk assessment.

Riesgo can be used as a standalone risk assessment tool or a contributory tool. The predefined information within Riesgo serves as a practical checklist for professionals, enabling them to cross-reference their project-specific risk matrices/registers with the established information in the system. Although a risk matrix that can be used as a checklist during the PPP risk assessment was created by the Global Infrastructure Hub

(Global Infrastructure Hub, 2019) [16], this tool takes a standard form, so it cannot be customized based on the needs of the conducted PPP project. Herein, a notable advantage of Riesgo lies in its customizable structure, empowering users to open a PPP template and modify it according to their project requirements using functions like "add a risk", "delete risk", or "edit risk." Alternatively, users can commence with an empty template and define all project risks from the ground up. With these advantages, Riesgo differs from most of the models presented in the literature, which were developed based on a specific location or PPP type. For instance, Ghimire et al. (2024) [129] assessed the risks of waste-to-energy projects in Nepal using the analytical hierarchical process method. Yang et al. (2024) [130] proposed a risk assessment model for PPP water environment treatment projects. These models are specific and cannot be adapted directly to all PPPs. Yet, Riesgo's generic approach and a high degree of customizable structure make it possible to use it in all PPP projects, irrespective of location and project type.

7.1.2. Suitable for All Stakeholders and Various Project Phases

PPPs include various risk factors, which must be fully assessed and balanced to attract the private sector (Zhang and Shahid, 2024) [131]. Hence, Riesgo was specifically developed for the public party and its consultants considering the public party's pivotal role as the primary stakeholder throughout the entire project lifecycle. The risk factors integrated into the model were identified to align with the risks that the public party is obligated to analyze regarding PPPs. Professionals involved in the verification process highlighted that the model's customizable structure extends its suitability to all major stakeholders in PPPs. Furthermore, a valuable recommendation emerged to transform Riesgo into a unified platform for all stakeholders. In practical terms, in a country engaging in PPPs, the public party could initiate the use of Riesgo and mandate its utilization by other stakeholders. This approach ensures that all parties engage in the risk assessment process using the same tool, fostering collaboration. Such a coordinated approach not only streamlines the risk assessment but also enhances communication among all involved parties.

Certain models proposed in the literature for PPP risk assessment focus on specific risks rather than all project risks. For example, the model by Alasad and Motawa (2015) [29] addresses demand risk, while Liu et al. (2017) [26] concentrate on revenue risk. Thus, such specialized models are associated with particular project phases. In contrast, Riesgo is a generic model designed to evaluate all project risks, and this ability makes it valuable across all the major stages in the typical PPP project cycle outlined by the World Bank (2017) [15]. To illustrate, in the project's early stages, such as feasibility, Riesgo aids in defining and assessing general project risks, contributing to a prompt assessment of a PPP project included on a country's PPP agenda. Furthermore, the platform can be utilized to assess alternative projects based on their risks, simplifying the selection process through comparative assessments.

Given that project risks are outlined in PPP contracts, Riesgo proves to be an ideal tool for contract preparation and drafting. Professionals can meticulously assess the risks designated for implementation in the PPP contract, subsequently integrating them into the contract. Riesgo helps to identify crucial risk factors, their interrelations, and their detailed aspects, enriching the contract preparation process and ensuring clarity without ambiguities.

Riesgo can also be used to assess the risks available in a prepared contract. Risk information from the contract can be input for the Riesgo risk assessment. For instance, stakeholders in the private sector can make informed decisions regarding participation in a PPP bid using the qualitative risk assessment conducted in Riesgo based on the prepared project contract.

During the validation process, professionals also highlighted Riesgo's suitability for monitoring project contract risks. The projects initially created in Riesgo can be easily duplicated and updated in the monitoring phase. The professionals also emphasized knowledge transfer challenges in the PPP sector arising from staff turnover in either public

institutions or the private sector. They expressed that utilization of Riesgo can facilitate knowledge and experience transfer, ensuring their continued utilization in future projects.

7.1.3. Fills the Gap in the PPP Sector for a Qualitative Risk Assessment Tool

Despite the proliferation of approaches for quantitatively assessing risks in PPPs (Rasheed et al. 2022) [23], there is a significant gap in the literature and sector concerning qualitative risk assessment for PPPs. The absence of a dedicated tool in the sector for qualitative risk assessment highlights a notable void in managing risk information in PPPs (Jiang et al., 2023) [24], which Riesgo has the potential to fill, thereby enhancing the overall risk assessment process in PPPs. The inadequacies of risk assessments, characterized by suboptimal in-house solutions like Excel sheet-based matrices/registers, can be circumvented through the adoption of a tailored and adaptable solution designed specifically for PPPs, exemplified by the case of Riesgo.

The current version of Riesgo is a prototype validated by the PPP professionals. The absence of a tool like Riesgo was also acknowledged by the professionals, and a desire to utilize it in real-world projects was expressed during the interviews. Furthermore, additional recommendations for future developments were provided. Applying these recommendations in the scope of future works can bolster the likelihood of Riesgo being widely utilized in actual PPP applications.

7.2. Limitations

During validation and verification, the prototype was used by experts involved in real-world PPP projects. These experts provided detailed feedback on the prototype's effectiveness by testing it on the real-world PPPs. One limitation of this study is that comprehensive testing of Riesgo on an actual PPP project throughout the project's lifecycle was not feasible, due to the extended time required. After implementing the improvements suggested by the experts on the prototype, the testing of Riesgo on an actual PPP, involving risk analysis at the beginning and collecting feedback on the risks encountered at later stages, can be undertaken as a case study.

In this study, Riesgo was developed as a simple prototype, with the aim to solicit expert feedback concerning the proposed approach. Due to time and budget constraints, the researchers opted to apply the minimum viable product (MVP) concept. This methodology allows for a tool or product's swift and cost-effective development, along with collecting feedback from potential users (Ries, 2011) [132]. In this regard, a desktop software model was chosen over a cloud-based collaborative web application model. This choice streamlined the development phase and aided in adhering to the project's budgetary limitations. Based on the feedback obtained during the validation and verification phase, the development of a cloud-based version of Riesgo, which will also enable collaborative project work within the same team and among different teams, is planned in the scope of future studies to enhance the model's accessibility.

7.3. Future Work

As part of future software developments, plans are in place to enhance accessibility through the creation of a web-based version of Riesgo. The web-based version will be designed to enable collaboration on the same project by multiple individuals within the same team. Alongside fostering collaboration within teams, there are also intentions to implement enhancements that facilitate collaboration among key stakeholders in PPPs. This would enable coordination of the risk assessment process for a project among the public party, private party, and lenders. A log-tracking feature can also be added to the Riesgo, which allows easy identification regarding where and by whom changes have been made. Additionally, a user role authorization feature can be beneficial. This feature allows some users solely to view the project, while others can make changes to it.

In line with recommendations from the professionals, plans include incorporating functions related to artificial intelligence (AI) into the software. One potential improvement

involves uploading the project contract into the software and automatically populating relevant fields by extracting information from the contract. This way, risk assessment regarding the contract can be conducted rapidly. Users can have the option to use AI as an assistant, providing automatic suggestions during the risk assessment process. AI can also answer user questions, expediting the assessment process. Users can leverage AI as an assistant to carry out the entire risk assessment process independently or as a supportive function to verify the assessment made.

If risks are assessed before the formation of the project contract, AI can utilize defined risk characteristics to generate relevant contract clauses. Thus, a draft project contract can be created automatically based on the information and data entered into the system. Numeric values in the project contract, also displayed in Riesgo's Financials menu (Figure 5), can trigger warnings if they surpass predetermined thresholds, notifying the user about the activated mechanisms. For instance, if the estimated annual traffic for a bridge in the contract is 1 million vehicles, and at the end of the year, it only reaches 800,000, Riesgo can report on the guaranteed amount to be paid by the treasury based on the current toll rate, as well as the mechanism that will be activated if this difference is not paid. Past court decisions can be taught to the AI in Riesgo, enabling it to learn the outcomes of similar cases. Thus, AI can inform the users about the legal consequences of risks. All these improvements aim to contribute to making Riesgo a more efficient and evolving model, thereby increasing the likelihood of its use in real projects.

Following the implementation of improvements selected from the suggestions outlined in the this section, communication with professionals will be initiated to test the new version using an actual PPP project. While utilization throughout the entire project lifecycle may not be feasible, implementation at specific stages for a real test can allow for a more in-depth exploration of its impact within the industry.

8. Conclusions

This paper introduces Riesgo, a qualitative risk assessment prototype for PPP projects. The development and research steps are explained in this paper using three main phases: (1) identifying risk register items and system requirements for the prototype, (2) developing the system architecture by implementing PPP risk factors, PPP information requirements, risk register items, and system functions to the model, and (3) conducting verification and validation processes for the prototype. The feedback collected during the validation and verification process reveals that the developed prototype Riesgo (1) is a customizable and knowledge-based system that utilizes extensive project information for qualitative risk assessment in PPPs, (2) is suitable for all stakeholders and various project phases, and (3) can fill the gap in the PPP sector for qualitative risk assessment.

Riesgo is an effective system for qualitative risk assessment in PPPs, guiding its users using knowledge-based content. With a diverse set of validated data entry fields and a predefined risk template, it streamlines assessments, saving time for users. Its customizable structure makes it suitable for all PPP projects, offering versatility as a standalone or contributory tool. It is designed for the public party and consultants in PPPs, and professionals in the sector found it suitable for all stakeholders, thanks to its customizable structure. The tool can be beneficial across various PPP phases such as early risk assessment, feasibility studies, contract preparation, and contract monitoring. Variations exist in PPP applications across different countries. Nonetheless, given that Riesgo encompasses generic PPP risk factors, items, and requirements within a customizable framework, it can be effectively utilized across different PPP models and diverse geographical locations. This advantage renders the model a universal tool, facilitating its application in various contexts. In other words, factors such as the PPP model implemented, the developmental stage of the host country, the legal system in place, or the political structure do not hinder the model's applicability.

The model can be utilized by all key stakeholders in PPPs, including the public party, private party, and lenders, for various purposes, according to their requirements. For

example, the public party can employ Riesgo during the initial stages of the project when making investment decisions. Private parties can evaluate PPP project risks based on draft project contracts and decide whether to participate in a PPP bid following the conducted risk assessment. Lenders can analyze overall project risks and utilize the model for financial risk assessments as an additional tool alongside their existing tools, aiding in the decision-making process regarding project funding. Subsequently, once the project is underway, all stakeholders can utilize Riesgo to monitor and manage project risks. The stakeholders can store and review their previous risk assessments conducted within Riesgo during the earlier project phases. This functionality facilitates the accumulation of PPP risk knowledge, which can also be transferred to future projects.

Riesgo's ability to act as an information repository facilitates knowledge transfer in the event of personnel changes in an organization. Its customizable design helps to avoid inefficiencies associated with in-house solutions like Excel-based matrices/registers. Riesgo addresses a notable gap in the literature, which is proliferated by quantitative risk assessment models, providing a qualitative risk assessment tool for PPPs to meet the predominant preference of the PPP sector. The positive validation feedback from professionals underscores the demand for such a tool in real world projects.

Future developments, such as the introduction of a web-based version, AI integration, and improved collaboration features, will likely enhance Riesgo's applicability and effectiveness in real PPP applications. The proposed improvements and ongoing efforts to seek feedback from professionals indicate a commitment to refining Riesgo for broader industry use, potentially transforming the landscape of PPP risk assessment.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings14040953/s1, Table Supplementary Material A: List of Software Reviewed for the Determination of System Functions in the Proposed Prototype; Table Supplementary Material B: PPP Risk Factors Used in the Proposed Prototype; Table Supplementary Material C: PPP Project Information Requirements Used in the Proposed Prototype; Table Supplementary Material D: PPP Financial Information Requirements Used in the Proposed Prototype; Table Supplementary Material E: Expert Profile Participated in the Delphi Study Conducted for Risk Factors Determination; Table Supplementary Material F: Expert Profile Participated in the Delphi Study Conducted for Information Requirements Determination; Table Supplementary Material G: Expert Profile Participated in the Verification and Validation of the Proposed Prototype; Table Supplementary Material H: Risk Register Items Explanations. References [133,134] are cited in the Supplementary materials.

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Determining the Critical Risk Factors of Implementing Public–Private Partnership in Water and Wastewater Infrastructure Facilities: Perspectives of Private and Public Partners in Iran

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Abstract: Due to the fact that risks can cause project delays and increase project implementation costs, successful construction project completion requires effective and holistic risk management. Identification and evaluation of critical risk factors (CRFs) associated with different types of projects are the most significant components of accurate risk management. This study aims to identify and evaluate the CRFs inherent with private–public partnership (PPP) projects specifically for the development of water and wastewater infrastructure (WWI) facilities in the developing country of Iran. In this line, a comprehensive literature analysis was undertaken to extract the CRFs in applying PPP projects for the development of infrastructure projects in developing countries in general. Then, four rounds of a Delphi survey were conducted to consolidate the major risks to the circumstances of Iran and WWI facilities. There were a total of 35 risks that were grouped into six categories. The main risks were then analyzed and ranked using the Measurement Alternatives and Ranking according to the Compromise Solution (MARCOS) technique. The overall ranking results of the various CRFs revealed that "lack of trust in government's economic programs" risk was ranked first in terms of importance, followed by the risk of "delay in timely fund payment for project financing and credits," and the risk of "delay in finalizing bank negotiations." The overall ranking of the risks placed "economic changes, such as inflation, increase or decrease in prices, and exchange rate" risk in the bottom position. According to the risk ranking findings based on the opinions of private experts, "lack of commitment to the project schedule" was placed first. Conversely, experts from the public sector considered "choosing the wrong financing method" to be the most CRF. It is anticipated that the key research findings and effective recommendations of this study will considerably contribute to the smooth development and remarkable improvement of risk management in applying PPP for WWI facilities in developing countries while enhancing different stakeholders' understanding of the CRFs for PPP projects, particularly towards WWI services in Iran.

Keywords: risk management; risk factors; PPP; water and wastewater; developing countries; MARCOS technique

1. Introduction

Today, risk and its related trends have found their place in various fields including investment; trade; insurance; safety; health and treatment; industrial and construction projects; and even political, social, and military issues. In the meantime, risk management has a special place and a common root with the project. Features such as the project

uniqueness; relative reliability in the assumptions; the project goals and requirements; uncertainty in the estimations, design, supply, and procurement of the main equipment of the project; the effect of environmental factors on the project; the relationship between the members and the goals of the project; and expecting to achieve the desired product at the end of the project process are the sources of risk in the project. Hence, there is an inevitable need for strategic management planning to check project uncertainties and risks [1].

Risk management is a logical and systematic method to analyze, evaluate, and deal with risk related to any type of activity, enabling organizations to minimize losses while taking advantage of opportunities. The greatest benefit of risk management for a company is the general reduction in the occurrence of avoidable accidents and related costs, subsequently contributing to the continuity of business activity. Risk management leads to more informed decision making, coherent planning, and efficient use of resources. The complexity of the environment, the intensity of competition, the spread of novel and advanced technologies, the development of information and communication technology, new ways of supplying goods and services, environmental issues, etc., are among the main factors leading to numerous and even unforeseen risks for organizations and economic enterprises during their lifetime [2].

Due to the limited financial and budgetary resources, governments often face many problems besetting with financing large-scale construction projects and infrastructure services. The demand for investment in large and infrastructural projects has prompted countries to use a method called public–private partnership (PPP) alongside the public sector [1].

PPPs have been widely used in developing countries to carry out numerous projects in the energy, water and wastewater, telecommunication, airport, railway, and port sectors. In recent years, there has been a strong need for infrastructure in many countries due to increasing population growth and economic development [1]. Hence, governments are trying to find a new solution for these shortcomings by employing and activating the private sector in infrastructure projects [3].

Ke et al. [4] investigated the preferred risk allocation in China's public–private partnership projects using the Delphi technique. The results indicated that the public sector was solely responsible for the risk (style of ownership and localization), and government officials were responsible for the majority of the next identified risks, which required their actions. In addition, 14 risks that the public and private sectors can deal with should be equally shared between the two parties. The private sector is responsible for 10 risks at the project level, according to which executive solutions should be proposed to overcome the identified risks. Chan et al. [5] investigated potential obstacles to the successful implementation of PPPs in Beijing and Hong Kong and prioritized 13 potential barriers to participation, extracted from the research literature. According to the research findings, lengthy delays in negotiation, lack of experience and appropriate skills, and lengthy delays because of the political debate were the top three obstacles rated by the Beijing respondents. Likewise, the first and third obstacles were also ranked within the top three by the Hong Kong respondents, while the factor of "very few schemes have reached the contract stage (aborted before the contract)" ranked as the second barrier to the partnership in Hong Kong.

Liu et al. [6] evaluated the critical factors affecting the effectiveness and efficiency of tendering processes in PPPs in Australia and China. The research identified 14 critical factors underpinning the implementation of PPP tendering under seven dimensions: robustness of business case development, quality of project brief, public sector capacity, governance structures, the effectiveness of communication, the balance between streamlining and competition, and level of transparency of tendering processes. The results of the comparative analysis of these factors in the two mentioned countries showed significant statistical differences regarding the importance of these factors among their PPP projects. It was emphasized that both public and private entities engaging in PPP projects would be in a better position to structure and manage the tendering processes by adopting the recommended strategies. Noorzai et al. [3] focused on selecting an appropriate PPP financ-

ing method to finance railroad projects in Iran. Sadeghi Shahedani et al. [7] investigated the priority development of PPPs in the transport sector of Iran. Najafi and Malekan [8] examined a strategy to finance new infrastructure PPP projects. Heibati et al. [9] studied the relationship between economic freedom and PPPs and provided a model for Iran. Maki-Abadi et al. [10] sought to identify and assess critical risk factors (CRFs) in HSR projects through PPPs in developing countries. Meanwhile, the precise identification of risks can significantly influence the management of risks within a project. The presence of risks within PPP contracts can lead to unfavorable outcomes and serve as a deterrent for contractors. In the context of developing countries, the reluctance to involve the private sector in the construction of water and sewage industry infrastructure can be attributed to the presence of several risks and uncertainties associated with such investment endeavors. Hence, the identification and examination of these risks and uncertainties, along with efforts to address them, can serve as a foundation for increased involvement of the private sector and the effective execution of PPP initiatives. Furthermore, the identification and thorough assessment of the risks involved can be regarded as a crucial first phase in the appropriate allocation of these risks between the private and public sectors. Consequently, this process will exert a substantial influence on the success and advancement of the objectives associated with these projects.

Prior research has not conducted a thorough examination of the risk assessment associated with PPPs in the water and wastewater sector. Hence, in order to address the existing research gaps, the primary objective of this work was to establish a robust methodology for the identification and assessment of risks associated with PPP initiatives in the context of water and wastewater infrastructure (WWI) development in Iran as a developing country. This study aimed to address two primary research questions: (1) What are the significant risks that pose a threat to PPP WWI facilities in the developing country of Iran? and (2) To what extent each of the identified risks can be considered a critical risk within the PPPs in Iran's WWI facilities? This can include a wide range of water and sewage projects that can be implemented with the PPP models, including water supply and water transfer projects, dam construction projects, and the construction of sewage treatment plants, etc. The presence of risks within PPP contracts might potentially lead to unfavorable outcomes and serve as a deterrent for contractors. So far, there has been a dearth of comprehensive studies examining the multifaceted risks associated with PPP initiatives in the realm of WWI development in Iran. In this study, comprehensive consideration has been given to the risks associated with infrastructure projects in Iran and other developing countries. These risks encompass various aspects such as cost, time, and quality. It is imperative to identify and address these risks in a localized and regional context. Hence, the identification and assessment of significant and influential risks, as well as their suitable allocation between the private and public sectors, will exert a substantial influence on the prosperity and advancement of project objectives.

2. Literature Review

The widespread demand and lack of capital for water infrastructure have led to the rapid growth of PPPs in the water sector. However, the current trend in this market shows that many foreign companies have either reduced their activity or are withdrawing from the market [11]. These conditions can be associated with specific risks in investing in water and wastewater infrastructure (WWI), including the current low level of water prices and the difficulty of (market) regulation. Thus, accurate identification of the risks of PPP projects in WWI is necessary along with appropriate solutions to deal with such risks [12–15].

Several studies have identified and investigated obstacles and risks related to WWI in developing countries [16,17]. According to these studies, various risks threaten the development of WWI, including failure to provide sufficient funds on time, failure to provide and pay the contractors and manpower claims on time, failure of the employer to obtain necessary permits, uncertainty, and purchase of the project site by the employer. Some studies also show that managerial, financial, legal, and political risks are the most

CRFs of water projects in developing countries, including Iran [18]. As can be seen, financial problems and issues are at the top of the risks related to the development of WWI in developing countries. PPP contracts can be a suitable solution to deal with this issue [14]. However, it is noteworthy that the use of such contracts should be accompanied by the necessary awareness of uncertainties, enabling the parties to the contract to participate in the development of infrastructure with greater certainty of success in the realization of their goals [14,18].

Risk results from the interaction of project goals, i.e., time, cost, quality, performance, the scope of work, and uncertainty, which can lead to threats or opportunities. The independent analysis of risk allocation in the water and wastewater sector has value and information content. Project risk management includes six steps: 1. risk management planning, 2. risk identification, 3. qualitative assessment, 4. evaluation, 5. risk response planning, and 6. risk monitoring and control [2].

Priya and Jesintha [19] discussed the public–private partnership among the domestic and foreign players and found that using both groups in these projects would lead to progress in India. Kayaga (2008) emphasized that local conditions in PPP water projects are often not carefully examined, due to which the project structure cannon comply with the prevailing constraints. As a result, many PPP water projects in developing countries are not carried out properly, face conflicts, or get involved in disputes that affect their performance negatively.

Ameyaw and Chan [20] introduced 40 risk factors in PPP water projects in developing countries and highlighted CRFs in this field after examining six cases from these countries. These factors included weak regulations, financial weakness, non-payment of claims, lack of experience in research related to risk identification, and limited evaluation of PPP contracts according to the environmental conditions of developing countries. Wibowo and Mohamed [21] investigated risk factors in PPP water projects in Indonesia and identified 39 risk factors, some of the most important of which included uncertainty of pricing (tariff), breach of contract by the government, lack of raw water, and high costs of infrastructure construction.

Ezeldin and Badran [22] identified 59 CRFs affecting PPP water projects through a literature review and interviews with experts and divided them into several CRFs groups. The risk factors were investigated by distributing a questionnaire among 25 experts who worked internationally and were active in the Egyptian market. They introduced risk factors such as financial and macroeconomic, commercial, legal, political, government supervision, government maturity, and technical and unforeseen risks as most CRFs groups.

In Ghana, Ameyaw and Chan [23] identified 40 risk factors in PPP water projects and introduced 22 risk factors in the form of three financial/commercial, social/political, and technical/technical groups as CRFs. In this investigation, the financial/commercial group had the highest level of total risk, followed by the social/political and technical/technical groups in the second and third ranks, respectively.

Yin et al. [24] examined PPPs in water projects in China and introduced nine risk groups, namely, construction, cooperation relationship, operational, policy, environment, political, design, macroeconomic, and financing risk factors. According to the results, financial risks were found to be the most critical group of risks in PPPs for water projects in China.

Issa et al. [25] focused on a risk allocation model for construction projects in Yemen and concluded that construction projects in Yemen always experience high levels of risk due to their complex and dynamic environments. The model was developed considering 54 risks in 10 groups. They stated that the 30 identified CRFs must be allocated to the owner or contractor, or shared between them. The results showed that this model is easy to understand and use by contract parties. The model also helps decision-makers make appropriate decisions regarding the selection among different projects based on risk factors in the bidding and price proposal stages. The risk allocation model enables risk management.

Liu et al. [6] obtained 14 critical factors in the implementation of PPP water projects according to a literature review, interviews with experts, and the distribution of questionnaires. Rezaei Noor and Mousavi [18] dealt with risk ranking in PPPs of water supply projects using failure mode and effect analysis (FMEA) and fuzzy synthetic evaluation methods in Qom province. First, 39 risk factors were introduced according to the literature and national and international research. The risk priority values were then obtained using the failure mode and effect analysis (FMEA) method. After normalization, 22 factors were recognized as CRFs and classified into four managerial, legal/political, financial, and technical subgroups. According to the examination and calculation of the overall level of risk in each subgroup using the fuzzy synthetic evaluation method, the managerial subgroup was the most critical subgroup, followed by the financial, legal/political, and technical subgroups in the next priorities. The total risk of PPPs for water projects in Qom province was 6.19, indicating high levels of risk for the mentioned projects. Rasouli et al. [1] identified, ranked, and allocated CRFs of public–private partnership stages using the Delphi technique in the framework of a resistance economy in WWI Gilan province. Their article identified, evaluated, and allocated CRFs of WWI projects in Gilan province in different stages and within each stage. The study used Build–Operate–Transfer (BOT) to extract CRFs from executive agents with direct responsibility for contracts concluded using the method of construction. A total of 37 samples were identified for the study. Then, using the Delphi technique, 17 risks with a significant degree of $\geq$3 were extracted and distributed among the samples through a questionnaire. Nonparametric statistical methods were used to analyze data collected in each stage of the public–private partnership (feasibility assessment, procurement, construction, operation, and transfer). The results showed a significant relationship between the risks with a significant degree of > 3 in different stages of public–private partnership in WWI of Gilan province. Also, this relationship was significant for each risk in each stage, except for one case.

The analysis of the identified factors in this research showed the significant contribution of different levels of risk awareness and the involvement of senior management in reducing and avoiding the identified risks. As revealed by the literature review, failure to address the risks of evaluation based on accurate approaches is an important research gap in the studies of public–private partnership projects. Therefore, the current study discusses new approaches in this field. Most of the reviewed studies used the Delphi technique, interviews, and literature review as their methodology. All these studies show that while the importance of risks identified in PPP projects varies among countries, the parties to the contract face relatively similar risks in implementing such projects in most developing countries. Therefore, a comprehensive investigation in this field can be a positive step toward the effective identification of the risks of these projects.

3. Research Methodology

The decision problem algorithm was designed based on the identification and prioritization of risks of public–private partnership projects and included three main parts. The first part was allocated to the identification of PPP risks through a literature review, including scientific articles, internet sources, books, and documents in construction companies. Then, a questionnaire was designed to ask the experts to value the risks and determine the importance of each. Risk screening was then carried out considering the mean of the total values and selecting the risks whose importance was higher than the obtained mean. The second part focused on evaluating each risk in public–private partnership projects. The questionnaire was designed and distributed in this section, while data analysis was conducted using the MARCOS method. The current study belongs to survey research. The statistical population of the study consisted of employers, consultants, executives, specialists, and experts active in WWi PPP projects all over Iran who had adequate knowledge, expertise, and experience in risk management. Figure 1 shows the approach used in this research.

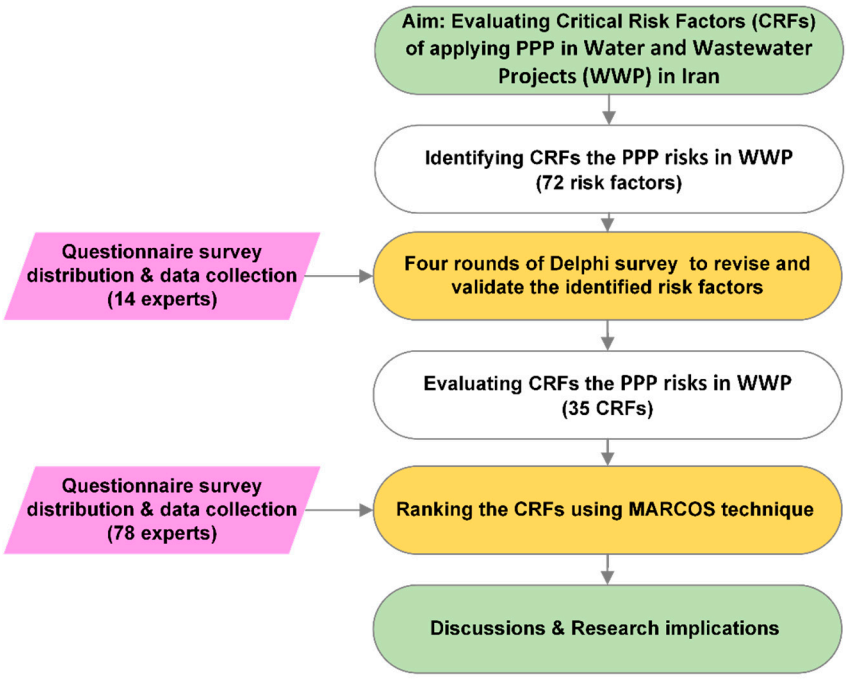

Figure 1. The research framework of the study.

3.1. Research Tools

In this study, a research questionnaire covering the risks of PPP for WWI in Iran was prepared. A total of 14 experts were asked to give their opinions on whether any identified factors could be considered risks of PPP projects in Iran's WWI. The experts provided their opinions on a five-point Likert scale (very much, much, to some extent, little, very little) to identify the risks. It is noteworthy that only items with an importance of $\geq$3.4 were selected after determining the significance of all items on a scale of one to five. This value is one of the criteria put forward by Fink et al. [26] to determine the consensus among participants regarding the inclusion or exclusion of specific elements in the Delphi method. According to Fink's perspective, the researchers have incorporated the threshold value of 3.4 to enhance the precision of screening the identified risks. In the fourth round, all the experts concluded that all the questions and categories in the questionnaire were appropriate, and a mean opinion of > 3.4 was obtained for all the questions. Therefore, the Delphi process was stopped. The researcher-made questionnaire was prepared considering the theoretical foundations along with national and international studies to identify the risks of PPP projects in WWI in Iran. The four Delphi rounds led to 7 groups (political, operational, financial, investment, environmental, economic, and managerial) and 35 risks.

The findings indicated that out of 72 risks identified in Iran's water and wastewater PPP projects through the literature review, 35 risks were critical, as represented in Table 1. The main basis for the risks identified was a comprehensive literature study pertaining to the research topic. In this context, an attempt was made to comprehensively identify all the risks connected with PPP initiatives, irrespective of their recurrence and frequency in prior research studies. Through this view, it was feasible to ascertain a comprehensive inventory of associated risks. To integrate and clarify the identified risks, risks that had similar substance and meaning were consolidated to prevent duplication and misunderstanding. Moreover, the identified risks were screened over the course of four Delphi rounds, wherein experts possessing relevant educational and professional backgrounds in PPP initiatives within the WWI sector were actively involved. Based on the Delphi survey rounds, a total of 35 dangers of significant importance were detected. The utilization of the Delphi technique for screening purposes facilitated the initial stage of risk identification in the specific context of Iran. The categorization of risks was conducted based on the classification established in prior research and afterward validated by experts through the Delphi method.

Table 1. Identified CRFs with high importance.

No.	Risk	Dimension	Source
R1	Fluctuations in the value of materials	Financial	[27]
R2	Economic instability of the country and lack of economic stability and security	Economic	[28–30]
R3	Economic changes, such as inflation, increase or decrease in prices, and exchange rate	Economic	[31]
R4	Failure to pay private sector claims on time	Investment	Expert opinion
R5	Inconsistency of the real and declared inflation by the relevant organizations and the loss of commercial enterprises	Financial	Expert opinion
R6	The disproportion between the investor's expenses with inflation and the economic conditions of the country	Investment	Expert opinion
R7	High bureaucracy dominating government institutions	Political	[29]
R8	Ambiguous economic outcomes of distribution outsourcing for the private sector	Economic	[32]
R9	Lack of trust in the government's economic programs	Economic	[33,34]
R10	Long and inefficient implementation of projects	Managerial	[35]
R11	Poor pre-investment studies and economic evaluation of projects	Economic	[32]
R12	Lack of healthy economic conditions and competition environment	Economic	[28,30]
R13	Delay in timely fund payment for project financing and credits	Financial	[36,37]
R14	Government instability and the PPP program suspension in terms of implementing infrastructure projects because of the government change	Political	[32,38]
R15	Failure in optimal allocation of credits to projects (insufficient credits) and discretionary budget allocation	Financial	[39]
R16	Lack of contractor commitment to project schedule	Managerial	[35,39]
R17	Failure to complete and deliver the project on time (with a score of 0.34 after the managerial dimension)	Managerial	[40]
R18	Lack of defined government policies to support the private sector	Political	[29,39]
R19	Continuous change of senior managers and subsequent lack of accountability and policy maintenance	Political	Expert opinion
R20	Failure to fulfill the responsibilities of the parties within the stipulated time	Operational	[38]
R21	Government and bank budget limitations to provide financial resources for partnership projects	Financial	[33,34]
R22	Changing the position of executive to investor	Investment	[35]
R23	Problems related to financial feasibility	Financial	[41]
R24	Delay in finalizing bank negotiations	Financial	[42]
R25	Increased repair and maintenance costs due to lack of proper forecasting	Financial	[43]
R26	Failure to conduct feasibility studies and cost–benefit analysis	Financial	[33,34]
R27	Outdated tax incentives	Financial	[36,37]
R28	Choosing the wrong financing method	Financial	[36,37]
R29	Lack of appropriate policies and organizational culture to create suitable grounds for investment	Investment	[33,34]
R30	Delay in the project approval by the government	Managerial	[43]
R31	Lack of credit coverage from the government for private sectors and entrepreneurs	Political	Expert opinion
R32	Lack of investment contract transparency and failure of the public sector to implement them	Investment	[33,34]

Table 1. *Cont.*

No.	Risk	Dimension	Source
R33	Excessive pollution of the urban environment	Environmental	[33,34]
R34	Environmental damage during project execution and suspension	Environmental	[44]
R35	Lack of timing, awareness, and participation of senior management due to the complex concept of the public–private partnership project	Managerial	[33,34]

The primary objective of the literature evaluation was to assess the potential risks associated with public and private partnership ventures during the First World War. The subsequent phase involved the development of a questionnaire that was formulated in accordance with the fundamental concepts of the assessments. The original questionnaire comprises a total of 72 items and was developed for the utilization of the Delphi method. Subsequently, the initial questionnaire was distributed to a panel of 14 experts [45,46]. The present study employed a purposive sampling technique to pick survey participants, an approach that has been utilized by previous scholars in comparable research domains [33]. In this context, a group of 14 individuals with extensive experience and expertise in the water and sewage business in Iran were carefully chosen from among relevant professionals. The number of respondents who participated in all four rounds of the Delphi survey remained consistent, with a total of 14 experts completing the questionnaires. The aforementioned 14 experts remained consistent throughout the Delphi procedure, and the identical fourteen-person team completed the questionnaires in all four rounds of the Delphi method. Following the establishment of a consensus, Kendall's coordination coefficient, as proposed by Siegel and Castellan [47], was employed as a prevalent statistical approach to assess the degree of agreement among the participants. The scale's value ranges from zero to one, denoting the level of consensus. A number greater than 0.9 signifies a very strong agreement, while a value of 0.1 indicates a very weak consensus [14]. According to Schmidt [48], even panels with more than 10 members regard modest values of W as meaningful. Furthermore, the final questionnaire underwent evaluation and received validation in relation to its reliability and validity. The questionnaire underwent a process of revision based on the input and insights of experts. Subsequently, the updated questionnaire was distributed to the experts for their evaluation, resulting in the development of a thirty-five-item questionnaire.

3.2. Sample Size

A preliminary study including 30 questionnaires was conducted to determine the sample size required for the current research because of the unlimited size of the statistical population. Equation (1) was used to determine the sample size in an unlimited statistical population [49], indicating a sample size of 78 appropriate for the study. Therefore, 78 questionnaires were distributed, of which 71 were returned, leading to a return rate of 91.03%.

$$n = \frac{Z_{\frac{\alpha}{2}}^2 \times S^2}{d^2} = \frac{\left(1.96^2 \times 0.051\right)}{0.05^2} = 78 \quad (1)$$

The standard error value (d), variance of the original sample (S^2), and acceptable confidence level ($Z_{\alpha/2}$) were 0.05, 0.051, and 1.96, respectively.

Sampling was conducted using the snowball sampling method, in which the research participants guide the researcher to other people who can help with the research topic. The Delphi method involves the involvement of individuals possessing knowledge and expertise in the research subject. Consequently, in accordance with the research subject's definition, the necessary expertise and composition of the Delphi panel are determined through non-probability sampling, employing a combination of targeted methods such as judgment and chain. According to the available information, an initial selection process resulted in the nomination of six experts who were deemed acceptable for inclusion in this

research study. The experts in question were affiliated with the academic staff, specializing in construction and civil engineering, construction management engineering trends, water and sewage, and occasionally other relevant areas. Subsequently, through these experts, the remaining individuals comprising the panel were introduced, each possessing a university education, pertinent professional background, and requisite expertise in PPPs within the domain of WWI initiatives. In addition, the selection of the Delphi panel members was non-probabilistic, and all individuals picked possessed expertise in the subject matter pertaining to risk management in Iran's water and sewage projects within the context of PPPs. Hence, given the panel members' expertise and familiarity with the research topic, additional training was deemed unnecessary, except for a briefing on the questionnaire's content and instructions for responding to the questions.

3.3. MARCOS Technique

The Measurement Alternatives and Ranking according to the Compromise Solution (MARCOS) technique can be defined as a novel multi-attribute decision making (MADM) method with various applications. This methodology, akin to other approaches within its category, such as TOPSIS, evaluates and prioritizes alternatives by constructing a decision matrix. In circumstances where decision-makers encounter challenges in articulating the benefits of a particular issue, this approach can serve as a highly efficacious instrument for decision making. There are various applications that can be identified, including selecting a suitable location for project development, selecting a reliable supplier, determining the business strategies of a company, and evaluating potential investment projects, among others. This method is developed on the basis of ideal and anti-ideal solutions. Afterward, the utility of the alternatives is measured, followed by the calculation of various utility functions based on the value of the alternative utilities to ultimately find the alternative weightings and their ranking. The methodology is applied to this study through the following steps [50]:

Step 1: Formation of the initial decision matrix: Multicriteria models include a set of n criteria and m alternatives. In the case of group decision making, a group of experts (r) should be formed to evaluate alternatives based on criteria. In the case of group decision making, the expert evaluation matrices are integrated into an initial group decision-making matrix.

Step 2: Formation of an extended initial decision matrix: In this step, the initial matrix is expanded by defining the ideal (*AI*) and anti-ideal (*AAI*) solutions.

$$X = \begin{array}{c} AAI \\ A_1 \\ A_2 \\ \vdots \\ A_m \\ AI \end{array} \begin{bmatrix} x_{aa1} & & x_{aan} \\ x_{11} & \cdots & x_{1n} \\ x_{21} & & x_{2n} \\ \vdots & \ddots & \vdots \\ x_{m1} & & x_{mn} \\ x_{ai1} & \cdots & x_{ain} \end{bmatrix} \quad (2)$$

The anti-ideal solution (*AAI*) is the worst alternative, while the ideal solution (*AI*) is the alternative with the best feature. Depending on the nature of the criteria, *AAI* and *AI* are defined using Equations (3) and (4):

$$AI = \max_i x_{ij} \quad if\ j \in B \quad and \min_i x_{ij}\ if\ j \in C \quad (3)$$

$$AAI = \min_i x_{ij} \quad if\ j \in B \quad and \max_i x_{ij}\ if\ j \in C \quad (4)$$

where *B* and *C* represent a group of benefit and cost criteria, respectively.

Step 3. Normalization of the extended initial matrix (X): The elements of the normalized matrix $N = \left[n_{ij}\right]_{m\times n}$ are obtained using Equations (5) and (6):

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \quad if \quad j \in C \tag{5}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \quad if \quad j \in B \tag{6}$$

where x_{ij} and x_{ai} represent the elements of matrix X.

Step 4. Determining weighted matrix $V = \left[v_{ij}\right]_{m\times n}$: The weighted matrix V is obtained by multiplying the normalized matrix N by the weighted coefficients of the criterion W_j, according to Equation (7):

$$V_{ij} = n_{ij} \times W_j \tag{7}$$

Step 5. Calculating the utility degree of K_i alternatives: The utility degrees of an alternative are calculated considering the ideal and anti-ideal solutions and using Equations (8) and (9):

$$K_i^- = \frac{S_i}{S_{aai}} \tag{8}$$

$$K_i^+ = \frac{S_i}{S_{aai}} \tag{9}$$

where $S_i (i = 1, 2, \ldots, m)$ shows the sum of elements of weighted matrix V, according to Equation (10):

$$S_i = \sum_{i=1}^{n} V_{ij} \tag{10}$$

Step 6. Determining utility function of alternatives, $f(K_i)$: The utility function represents the alternative trade-off related to the ideal and anti-ideal solutions. The utility function of alternatives is defined by the following equation:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1-f\left(K_i^-\right)}{f\left(K_i^-\right)}} \tag{11}$$

where $f\left(K_i^-\right)$ shows the utility function related to the anti-ideal solution, while $f\left(K_i^+\right)$ represents utility function related to the ideal solution. The utility functions related to ideal and anti-ideal solutions are determined using Equations (12) and (13):

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{12}$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{13}$$

Step 7. Ranking of alternatives: The alternative ranking is based on the final values of the utility function. In the most optimal case, an alternative has the highest possible value of the utility function.

This study involved conducting calculations pertaining to the Delphi rounds and reviewing the inferential findings of the study. These calculations included analyzing the demographic characteristics using the SPSS software version 25, assessing the structural validity of the questionnaire using the SmartPLS software version 4. Furthermore, the process of prioritizing the critical risks was carried out by utilizing Microsoft Excel software version 2023 to implement the MARCOS technique's calculating methodology as described in different stages.

4. Presentation of the Study Results

4.1. Statistical Analysis

This part of the statistical analysis investigated the distribution of statistical samples in terms of demographic variables. Males and females formed 74.6% and 25.4% of the participants, respectively. Moreover, 52.1% of participants were in the age range of 35–45 years, with 25.4% between 25 and 35 years, 18.3% between 45 and 55 years, and 4.2% over 55 years old. Out of the study participants, 66.2%, 16.9%, and 16.9% had MSc, MA, and Ph.D. degrees, respectively. The work experience of 31.0% of participants was 15–20 and more than 20 years, while 14.1% and 23.9% had experience of <10 and 10–15 years, respectively. On the other hand, work experience in water and wastewater was <10 years, 10–15 years, 15–20 years, and more than 20 years in 36.6%, 28.2%, 16.9%, and 18.3% of participants, respectively. Work experience in PPP projects was <10 years, 10–15 years, and 15–20 years in 53.5%, 33.8%, and 12.7% of participants, respectively. Contractors, employers/employer representatives, consultants, faculty members, experts, and financial experts formed 26.8%, 15.5%, 23.9%, 2.8%, 23.9%, and 7.0% of participants, respectively. Concerning the type of responsibility, experts/senior experts, managers, deputies, employees, supervisors/head supervisors, executive agents, and other responsibilities formed 25.4%, 23.9%, 9.9%, 18.3%, 15.5%, and 2.8% of participants, respectively. Tehran and Bandar Abbas were the cities where 38.0% and 35.2% of participants worked, respectively. Moreover, 1.4% of participants worked in Isfahan, Parsian, Bandar Lenge, Tabriz, Rasht, Mashhad, and Kerman. Karaj and Qeshm, Shiraz, and Golestan were the cities where 4.2%, 5.6%, and 2.8% of participants worked.

4.2. Ranking of CRFs of Public–Private Partnership Projects

The MARCOS method was used to rank the CRFs of PPP projects in WWI. The calculations are shown in Table 2.

Table 2. The degree of desirability of alternatives and final ranking.

Si		K−	K+	F (K−)	F (K+)	F (K)	Rank
AAI	**0.815**						
R1	0.935	1.148	0.935	0.449	0.551	0.685	6
R2	0.939	1.152	0.939	0.449	0.551	0.687	4
R3	0.855	1.050	0.855	0.449	0.551	0.626	35
R4	0.901	1.106	0.901	0.449	0.551	0.660	25
R5	0.917	1.126	0.917	0.449	0.551	0.672	14
R6	0.924	1.134	0.924	0.449	0.551	0.676	10
R7	0.918	1.127	0.918	0.449	0.551	0.672	12
R8	0.900	1.105	0.900	0.449	0.551	0.659	26
R9	0.961	1.179	0.961	0.449	0.551	0.703	1
R10	0.914	1.122	0.914	0.449	0.551	0.669	18
R11	0.912	1.120	0.912	0.449	0.551	0.668	19
R12	0.929	1.140	0.929	0.449	0.551	0.680	8
R13	0.942	1.156	0.942	0.449	0.551	0.690	2
R14	0.929	1.140	0.929	0.449	0.551	0.680	9
R15	0.916	1.124	0.916	0.449	0.551	0.671	17
R16	0.918	1.127	0.918	0.449	0.551	0.672	13
R17	0.917	1.126	0.917	0.449	0.551	0.671	15
R18	0.909	1.116	0.909	0.449	0.551	0.666	23

Table 2. *Cont.*

Si		K−	K+	F (K−)	F (K+)	F (K)	Rank
AAI	**0.815**						
R19	0.935	1.148	0.935	0.449	0.551	0.685	7
R20	0.894	1.097	0.894	0.449	0.551	0.654	27
R21	0.887	1.089	0.887	0.449	0.551	0.649	31
R22	0.889	1.092	0.889	0.449	0.551	0.651	30
R23	0.910	1.117	0.910	0.449	0.551	0.666	21
R24	0.940	1.154	0.940	0.449	0.551	0.688	3
R25	0.893	1.096	0.893	0.449	0.551	0.654	28
R26	0.911	1.118	0.911	0.449	0.551	0.667	20
R27	0.916	1.125	0.916	0.449	0.551	0.671	16
R28	0.936	1.149	0.936	0.449	0.551	0.685	5
R29	0.910	1.117	0.910	0.449	0.551	0.666	22
R30	0.922	1.132	0.922	0.449	0.551	0.675	11
R31	0.902	1.107	0.902	0.449	0.551	0.660	24
R32	0.877	1.077	0.877	0.449	0.551	0.642	33
R33	0.882	1.083	0.882	0.449	0.551	0.646	32
R34	0.891	1.093	0.891	0.449	0.551	0.652	29
R35	0.860	1.056	0.860	0.449	0.551	0.630	34
AI				1.000			

The ranks of CRFs were assessed and compared according to public and private sector professionals' opinions using the MARCOS approach. Table 3 presents the conclusive rankings of different options within the private and public sectors, separately. In fact, Table 2 presents the overall risk ranking derived from the collective perspectives of all respondents, encompassing both the public and private sectors. Conversely, Table 3 delineates the risk ranking outcomes obtained from the distinct viewpoints of the private and public sectors individually.

Table 3. The final rankings of alternatives between the private and public sectors.

Risk	Private Sector				Public Sector			
	F (K−)	F (K+)	F (K)	Rank	F (K−)	F (K+)	F (K)	Rank
R1	0.432	0.568	0.669	17	0.433	0.567	0.694	2
R2	0.432	0.568	0.685	9	0.433	0.567	0.680	7
R3	0.432	0.568	0.619	33	0.433	0.567	0.616	35
R4	0.432	0.568	0.619	32	0.433	0.567	0.663	20
R5	0.432	0.568	0.670	16	0.433	0.567	0.668	17
R6	0.432	0.568	0.675	13	0.433	0.567	0.653	26
R7	0.432	0.568	0.653	22	0.433	0.567	0.664	19
R8	0.432	0.568	0.659	18	0.433	0.567	0.673	11
R9	0.432	0.568	0.701	3	0.433	0.567	0.692	3
R10	0.432	0.568	0.678	12	0.433	0.567	0.658	25

Table 3. *Cont.*

Risk	Private Sector				Public Sector			
	F (K−)	F (K+)	F (K)	Rank	F (K−)	F (K+)	F (K)	Rank
R11	0.432	0.568	0.684	10	0.433	0.567	0.643	32
R12	0.432	0.568	0.686	8	0.433	0.567	0.669	16
R13	0.432	0.568	0.705	2	0.433	0.567	0.673	12
R14	0.432	0.568	0.698	5	0.433	0.567	0.644	31
R15	0.432	0.568	0.652	23	0.433	0.567	0.681	6
R16	0.432	0.568	0.706	1	0.433	0.567	0.653	28
R17	0.432	0.568	0.698	4	0.433	0.567	0.641	33
R18	0.432	0.568	0.658	19	0.433	0.567	0.673	10
R19	0.432	0.568	0.670	15	0.433	0.567	0.689	4
R20	0.432	0.568	0.643	25	0.433	0.567	0.671	13
R21	0.432	0.568	0.641	26	0.433	0.567	0.670	15
R22	0.432	0.568	0.614	34	0.433	0.567	0.675	9
R23	0.432	0.568	0.674	14	0.433	0.567	0.660	23
R24	0.432	0.568	0.695	6	0.433	0.567	0.682	5
R25	0.432	0.568	0.645	24	0.433	0.567	0.670	14
R26	0.432	0.568	0.688	7	0.433	0.567	0.649	29
R27	0.432	0.568	0.684	11	0.433	0.567	0.661	22
R28	0.432	0.568	0.626	30	0.433	0.567	0.712	1
R29	0.432	0.568	0.639	28	0.433	0.567	0.663	21
R30	0.432	0.568	0.657	21	0.433	0.567	0.676	8
R31	0.432	0.568	0.657	20	0.433	0.567	0.653	27
R32	0.432	0.568	0.641	27	0.433	0.567	0.638	34
R33	0.432	0.568	0.620	31	0.433	0.567	0.668	18
R34	0.432	0.568	0.635	29	0.433	0.567	0.658	24
R35	0.432	0.568	0.605	35	0.433	0.567	0.646	30

5. Discussions of Study Results

The present research sought to evaluate and rank the CRFs of PPP projects in the development of WWI in the developing country of Iran using a multi-criteria decision-making method.

The results of identifying and assessing the risks of PPP projects in the development of WWI in the developing country of Iran showed that the 10 most CRFs of PPP projects of WWI in the developing country are fluctuations in the value of materials; the contradiction in government policies; government instability and the PPP program suspension in terms of implementing infrastructure projects because of the government change; lack of defined government policies to support the private sector; economic changes, such as inflation, increase or decrease in prices, and exchange rate; long and inefficient implementation of projects; the economic instability of the country and lack of economic stability and security; insufficient resources for the implementation of the project by the relevant institutions and investors; poor management of sub-contracts; and delay in finalizing bank negotiations.

Risk assessment is necessary to achieve success in construction projects. The results of ranking the CRFs of PPP projects in WWI of the country revealed the following risks in the first to the tenth ranks: lack of trust in the government's economic programs, delay in

timely fund payment for project financing and credits, delay in finalizing bank negotiations, failure to pay private sector claims on time, increased repair and maintenance costs due to lack of proper forecasting, fluctuations in the value of materials, continuous change of senior managers and subsequent lack of accountability and policy maintenance, lack of healthy economic conditions and competition environment, government instability and the PPP program suspension in terms of implementing infrastructure projects because of the government change, and the disproportion between the investor's expenses with inflation and the economic conditions of the country.

A comparison of the ranking results obtained from the opinions of private and public sector experts indicated that the former considered the lack of contractor commitment to the project schedule, delay in timely fund payment for project financing and credits, and lack of trust in government economic programs as the most critical PPP project risks in the country's WWI. According to experts in the public sector, choosing the wrong financing method, fluctuations in the value of materials, and lack of trust in the government's economic programs were the most CRFs of PPP projects in the country's WWI.

If these economic and financial risks emerge in the early stages of the project, decision-makers of WWI PPP projects can withdraw before overinvestment. On the other hand, decision-makers can avoid these risks through insurance against the economic and financial risks of WWI PPP projects. This insurance would be even more financially acceptable if those responsible for WWI PPP projects have already invested in other projects. Large-scale projects allow power holders to control investments with varying degrees of risk exposure, subsequently reducing the overall risk of failure. However, insurance protection is not effective for risks with traffic permits and the condition of nearby buildings, which are always outside the control of the project management team. These risks can delay (or undermine the outcome of) WWI PPP projects and reduce their value. In these cases, decision-makers of WWI PPP projects can choose between continuing the project while trying to maintain economic and financial balance, or suspending the project if these risks affect the possibility of achieving the planned return on investment. Finally, the risks resulting from failure to use and share experiences, incorrect technical knowledge transfer, and the weakness of pre-investment studies and economic evaluation of projects can also play a critical role by delaying the implementation of WWI PPP projects while weakening its management and coordination. Meanwhile, these risks can be directly controlled because they relate to the processes enabled by the management of WWI PPP projects. The incorrect technical knowledge transfer can usually be addressed through appropriate training courses that can properly transfer knowledge and show how to benefit from technology for WWI PPP projects. The same solution applies to poor pre-investment studies and economic evaluation of projects, which can jeopardize the feasibility study of WWI PPP projects. Overall, the recruitment of qualified managers and consultants should minimize forecasting errors of the management team.

Within the scope of the identified critical risks, certain risks pertain to intra-project matters while others pertain to extra-project matters. However, it is important to note that all of these risks have the potential to exert a substantial impact on the success of PPP projects aimed at developing WWI. The extent of this impact may vary depending on the prevailing conditions, such as the level of development in the country in question. Certain external risks, such as economic fluctuations like inflation or fluctuations in prices, are outside the control of the entities overseeing WWI PPP projects. These risks can significantly affect the life cycle stage in particular. Indeed, should these economic and financial risks manifest during the initial phases of the project, the individuals responsible for making decisions on water and sanitation infrastructure PPP initiatives may find themselves in a position where they can only hope that they have not already made excessive investments. However, it is possible for decision-makers to mitigate these risks by utilizing insurance as a means of safeguarding against the economic and financial uncertainties associated with WWI PPP projects. The financial viability of this insurance would be further enhanced if the stakeholders involved in WWI PPP initiatives have

previously made prior investments in other ventures. The process of expanding the project enables established entities to manage investments with different levels of risk exposure, thus effectively mitigating the overall risk of potential failure. Nevertheless, insurance coverage is ineffective in mitigating risks associated with traffic permits and the condition of neighboring structures, as these factors consistently lie beyond the purview of the project management team. If these risks manifest, they have the potential to impede the progress or effectiveness of water and wastewater infrastructure PPP projects, thereby diminishing the overall value of such projects. In such instances, the decision-makers overseeing water and wastewater infrastructure projects implemented through public–private partnerships (PPPs) face the option of either persevering with the project while striving to uphold economic and financial equilibrium, or opting for its liquidation if the associated risks impede the attainment of the projected return on investment. In conclusion, the absence of utilization and sharing of experiences, inadequate methods of transferring technical knowledge, and insufficient pre-investment studies and economic evaluations of projects can significantly affect the implementation of WWI PPP projects. These factors can lead to delays in project execution and undermine the effectiveness of project management and coordination, similar to the aforementioned cases. Simultaneously, these factors can be directly regulated as they pertain to the operations facilitated by WWI PPP initiatives. The ineffective method of transmitting technical knowledge may often be resolved by implementing suitable training programs that effectively disseminate knowledge and provide guidance on leveraging technology for WWI PPP initiatives. The aforementioned issue pertains to the vulnerability of pre-investment studies and economic evaluations in the context of WWI PPP projects, hence posing a potential threat to the viability assessment of such endeavors. Indeed, the utilization of competent managers and consultants has the potential to mitigate forecasting errors made by the management team.

As anticipated, given the temporal constraints imposed by sanctions and significant economic challenges in Iran, the primary PPP initiatives pertaining to WWI were associated with the category of economic hazards. The imposition of sanctions on Iran has led to a reduction in available funds and a rise in inflation, consequently impacting the cost of equipment and materials. Consequently, factors such as fluctuations in exchange rates and inflation, coupled with changes in bank interest rates, introduce significant uncertainties for WWI projects operating under the public–private partnership model. The underlying cause for this phenomenon can be attributed to the reliance on imported mechanical, electrical, and construction components and equipment from industrialized nations for water and sewerage projects in Iran. Hence, the expenses associated with the development of WWI in Iran exhibit a direct correlation with variations and swings in the currency rate. Moreover, the acquisition of these projects frequently encounters challenges, thus leading to adverse consequences during project execution and consistently impeding the progress of water and sewage initiatives in Iran. Given the unique characteristics inherent in these projects, the successful attainment of project completion necessitates the presence of a proficient and knowledgeable personnel. In Iran, a significant proportion of the workforce possesses expertise primarily in the domain of uniform building goods. Consequently, there is a pronounced demand for training programs to address this specific area of specialization. The aforementioned matter is readily apparent in relation to the installation of mechanical and electronic apparatus. Conversely, the appreciation of the exchange rate has rendered the employment of foreign professionals in water and sewage development projects by government and private entities in Iran exceedingly challenging. The cost of constructing water and sewage projects will be significantly influenced by the importation of technical and engineering services in this particular context. In relation to the potential risk of investors' spending becoming disproportionate to inflation and the prevailing economic conditions, it is recognised that economic challenges might indeed result in a reduction of contractors' profit margins. Consequently, this may give rise to various claims being made thereafter. The outcome of this matter will have implications not only on the management

of executive affairs and the final product quality, but also on the potential legal ramifications and difficulties faced by the involved parties.

The results of this study align with prior research investigations. The findings presented exhibit similarities to the research conducted by Valipour et al. [42]. They demonstrated that risk indicators in highway PPP projects in Iran primarily stem from factors such as domestic and international fluctuations, the country's economic efficacy, labor force dynamics, construction attributes, and consulting and contractual provisions. There exists a correlation between the two. In another investigation, Chan et al. [51] employed the Delphi technique to ascertain and rank a set of risk assessment criteria pertaining to social, economic, environmental, and technological prerequisites that are closely associated with the advancement of PPP initiatives. The risks associated with a project are subject to change based on the prevailing project conditions. However, the outcomes of this study align closely with prior studies. In their study, Hatfi et al. [52] assessed the risks associated with projects implemented through the Build–Operate–Transfer (BOT) method. The identified risks encompassed initial price fluctuations, inflation rate increases, exchange rate fluctuations, bank interest fluctuations, and tax increases, as well as the absence of clear policies. In terms of attaining financial success, in a separate study, Kumar et al. [53] elucidated the potential risks associated with inflation, government bonds, local legislation, equipment suppliers, and technology choices in the context of PPP projects. Furthermore, in a separate study aimed at assessing risk indicators in PPP projects, the researchers documented many factors including the economic efficiency of the country, the labor dynamics, and the construction characteristics, as well as the quality of consulting and contractual services.

The findings of this study have practical implications for project stakeholders, as they may utilize them to effectively achieve the primary goals of the project. This can be accomplished by giving particular consideration to the risks that have the greatest impact on the project's performance over its entire life cycle. In relation to this matter, one of the risks identified in this study pertains to the potential influence of exchange rate changes on all project objectives. Hence, the implementation of projects in countries and/or time periods characterized by a stable currency rate enhances the attainment of project objectives. Nonetheless, it is important to acknowledge that project risks exhibit fluctuations over time, contingent upon the project's advancement [54,55]. This holds particularly true for financial risks, including the volatility of exchange rates, which have the potential to undergo abrupt alterations as a consequence of unforeseen occurrences [56], particularly those originating from external sources. Therefore, considering the project's life cycle [57–59], it is evident that the influence of the identified risk groups cannot be limited to certain periods of WWI project construction. I engaged in a study utilizing the PPP concept. When examining the domain of "management" risks, it becomes evident that the constituent risks within this category hold significance across many stages of the WWI projects' life cycle when implemented with the PPP model. This scenario pertains to the occurrence of "governmental delay in granting design approval," which tends to be more prevalent during the initial phases of WWI projects implemented under the PPP model. Another significant risk that persists throughout all project stages is the "inadequate management of component contracts." The water and wastewater sector operates under a PPP model, encompassing several aspects such as design and engineering, as well as procurement and construction. Given the aforementioned considerations, it is advisable for practitioners to address and minimize individual risks that are prone to occur at various stages of the water and wastewater project life cycle in PPP. Additionally, it is crucial to continuously monitor the development of risks and their impact on project performance, even after the stages where they are anticipated to arise have been surpassed. This can be achieved through the utilization of methodologies such as the real options method or scenario-based approach, as demonstrated by previous studies [60,61]. In general, WWI projects implemented using the PPP model may encounter disparities in both external and internal conditions, leading to the emergence of unforeseen dangers that were previously

deemed improbable. Therefore, it is imperative for professionals to diligently consider risks and changes in both the internal and external environment and adequately equip themselves to address their manifestations [62].

This study examined the factors contributing to the increased risks of WWI PPP projects in Iran. The review was conducted by a panel of experts who possess a high level of proficiency in the subject matter pertaining to risk management in public–private partnership projects. Based on the findings, it was determined that 35 risks were within the critical range. Subsequently, the final assessment of critical risks in PPP projects within the WWI industry was conducted by integrating the outcomes of the first stages and employing the MARCOS method. The comparison of the findings from this study with those of previous research demonstrates the robustness of the results and suggests that the key risk factors have been accurately identified, with the outcomes possessing adequate validity. WWI infrastructure development has emerged as a significant priority in numerous developing nations, with Iran being no exception, over the past few years. The findings are given in alignment with prior questionnaires and existing literature, thus offering a foundation for practical initiatives and potential enhancements to the quality of infrastructure.

6. Conclusions

Risk assessment in construction projects is necessary to ensure successful implementation. The current study aimed to identify, evaluate, and rank the CRFs of PPP projects in the development of WWI in Iran as a developing country. The results highlighted 35 risks as critical. Fluctuations in the value of materials, the contradiction in government policies and instability of the government, and the PPP project suspension when implementing infrastructure projects due to government change ranked the first to the third CRFs. Accurate risk assessment is carried out using different criteria. This study identified 13 risk assessment criteria using the research background. The results of ranking 35 risks of PPP projects in WWI of Iran using the MAROS method indicated that lack of trust in the government's economic programs, delays in timely fund payment for project financing and credits, and delay in finalizing bank negotiations were the first to third priorities. A comparison of risk ranking according to the opinions of experts in the public and private sectors indicated that choosing the wrong financing method and lack of contractors committed to the project schedule were ranked first by the public and private sector experts, respectively.

The risks associated with PPP projects in WWI facilities are integral to the executive measures involved in the development and implementation of project-oriented activities. These risks cannot be disregarded by organizations and are consistently incorporated into the project planning system. The user's text is a simple statement. In the context of PPP initiatives, it is imperative for execution companies to adopt appropriate effective measures to cope with and mitigate the risks associated with such endeavors. This entails the execution of proper control mechanisms aimed at minimizing the impact of recognized risks on the whole project delivery process. In cases where some risks are deemed uncontrollable, corporations should handle them directly. It is imperative to make adequate efforts and preparations in order to deal with and mitigate any risks arising. The objective of this study was to ascertain the essential risks associated with PPP projects. To achieve this, an innovative framework was developed utilizing the MARCOS approach. The study's findings have provided a strong foundation for proper risk management in PPP projects, offering valuable insights for WWI firms in Iran and other developing nations. These insights enable these companies to effectively and efficiently monitor and detect the key risks associated with PPP projects.

The study's findings propose several successful implementation options and insightful measures that policymakers might consider to enhance the position of private sector investment in developing nations, hence offering practical implications for policy development, formulation, and decision making. For example: (i) The primary objectives include the acquisition of foreign exchange and the elimination of obstacles and concerns related to

investment. (ii) Another goal is to fulfill international trade obligations, such as reducing clearance time, and maintaining political stability within the country to enhance satisfaction among foreign investors. (iii) The government aims to achieve a satisfactory return on capital within a specified timeframe. (iv) The government of developing nations seeks to identify competent integration managers who possess a strong educational background and abundant professional experience. These managers play a crucial role in engaging with private investors and garnering support for WWI projects. Based on the available information, it is crucial for both practitioners and policymakers to actively engage in the effective implementation of PPPs. Specifically, institutions must prioritize ensuring adequate transparency and conducting unbiased evaluations of legislation to develop and assess the PPP selection criteria for potential bidders. These factors are identified as primary determinants for achieving success in PPP initiatives. In this context, it is essential for policymakers to initiate the establishment of a comprehensive regulatory framework, accompanied by well-defined and explicit selection criteria, to effectively identify the most competent private sector partners for participation in PPPs in the field of water and wastewater infrastructure facilities in developing nations like Iran.

The main limitation of this research is the small number of experts who participated in the survey, although they can certainly be regarded as suitable for the research. Future studies should increase the validity of the proposed results by either a greater number of experts participating in the survey or replicating the presented study in other developing countries. In addition, it would be interesting to compare the results between developing and developed countries to identify their similarities and differences. The findings of the present research study can be a suitable tool for decision making in both public and private sectors to successfully implement proper risk management of PPP projects in the WWI sector.

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Exploring Risk Factors Affecting Sustainable Outcomes of Global Public–Private Partnership (PPP) Projects: A Stakeholder Perspective

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Abstract: As a model for delivering infrastructure initiatives, public–private partnerships (PPPs) have gained significant popularity in recent years. The globalization of PPP has exposed them to elevated risks emanating from the international real economy and financial market, which can ultimately result in project cancellations or distress. This study analyzes risk factors affecting the sustainable outcomes of global PPP projects from a stakeholder perspective. After identifying the interests of key stakeholders and examining how various risks influence stakeholders' interests, a two-step binomial probit model is used to investigate domestic and international risk factors in PPP arrangements based on the World Bank PPI database. The empirical results indicate that inflation has a substantially positive effect on project failure, while factors such as PPP experience, central government involvement, exchange rate fluctuations, etc., significantly contribute to PPP success. In addition, the study demonstrates that trade openness and net foreign direct investment (FDI) inflow are crucial for the transmission of global risks. The study also provides policy implications and recommendations from a risk allocation–stakeholder relationship perspective to enhance the resilience of PPP initiatives based on these findings.

Keywords: public–private partnership (PPP); risk factors; sustainable outcomes; stakeholder relationship

1. Introduction

Over the last two decades, the public–private partnership (PPP) model has been widely implemented in over 134 countries to deliver infrastructure, with the market growing to USD 1049 billion, contributing 15–20% of total global infrastructure investment [1]. With the widespread adoption of the PPP model, the economic and financial sustainability of PPP projects has emerged as a crucial concern in both the practical and academic spheres. PPP aims to combine the benefits of competitive bidding and flexible negotiation and to allocate risk between the public and private sectors on an agreed-upon basis [2,3]. As a prominent method for achieving performance, reducing transaction costs [4], fostering innovation and competition, and transferring procurement risks [5], the PPP form of procurement is theoretically recognized as an efficient means of delivering value-for-money infrastructure and public services [6]. However, the outcomes of these projects often fall short of expectations due to various internal and external risk factors that persist throughout the project's lifecycle. These factors pose significant obstacles to the sustainable development of PPP projects [7–9].Evidence from the industry indicates that some infrastructure projects have failed at the country or project level, with some critical determinants linked to global risk factors.

The notion of project resilience and sustainability gained prominence in the late 1980s [10], and emerged as a pivotal global concern in the industry, particularly within the realm of project management and infrastructure investment [11]. In the past decade, along with the introduction of the Sustainable Development Goals (SDGs) by the United

Nations [12], the concepts of project resilience and sustainability have increasingly gained significant attention and popularity [9,13]. This surge in interest coincided with the construction industry's pioneering efforts in addressing environmental, economic, and social factors in the whole life cycle management of buildings and infrastructure [10], where resilience is commonly associated with responding to extreme events [14].

More recently, the concept of infrastructure project resilience has expanded its scope beyond construction, engineering, and ecological resilience in the face of enduring challenges and unprecedented incidents to encompass essential project management facets, including financial robustness, economic viability, and long-term socio-economic benefits [10,11]. Public–private partnership (PPP) concessions typically span 8 to 30 years [7] and involve diverse stakeholder interests [15–20]. PPP's foundational premise lies in its theoretical capability to judiciously allocate risks among participants, harmonize stakeholder interests, and thereby bolster the project's long-term financial and operational resilience. The overarching goal of PPP lies in its potential to achieve sustainable outcomes aligned with the principles of resilient infrastructure [10].

Globalization is another trend that is reshaping the conventional landscape of infrastructure delivery. Globalization has accelerated at an unprecedented rate through increased trade and investment, cross-border migration and mobility, economic and security interdependence, and the worldwide involvement of multinational enterprises (MNEs) and financial institutions that have diversified their global assets. In the last two decades, the involvement of foreign investors, contractors, and multilateral organizations has become a key feature of global infrastructure development. Institutional investors from various countries have invested in a range of infrastructure projects [1]. Furthermore, the rise of international contractors is changing the infrastructure and PPP arena. The top 250 international contractors in the construction industry have a combined contracting revenue of USD 522 billion from projects outside their home countries. Research indicates that the involvement of multinational enterprises (MNEs) and multilateral development banks (MDBs) in PPP projects may have a detrimental impact on project survival [21].

Although there is a heated discussion on the winners and losers of globalization, it is undeniable that globalization has brought shared prosperity and shared risks. In a globalized world, countries and projects are interconnected through investment and trade, resulting in the international transmission of financial stress and economic shocks, which can transfer risk from one specific country or group of countries to the entire global economy. During the Eurozone sovereign debt crisis, sovereign rating downgrades and rising costs of debt led to the bankruptcy of many PPP projects. Considering the various stakeholders involved in a PPP arrangement, the channels of risk transmission that affect project outcomes are complex, and the channels themselves can be highly interconnected.

This paper aims to examine the factors that contribute to the success of PPP, with a particular focus on the impact of risks that transcend national borders. To achieve this goal, the study draws on a global database and a quantitative approach to validate existing literature on the key determinants of PPP outcomes. The empirical findings underscore a significant positive correlation between inflation and project failure. Conversely, attributes such as PPP experience, central government engagement, and exchange rate fluctuations exert notable influences, collectively contributing to the success of PPP ventures. Furthermore, the study underscores the critical significance of trade openness and the inflow of net foreign direct investment (FDI) in facilitating the transmission of global risks. Within this context, the government emerges as a central stakeholder, assuming a pivotal role in effectively managing international risks. Equipped with an array of financial and monetary policies, the government stands poised to address and mitigate these multifaceted challenges. Drawing from these insights, this study contributes to the body of knowledge in two ways: (1) it offers a fresh perspective in the context of today's interconnected world, highlighting the links between global economic cycles, cross-border risk, foreign investment, and PPP outcomes; and (2) it enriches the stream of research on project success/failure by linking stakeholder analysis to project survival and revealing the potential justification for government and

multilateral development bank (MDB) support for PPP projects in the face of global risk and economic fluctuations, which help to increase the resilience and sustainable outcomes of PPP projects.

2. Overview of World Bank PPI Database

The World Bank Private Participation in Infrastructure (PPI) database is a comprehensive resource that documents PPP/PFI projects across approximately 130 emerging economies, which includes a total of 16,330 project records. After removing duplicate entries, the dataset comprises 7286 projects, of which 383 are classified as failed projects. This gives an overall failure rate of 5.26%. The PPI database is widely used in the literature and provides valuable insights into the performance of PPP/PFI projects in emerging economies.

Analysis of the PPI database reveals an uneven distribution of PPP development in emerging countries, with East Asia and Latin America leading in the number of projects while Africa and the Middle East lag behind. Furthermore, the data highlights a positive correlation between economic development and the number of PPP projects, with upper-middle-income countries accounting for the majority of projects. In terms of sectoral distribution, Energy projects exceeded the number of Transport projects by more than twofold and more than triple the number of Water and Sewerage projects. In contrast, ICT projects were the least common (See Figure 1).

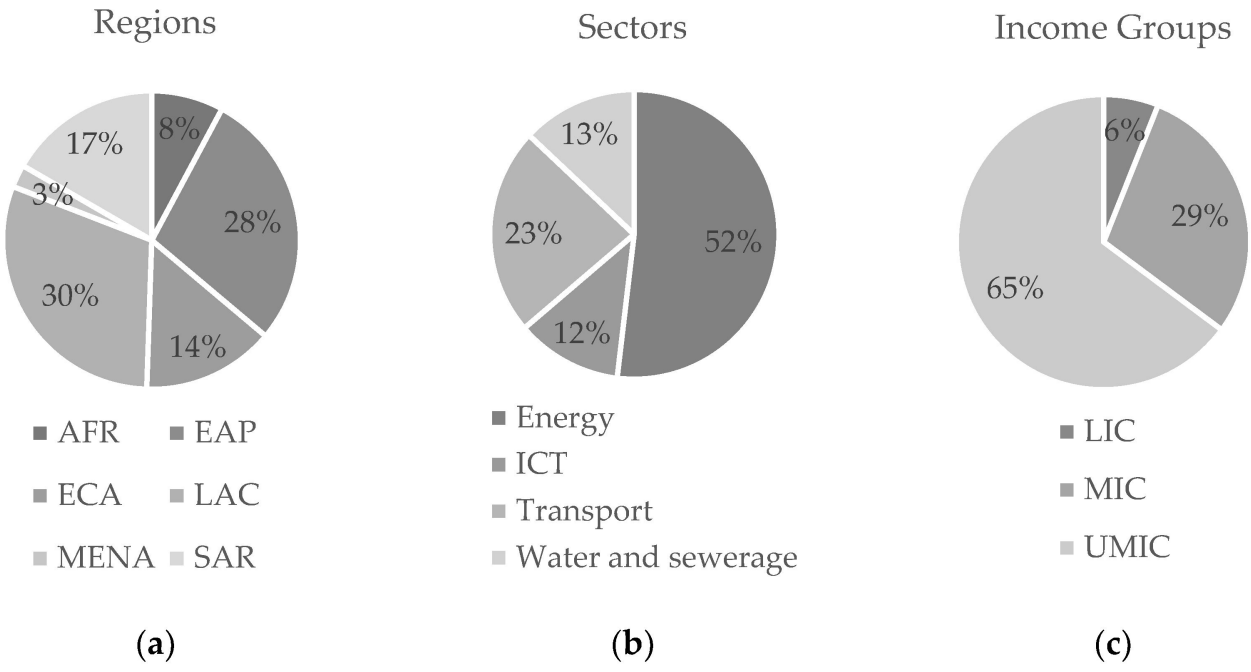


Figure 1. Devision of the database by (**a**) regions, (**b**) sectors, and (**c**) income groups.

Figure 2 provides a visual representation of the number of new and failed projects between 1990 and 2015. The solid line shows the number of new projects that reached financial closure each year, while the dotted line represents the number of projects that failed during the same period. It is worth noting that both trends show a similar pattern, with a correlation coefficient of 0.41 (Figure 3).

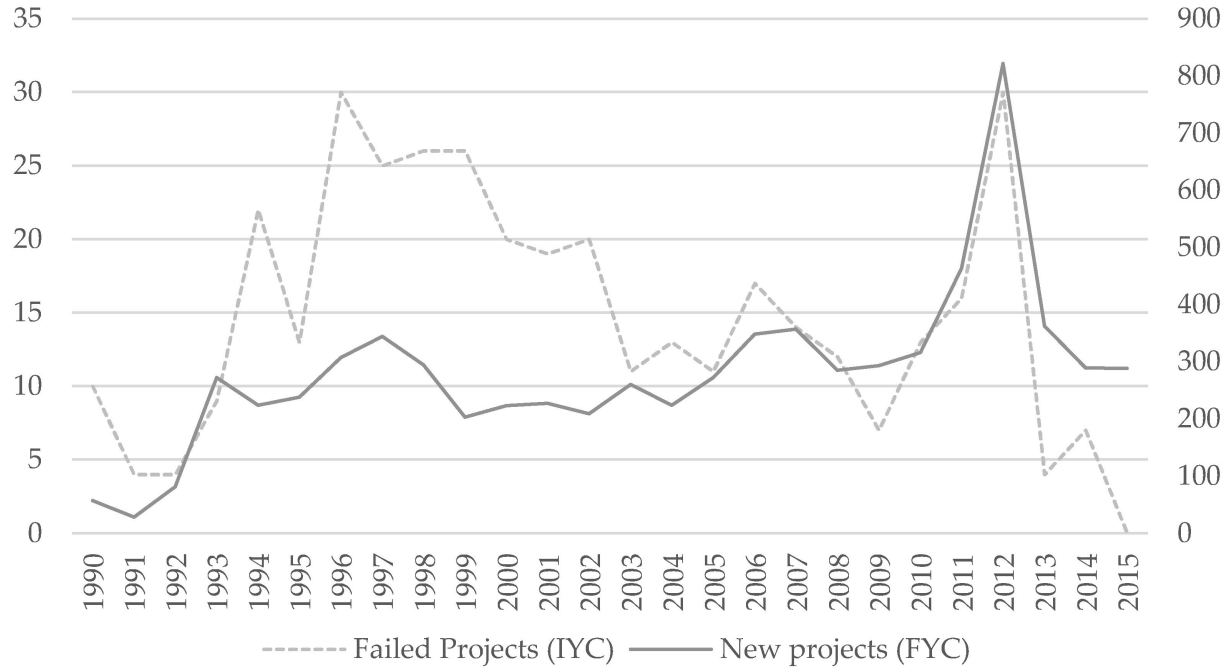


Figure 2. Global trend in failed projects and new projects.

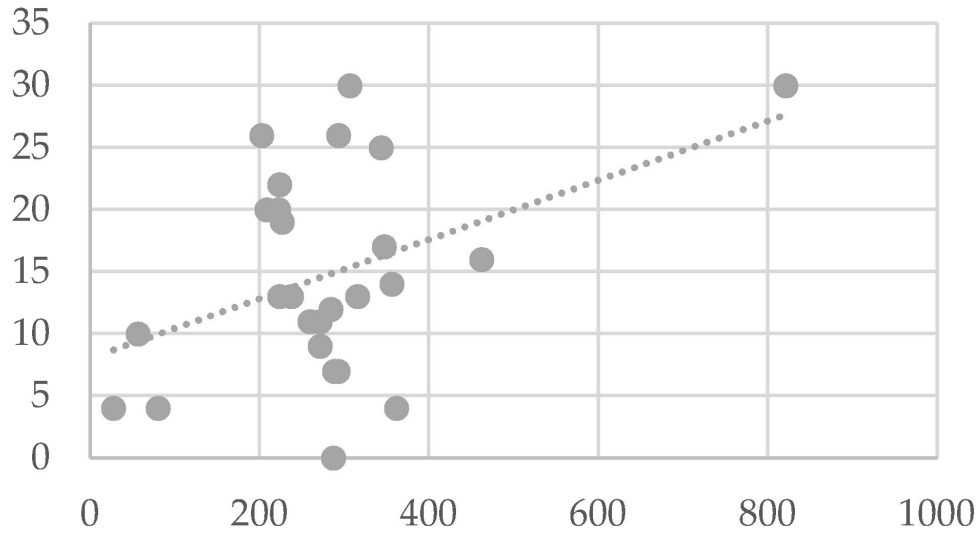
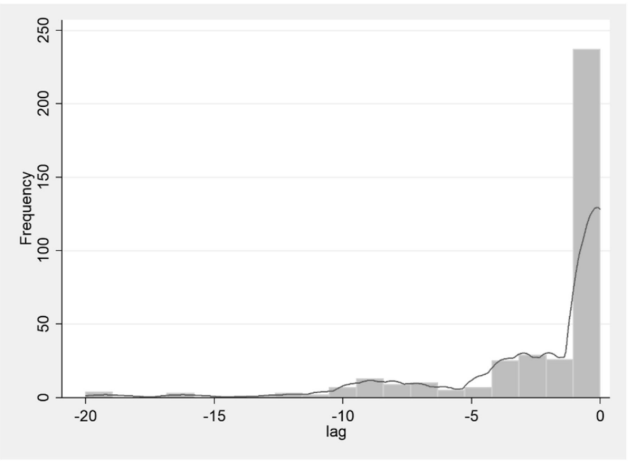


Figure 3. Correlation between failed projects and new projects.

There are two anomalous surges in project activity that occurred between 2006 and 2007 and between 2011 and 2012, which deviated from the global downward trend observed since 1997/98. Notably, the first surge was followed by the global financial crisis of 2007–2008, while the second surge coincided with the sovereign debt crisis. It is noteworthy that a one-year temporal lag was observed between the first surge and the onset of the financial crisis, whereas the second surge occurred one year after the onset of the sovereign debt crisis. This finding aligns with Chudik and Fratzscher's analysis [22], which highlights the differing impacts of these two crises on global economies. The present study's findings lend support to the notion that international factors, such as macroeconomic conditions, can have a profound impact on PPP resilience, and should be given due consideration when assessing risk in such ventures.

With respect to failed projects, our analysis reveals that the period between financial closure and the year in which a project is classified as "Cancelled" or in "Distress" is

typically less than ten years. In the majority of cases, failed projects exhibit a swift decline in performance immediately following financial closure. Specifically, a large proportion of failed projects are classified as being in distress within the first year after achieving financial closure. These findings underscore the importance of carefully assessing project viability and risk prior to financial closure and suggest that early indicators of project distress should be closely monitored and acted upon to minimize the risk of project failure (Figure 4).



lag	Freq.
-20	1
-19	3
-17	1
-16	3
-14	1
-13	1
-12	3
-11	2
-10	7
-9	13
-8	9
-7	10
-6	5
-5	7
-4	25
-3	29
-2	26
-1	29
0	208

Figure 4. Time lag between financial closure and project failure.

Figure 5 illustrates the number of new projects that achieved financial closure each year (represented by the solid line), as well as the number of projects that failed during the same period (represented by the dotted line). By breaking down the global trend into regional trends, the analysis reveals how region-specific economic phenomena can impact the outcomes of PPP projects. For example, the steep increase observed in the East Asia region between 1995 and 1998 can be attributed to the Asian Financial Crisis of 1997–1998, which was largely driven by currency risks. Similarly, the impact of the Latin American Economic Liberalization movement of the 1990s is evident in the graph, which shows a sharp rise in both failed and new projects between 1990 and 1999, followed by a gradual decline. These findings provide compelling evidence that the determinants of PPP project outcomes go beyond individual countries and are influenced by global and regional economic trends. As such, it is crucial to consider such factors when assessing the risks associated with PPP projects and developing effective risk mitigation strategies [23].

Figure 5. Trends of new and failed projects in (**a**) East Asia and (**b**) Latin America.

By analyzing the data on a sectoral basis, it is noteworthy that the Energy sector experienced a significant increase in the number of new projects (represented by the solid line) from 2011 to 2013. This trend may be attributed to the high level of oil prices during the period from 2011H1 to 2014H1, as depicted in Figures 6 and 7.

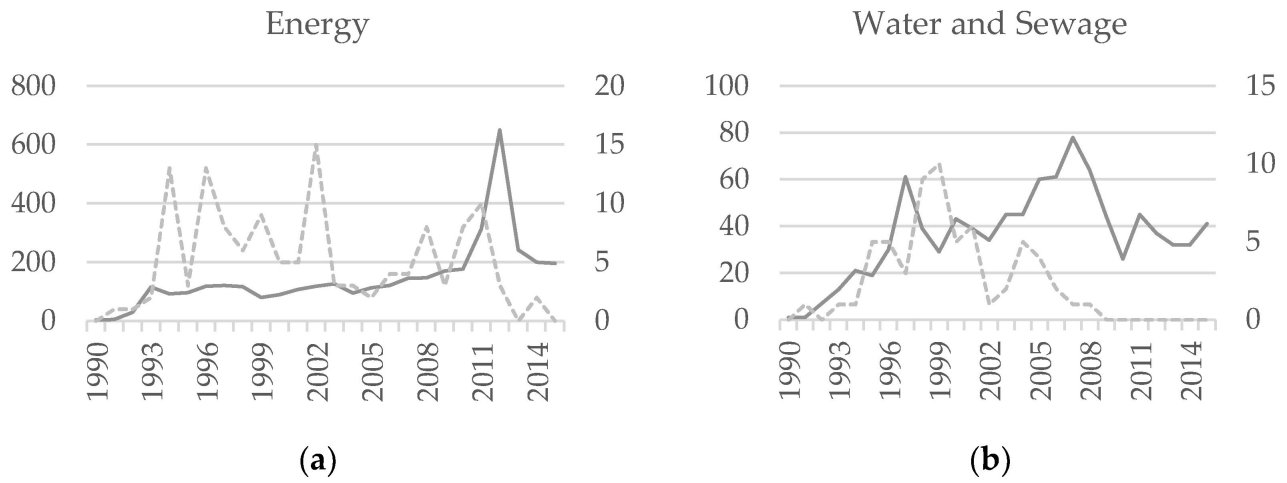


Figure 6. Trends of new projects (represented by the solid line) and failed projects (represented by the dotted line) in (**a**) Energy and (**b**) Water and Sewerage sector.

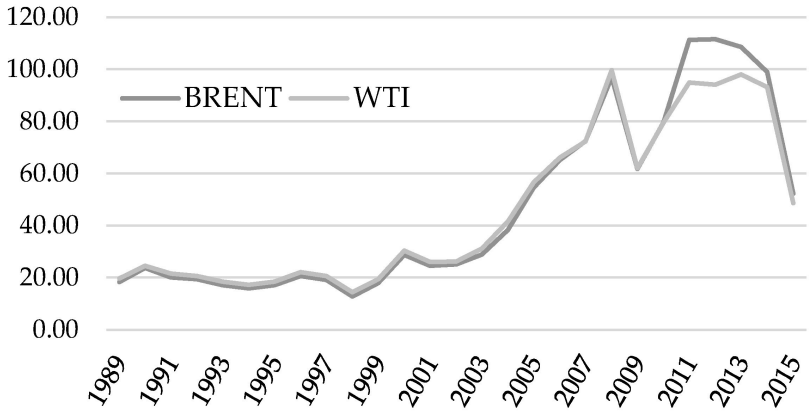


Figure 7. BRENT and WTI oil prices (1989–2015).

3. Literature Review

A notable feature of PPP projects is the involvement of multiple stakeholders with diverse interests, making it challenging to identify the risk factors that contribute to the sustainable outcomes or failure of projects [15,16]. Stakeholder theory was selected as the most appropriate framework for the research question [2,15–17], while other theories such as incomplete contract theory [24], agency theory [5], transaction cost theory [4,25,26], the perspective of critical success factors (CSF) [27–29], or collaboration, network, and governance perspectives [15,30–32] were not employed. For instance, agency theory was not pursued as it focuses on the principal–agent relationship (public sector and the SPV) [5,17] and does not delve into the interrelationships among various stakeholder groups as explored in this study. Furthermore, the exploration of network and governance perspectives was omitted due to the intricate nature of such analyses, which would necessitate in-depth case-by-case analysis to uncover nuanced factors such as trust, entrepreneurship, and resource allocation capabilities [15,30,31].

3.1. Risk Allocation and Stakeholders in a PPP Project

This paper will focus on stakeholder theory in the specific context of PPP and its unique features [2,17,18,33]. Despite the fact that PPP lacks a common definition, the definition widely used by the practitioners may be structured as follows: "A cooperative venture between the public and private sectors, built on the expertise of each partner that best meets clearly defined public needs through the appropriate allocation of resources, risks, and rewards" [11]. According to stakeholder theory, stakeholders are defined by Freeman as any group or individual who can affect or is affected by the achievement of the organization's objectives [34]. El-Gohary et al. [19] further define stakeholders in a PPP arrangement as any person or organization that has a legitimate interest in a project. The approach to stakeholder analysis involves three levels of stakeholder analysis: rational, process, and transactional. The rational level addresses stakeholder identification and perceived stakes, while the process level involves classifying stakeholders based on their interests, stakes, and power [34,35]. The transactional level focuses on managing stakeholder relations, trade-offs, and understanding stakeholder legitimacy. Clarkson also distinguishes between primary stakeholders, who significantly impact the organization's survival, and secondary stakeholders, who influence or are influenced by the transaction but are not directly involved in transactions with it [36].

Infrastructure projects, especially in the context of PPP, require the careful consideration of stakeholders throughout the project life cycle. Stakeholders may possess different relationship traits or attributes, including power, legitimacy, and interests [37]. The primary concern is identifying stakeholders with a significant potential influence on the project's success and allocation of responsibilities and accountability. Figure 8 depicts the intricate network of stakeholder relationships between those parties in a typical PPP arrangement with international participants, and most projects in the World Bank PPI Database may fall into this category. Below we will illustrate the role, function, power, and interests of each party in more detail.

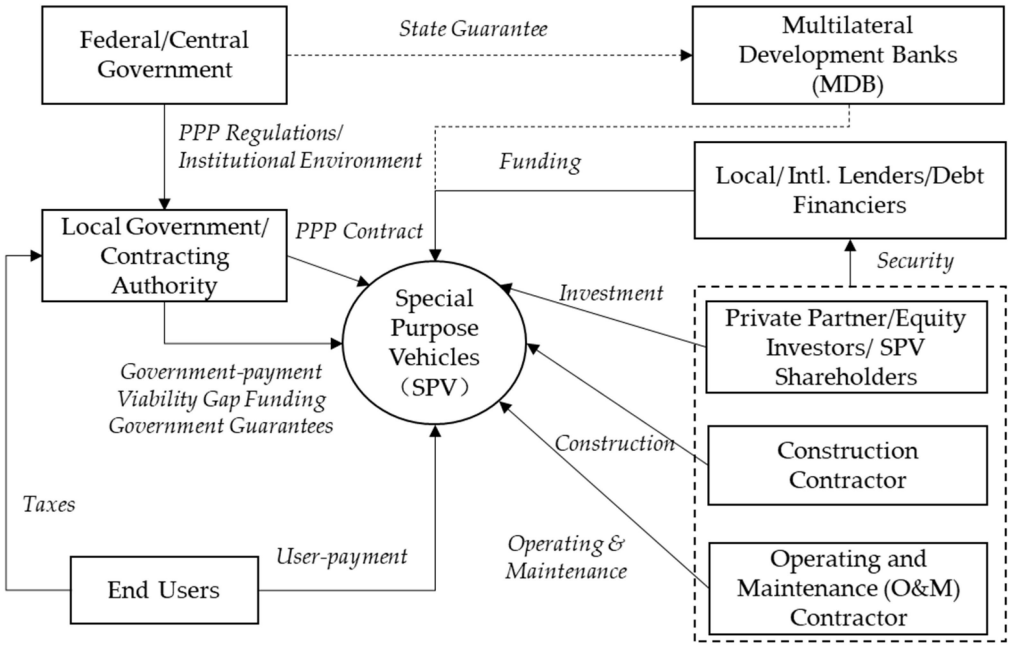


Figure 8. Stakeholder relationships in a typical international PPP project (drawn by authors).

The government's power and interests are four-fold: firstly, as the project sponsor, local governments are responsible for ensuring that the project aligns with the central government's policies, long-term objectives, and public interests when negotiating with other local governments [38]; secondly, as the contract-awarding party, tendering party,

and party which proactively selects its private partner for the special purpose vehicle (SPV), the government is responsible for ensuring the private partner's qualifications and the effectiveness of the contract, the output specifications being clearly outlined, the decision-making process and the tendering process being competitive and transparent, and avoiding allocating too much risk to investors or lacking accurate predictions of demand. Thirdly, the government is normally responsible for the following during the project planning and construction phase: (1) the delivery of the land and site; (2) coordinating and facilitating all dealings with the appropriate government authorities; (3) obtaining, in a timely manner, and thereafter maintaining the approvals required for construction [11]; fourthly, for long-term project resilience, particularly government-pay projects, government payments, viability-gap funding [18], or some form of government guarantee [39–41] or credit enhancement [42] will be required. Unrealistic or unreasonable guarantees and assurances made by local governments lead to high costs to fulfill contracts, resulting in unfavorable outcomes such as renegotiation or project failure [43].

Private partners/equity investors in international public–private partnerships (PPPs) typically include MNEs, pension funds, insurance companies, and sovereign wealth funds, collectively known as "financial sponsors," who seek long-term stable returns [44]. In recent years, there has been a rise in infrastructure mergers and acquisitions, leading to the emergence of "strategic sponsors" who are willing to take on higher risks for potential returns in the early stages of project development. Some of these sponsors are specialized infrastructure funds [45]. Private investors are primarily concerned with the creditworthiness risk of local governments, and they must assess the liability of government officials' decisions. Consequently, it is imperative that the private sector seek the government's cooperation and assistance; however, the institutional quality of some local governments may considerably increase the cost of such cooperation and assistance [46]. Especially for foreign investors, the nature and quality of host country institutions affect FDI in a variety of ways [47]. The commitment of private partners to longer-term investment and operation is essential to the resilience of a project. Infrastructure is not typically considered a financial asset, but it does exhibit certain characteristics that are common to financial assets, such as longer-term maturity with lower liquidity, predictable and often inflation-linked cash flows, and low correlation with other asset classes [1]. The private partners place a premium on long-term returns and performance relative to global equity investments.

Lenders/debt financiers are a key source of infrastructure financing, particularly for projects in emerging markets, and they often rely on bank lending from advanced economies, particularly international financial institutions [1]. These loans are typically indexed to the London Interbank Offered Rate (LIBOR) with a margin added to it. However, since the 2008 financial crisis, new regulations such as Basel III have placed significant constraints on the long-term financing capacity of commercial banks. This has particularly affected infrastructure assets with longer contract periods, which may struggle to secure long-term financing at affordable rates [48]. Since the majority of PPP ventures are structured with project financing, SPV normally lacks sufficient collateral to cover the loans. The lenders rely on government guarantees, collaterals from private partners, or other credit enhancement measures to compensate for the risks associated with the project [49]. Banks also execute "Direct agreements" with the SPV to guarantee the bank's ability to intervene directly in crisis circumstances to take direct control over the borrower's contracts with the government or the contractors [50]. Lenders are susceptible to credit risk and liquidity dry-ups, but they are generally committed to the long-term viability of projects, as the majority of project loans are long-term loans that will mature after the construction period.

Contractors are generally categorized in two ways: construction contractors or operation and maintenance contractors which intervene at different phases of the projects. The two types of contractors normally have certain ways of collaborating to ensure a smooth takeover from construction to operation. As the project moves from the design/construction to the operation/maintenance stage, the risk/return profile changes, and risks are shifted/reallocated to the party best able to manage it. In the past, PPP

practitioners have always viewed the risks associated with the construction stage to be more prominent. However, as project management techniques improve over the years, such as the EPC/turnkey methods of delivery that have already made risk management and cost control, i.e., cost overrun, inflation of the price of the raw materials, considerably less risky [51]. In the meantime, the resilience of O&M operators is becoming more of a question, considering the supply and demand of the provided services tend to become increasingly less sustainable, especially in the case of high inflation in user-payment projects and government payment default in government-payment projects, O&M operators often struggle to meet the financial requirements and standards as predicted at the project planning stage [21,29,50].

As for the end users, based on the principle of public goods, the PPP's foundation is publicness and the pursuit of public interests, and its main purpose is to address public needs by providing public services [51]. On the contrary, a 'white elephant' has been defined as an investment project that results in negative social outcomes and inefficient redistribution of wealth. To avoid the "white elephant" in infrastructure [52], users should be at the center of the entire PPP process (design, delivery, and outcome evaluation). If the project poses no significant demand risk for the private party, there will be incentives for the government to promote any form of project, some of which may become white elephants.

In summary, public–private partnerships (PPPs) highlight the intricate nature of the process and the diverse range of stakeholders involved, setting them apart from other infrastructure delivery models. The dynamic relationships among these stakeholders, constantly evolving within the PPP framework, presents a substantial challenge in effective project management [17,20]. De Schepper [20] underscores a noticeable research gap, with limited research (covered by 22 research articles) directed towards stakeholder management within PPPs, and even fewer studies centering on project success. Wegrzyn and Wegrzyn [16] propose that the success of PPP projects hinges upon the knowledge of stakeholders, their capacity to influence the project, their motivation, the urgency of project implementation, and their adeptness in fostering relationships with other stakeholders, etc. Jiang et al. [26] examined the bargaining process in PPP projects between multinational investors and contractors (MNEs) and the host government, emphasizing the significance of the governance and ownership structure of the Special Purpose Vehicle (SPV). While current stakeholder analysis guidelines offer a foundational framework, they omit crucial intricacies surrounding the actual engagement or the process of influence [16,20]. Given this backdrop, the examination of risk factors influencing the outcome of PPP projects from a stakeholder perspective adds a compelling dimension to this study.

3.2. Risk Determinants in Global Risk Transmission

Our attention now turns to the global risk transmission mechanism, which proposes that risks originating in one country or the global economy can affect PPP projects and create risks in other countries. This study aims to identify the channels through which global risks impact PPP projects, either by directly affecting them financially or by indirectly affecting the real economy of the country and subsequently impacting PPP projects. In contemporary international economics, the perception of international trade and finance as distinct domains has been a prevailing perspective [53,54]. However, a pivotal aspect of grasping this interconnection lies in comprehending the intricate relationship between interest rates, exchange rates, and inflation rates. The interactions between these factors significantly shape trade dynamics and investment patterns [55]. Another noteworthy contemporary development pertains to the shift in focus. Initially, the analysis centered on a country-wide perspective, drawing insights from national trade and foreign direct investment (FDI) statistics. Subsequently, attention is redirected toward the behaviors of multinational enterprises (MNEs). Rather than solely observing the entirety of a country, the emphasis evolved to scrutinize individual stakeholders. This involved delving into specific dynamics, such as the intricate relationship between governments and MNEs [56]. Remarkably, this aligns with the stakeholder perspective central to our study's framework.

On a global scale, Chudik and Fratzscher [22] investigated the transmission of shocks to risk and liquidity across 28 economies, including 10 advanced and 18 emerging economies. They focused on two specific periods of global risk outburst: the 2007–2008 financial crisis and the 2010–2011 sovereign debt crisis. The research found that the perception of risk transmission varied across countries and was influenced by portfolio choice decisions by investors, the strength of countries' fundamentals (such as sovereign rating and quality of institutions), and their financial exposure to the U.S. Furthermore, the geographic flight-to-safety phenomenon observed during the 2007–2008 crisis became less compelling during the 2010–2011 crisis. Notably, the authors found that the signs of emerging market elasticities during the crisis were always opposed to those of advanced economies, suggesting a differentiated effect of U.S. variables on the rest of the world.

Dovern and van Roye [57] extended the time horizon from 1970 to 2012 and found that the correlation of financial stress across countries had increased considerably over the four decades, peaking during the 2007–2008 financial crisis. They used five risk indicators, i.e., stock market volatility, exchange rate volatility, stock market returns, government bond volatility, and banking sector volatility, and demonstrated that the correlation of financial stress was stronger with increased financial openness/exposure. The research emphasized the negative impact of financial stress on economic activity and the significant role of the United States in the global transmission of financial stress. Furthermore, the authors identified industrial production as a good indicator for capturing global shocks. In a similar approach to Chudik and Fratzscher [22], Cashin et al. [58] investigated two significant scenarios of global risk transmission: China's economic slowdown and the surge in global financial market volatility. The study comprised 33 economies, representing more than 90% of the world's GDP. The authors found that China's slowdown had a significant impact on less-diversified commodity exporters and ASEAN countries, with evidence of a fall in global inflation and short-term interest rates, which negatively affected global equity and oil prices in the short run, and impacted interest rates in the long term.

It is crucial to recognize that international risks do not have a uniform impact, and their effects on each country and its projects can vary significantly. As an illustration, the International Monetary Fund estimates that China's economic slowdown will predominantly impact the economies of the Association of Southeast Asian Nations (ASEAN), with the exception of the Philippines, owing to their significant trade exposure to China [22].

4. Risk Determinants of Project Outcome

Many studies have identified the factors that contribute to the success or failure of PPP projects [27–29,59,60], while our objective here is to establish quantitative relationships between the risk factors and the project outcomes [26,61]. Through an extensive review of the literature, this study has identified several key risk factors influencing PPP development. Notably Hammami et al. [62] identified seven key channels affecting PPP development, including government constraints, the political environment, market conditions, macroeconomic stability, institutional quality, the legal system, and past experiences with PPP. Their research confirmed that heavy government fiscal burdens, good market conditions, low inflation, good institutional quality, and previous experiences with PPP contribute to PPP development; Reside [63] and Reside and Mendoza [64] found that factors such as exchange rate fluctuations, government guarantees, debt ratios, and project support influence PPP failure rates. Further research conducted by Jimenez et al. has a pronounced regional focus, linking country risk to the outcomes of PPP projects in Eastern Europe [65] and Latin America [66]. We will provide a more detailed elaboration on these risk factors and the previous research supporting the inclusion of these factors.

To aid in this process, risks have been classified into various categories for presentation purposes, although it is important to note that these categories are not necessarily independent of one another. For example, Reside and Mendoza [64] have shown that political risk often arises from macroeconomic risk, while Dailami and Klein [67] have highlighted the connection between market risk and credit risk, particularly in emerging

markets. Similarly, fluctuations in commodity prices—a sectoral risk—can sometimes lead to government intervention and the realization of political risk [63]. Another constraint stems from the unique attributes of each project. The list of risks presented below may not encompass all the potential risks associated with the project. This constraint can be more pronounced when we take into account that risks can be reduced, increased, or transferred during different phases of the project development [7]. For example, the risk associated with construction may be eliminated as the project transitions from the construction phase to the operation phase. This article adopts a holistic and result-oriented view by focusing on the project outcome rather than the process, in order to explore the overall effect of risk on project resilience.

4.1. Domestic Risk Determinants

4.1.1. Market Risk

Market risk, also known as commercial risk or revenue risk, is associated with the ability to purchase infrastructure services at market prices. Market risk is highly sensitive to changes in both prices and demand, and fluctuations in inflation rates can potentially harm project success [68]. Market/revenue risk is particularly important if the project's primary revenue source is market-based, where short-term revenue shortfalls could undermine the project's long-term viability [69].

Considering the extensive involvement of various emerging and developing economies in the database, another category of indicators pertains to trade. Many emerging economies significantly depend on trade to sustain their domestic economies [70], as the average trade-to-GDP ratio is 58% for the economies in our project database. Empirical investigations [2,24,58] have shown that risk transmission is amplified in the presence of heightened trade exposure, while the dependence on tariffs as a source of fiscal income incentivizes governments to expand their trade exposure [71].

Another indicator of market risk is inflation. High inflation may cause a significant decrease in end users' affordability and an increase in labor and material costs, resulting in a rise in project construction and operation costs, which will impact the contractors' financial performance [28,62]. Table 1 details the market risk indicators and their impact on primary stakeholders.

Table 1. Market risk indicators.

Indicators	Indicator Description	Impact on Primary Stakeholders
GDP per capita	Average per capita GDP growth, indicating the level of affordability in a consecutive period (Source: World Bank)	End users
Openness (Trade Exposure)	1. Openness/Trade exposure: Average ratio of total exports and imports divided by GDP 2. Average ratio of fuel and industrial exports to total exports (Source: World Bank)	Government
Inflation	Average inflation rate (Source: World Bank)	End users/Contractors

4.1.2. Fiscal Risk

The fiscal position of the government indicates the constraints and ability of the government to fulfill its obligations. Several governments worldwide, including Brazil, Canada, Chile, China, Colombia, Spain, and the United Kingdom, have implemented measures such as the provision of a minimum revenue guarantee (MRG) [72], viability gap funding [18], or government subsidies [73]. However, such government support can also

pose a significant fiscal risk, especially if the project is backed by a government guarantee. Falling government revenues and shrinking domestic financing, such as government treasury funds, can exacerbate this problem and create long-term budgetary and debt-related consequences for the government [74]. Table 2 details the fiscal risk indicator.

Table 2. Fiscal risk indicators.

Indicators	Indicator Description	Impact on Primary Stakeholders
Fiscal position	Average net lending in terms of either surplus or deficit (Source: World Bank)	Government

4.1.3. Country Risk

The concept of country risk brings to the fore the distinct characteristics of each country's natural and economic endowment [75], political and regulatory systems [65,66], political stability [26,76], fiscal and monetary stability, as well as their previous experiences with public–private partnerships (PPPs), i.e., whether the central government has implemented the PPP model before and whether the country has the corresponding expertise in risk management [77,78]. Jimenez et al. [75] further classified country risks into endogenous and exogenous country risks through whether the risk is endogenous or exogenous to the PPP projects.

Given that PPPs rely heavily on contractual arrangements, the quality of the legal and contractual environment is critical to their success [79]. Within an institutional environment marked by an absence of the rule of law and accountability, policy makers wield the authority to unilaterally alter the terms and conditions stipulated in concession agreements, and in more severe instances, opportunistically expropriate a private partner's profits or assets [76,80]. If the contract is awarded directly by the central government, such projects are generally viewed as more attractive due to state guarantees [11], and such projects typically involve MDB support. The MDBs are not necessarily the project's stakeholders, but their presence implies that the external institutional environment and the internal governance of the project are somewhat guaranteed or sufficient enough for PPP [21]. Table 3 details the country risk indicators.

Table 3. Country risk indicators.

Indicators	Indicator Description	Impact on Primary Stakeholders
PPP experience	Discrete variable—1 if the country has implemented a PPP initiative before the underlying PPP project, 0 if otherwise (Source: World Bank's PPI database)	Government/Private Partner
Federal or local government granted the contract	Discrete variable—1 if the project was contracted with the federal government, 0 if otherwise (Source: World Bank's PPI database)	Government/Private Partner
Support from multilateral institutions (MLS)	Discrete variable—1 if the project received a political risk guarantee from MFIs, 0 if otherwise (Source: World Bank's PPI database)	Government

4.1.4. Currency Risk

Infrastructure projects in developing countries typically rely on significant amounts of foreign capital in the form of equity investment or loans to finance PPP. Financial exposure is a critical component to transmit global risks [22,57]. The degree of financial exposure can be measured through the indicator of Foreign Direct Investment (FDI) [81]. The government has a strong motivation to encourage foreign direct investment (FDI), highlighting the importance for the government of maintaining a stable currency [82].

Unlike debt repayments and payments to contractors, which are normally denominated in foreign currency, dividends from private partners' investments, which stem from

project cash flows, typically accrue in the local currency. In many emerging countries with underdeveloped financial markets, hedging instruments (such as exchange rate swaps) for currency risks are scarce. Unexpected devaluations can significantly impact project profitability [83]. If strong fluctuations impact the revenue repatriation for a consecutive period, the project's financial viability will be in dispute. This was particularly evident in the 1990s when several public–private partnerships (PPPs) in Latin America [66] and Southeast Asia experienced financial challenges due to unexpected currency fluctuations [62]. Table 4 details the currency risk indicators.

Table 4. Currency risk indicators.

Indicators	Indicator Description	Impact on Primary Stakeholders
FDI (Financial Exposure)	Average change in FDI net inflows (Source: World Bank)	Government
Exchange rate	Standard deviation in the real exchange rate (Source: World Bank)	Private Partners

4.1.5. Credit Risk and Liquidity Risk

Credit risk refers to the increase in financing costs that can result in higher debt service payments and elevated project costs, rendering previously feasible projects no longer bankable [83]. Lenders/debt financiers carefully analyze the cash flows associated with a project to ensure that the profits are sufficient and that the creditworthiness of the project is strong enough to enable loan repayment [84]. The ratio of short-term foreign debt to exports serves as an indicator of the creditworthiness of the sovereignty [85].

In some cases, credit risk leads to liquidity risk, which involves the unavailability of shorter-term financing. The interest rate indicates the risk-free cost of capital in the economy. Interest rate hikes either raise project financing costs or dry up liquidity, which will force lenders to meet redemption calls, significantly restricting the capital available for PPP projects [22]. Burger et al. [74] examined the impact of the 2007–2008 financial crisis on PPP and concluded that the increased financing costs and limited financial liquidity significantly affected PPP projects. Table 5 details the credit and liquidity risk indicators.

Table 5. Credit risk and liquidity risk indicators.

Indicators	Indicator Description	Impact on Primary Stakeholders
Interest rate	Average change in real interest rate (Source: World Bank)	Lenders
Short-term debt	Average ratio of short-term debt to exports (Source: World Bank)	Lenders

4.1.6. Construction Risk

Infrastructure projects typically entail high upfront costs and may require a lengthy period before generating revenue, making greenfield projects riskier than brownfield projects. Greenfield contractors must ensure that all necessary administrative work, including obtaining business permits and licenses, complying with environmental regulations, and securing land handover, is completed and approved, otherwise construction risks may lead to costly delays and significant losses for the project [69].

4.1.7. Sectoral-Specific Risk

It is worth noting that each infrastructure sector exhibits unique risks and characteristics [86]. For example, the energy sector is intricately linked to energy prices and is consequently exposed to price fluctuations. Conversely, macroeconomic conditions exert a significant influence on the information and communication technology (ICT) and transport

sectors [87]. In contrast, the demand for water and sewerage services tends to be relatively inelastic, rendering this sector less vulnerable to external factors [88].

4.2. International Risk Determinants

4.2.1. Risks Transmitted through the Global Real Economy

Widely recognized as the most potent indicator of global economic activity, GDP serves as an indispensable metric for analyzing both demand and supply side factors. Under the impact of the global economic downturn, changes in raw material prices, and reduced global demand, market and financial risks are likely to intensify. The impact on GDP growth affects various stakeholders universally, albeit to varying degrees, and influences their decision-making in diverse ways [89].

This study also examines the possibility of a single country exerting significant influence over global risk transmission. Chudik and Fratzscher [22] and Cashin et al. [58] have both posited the United States' dominance in global risk transmission. Cashin et al. [58] and Cesa-Bianchi et al. [45] have further highlighted the increasing significance of the Chinese economy in this regard. Given these factors, the economic growth of both China and the United States has been incorporated into the model. Table 6 details the indicators for risks transmitted through the global real economy.

Table 6. International risk indicators (real economy).

Indicators	Indicator Description	Impact on Primary Stakeholders
External GDP growth (U.S./China)	GDP Growth (Source: World Bank)	All stakeholders

4.2.2. Risk Transmitted through the Global Financial Market

Several risks are directly linked to the global financial market. Credit risk, for instance, can be gauged by fluctuations in the London Interbank Offered Rate (LIBOR) [22]. To measure stock market fluctuations, the NASDAQ Composite Index has been widely utilized as the variable [22,58]. Previous studies [22,58,90–92] have demonstrated the connection between commodity prices/oil prices and global risk transmission. Contractors will face significant challenges in managing project costs due to the drastic increase in commodity prices, with cost overruns posing a significant threat to project resilience [7]. Table 7 details the indicators for risks transmitted through the global financial market.

Table 7. International risk indicators (financial market).

Indicators	Indicator Description	Impact on Primary Stakeholders
LIBOR fluctuations	Standard deviation of LIBOR (Source: Federal Reserve Economic Data)	Lenders
Stock market fluctuations	NASDAQ Composite Index (Source: Federal Reserve Economic Data)	Private Partners
Oil price fluctuations	BRENT Crude Oil Price (Source: Federal Reserve Economic Data)	Contractors

5. Materials and Methods

5.1. Data Description

The World Bank's Private Participation in Infrastructure (PPI) database is the primary data source for this study (available at https://ppi.worldbank.org/ (accessed on 31 July 2022)). The World Bank PPI database is widely used by many researchers to investigate diverse forms of PPP. [26,32,62–65,75]. The PPI database is cross-sectional and each project is considered independent. The dependent variable in this study is project status, which is binary. A value of 1 indicates a distressed or canceled project, while a value of 0 indicates an ongoing or successfully completed project [26,75].

The economic data used in this study were obtained from World Bank Open Data (available at https://data.worldbank.org/ (accessed on 1 August 2022)). Financial indicators were sourced from Federal Reserve Economic Data (available at https://fred.stlouisfed.org/ (accessed on 1 August 2022)). For a complete list of independent variables and data descriptions, please see Appendix A. Independent variables were adjusted based on either the year in which the project reached financial closure (Financial Closure Year) for the exogenous ones or the most recent year in which the project was updated in the database (Year before the Outcome) for the endogenous ones. However, it is worth noting that the variable for institutional governance, represented by World Governance Indicators (WGI) (available at http://data.worldbank.org/data-catalog/worldwide-governance-indicators (accessed on 8 August 2022)), was held constant throughout the 25-year period. Table 8 presents the descriptive statistics of the dependent and independent variables:

Table 8. Data Description (Dependent Variable and Independent Exogenous Variables).

No.	Indicators	No. of Obs.	Average	St. D.	Min.	Max.
1	Project Status	7286	0.0525666	0.2231819	0	0.58
2	GDP per capita growth	7266	0.0412766	0.0394792	−0.2143894	0.1793668
3	Inflation	7242	34.63687	202.1898	−12.59891	9630.281
4	Fiscal Position	6923	−2756.323	14649.38	−245670.3	9630.281
5	Openness	7266	58.33845	32.37531	0	215.8228
6	PPP experience	7286	0.9669229	0.1788503	0	1
7	MLS	7286	0.8734559	0.3324843	0	1
8	Central Gov.	7286	0.4360417	0.4959265	0	1
9	Net FDI inflow (ac.)	7266	0.041736	0.6104446	−13.06869	6.226839
10	Real exchange rate (std.)	4301	2.593689	2.688933	0	87.86307
11	Real interest rate	7266	0.0846632	5.035214	−40.7934	46.72787
12	Short debt to exports (av.)	6731	22.65931	16.96856	0	299.8865
13	Ratio ind. exports (av.)	7266	18.6997	17.07576	0	98.10608
14	China GDP Growth	6364	9.479046	2.067778	3.907114	14.23139
15	U.S. GDP Growth	6364	2.230547	1.528975	−2.77553	4.6852
16	LIBOR (std.)	7286	0.2240708	0.2528473	0.005359	1.202141
17	BRENT (ac.)	7286	1.441581	17.67275	−46.65	31.65
18	Nasdaq (std.)	7286	182.1118	107.9594	27.7693	581.6638

The correlation matrix for the independent exogenous variables is shown in Table 9. As Table 9 demonstrates, none of the variables exhibit any significant pairwise correlation.

Table 9. Correlation Matrix (Independent Exogenous Variables).

Correlation Matrix	1	2	3	4	5	6	7	8	9	10
1. PPP experience	1.00									
2. MLS	0.07	1.00								
3. Central Gov.	0.04	−0.09	1.00							
4. Real interest rate	−0.01	0.00	−0.04	1.00						
5. Short debt to exports (av.)	−0.04	−0.03	−0.09	0.10	1.00					
6.Ratio ind. exports (av.)	−0.06	−0.16	0.17	0.00	0.25	1.00				
7. GDP per capita growth	0.13	0.10	−0.17	−0.04	−0.14	−0.26	1.00			
8. Inflation	−0.20	0.04	−0.09	0.03	0.19	−0.01	−0.35	1.00		
9. Fiscal Position	−0.03	−0.02	−0.06	−0.04	0.08	0.00	−0.01	0.00	1.00	
10. Openness	−0.05	−0.06	0.15	−0.01	−0.09	−0.09	−0.03	−0.04	−0.15	1.00
11. Net FDI inflow (ac.)	−0.01	−0.01	−0.08	0.05	−0.13	0.09	0.08	0.02	−0.02	−0.13
12. Real exchange rate (std.)	−0.07	0.00	−0.02	0.00	0.08	0.04	−0.13	0.20	−0.14	−0.17
13. China GDP Growth	0.11	0.00	−0.15	−0.10	−0.11	−0.15	0.15	0.13	0.09	0.00
14. U.S. GDP Growth	−0.02	0.00	−0.18	0.03	0.15	0.07	−0.06	0.06	0.02	−0.03
15. LIBOR (std.)	0.02	0.01	−0.15	−0.10	−0.05	−0.02	0.11	0.01	0.09	−0.04
16. BRENT (ac.)	0.04	0.03	−0.03	−0.20	−0.06	−0.07	0.17	−0.01	0.02	0.01
17. Nasdaq (std.)	0.05	−0.03	−0.03	−0.09	−0.03	0.04	−0.04	−0.16	0.02	−0.03

Table 9. *Cont.*

Correlation Matrix (Cont'd)	11	12	13	14	15	16	17
11. Net FDI inflow (ac.)	1.00						
12. Real exchange rate (std.)	0.08	1.00					
13. China GDP Growth	0.16	−0.09	1.00				
14. U.S. GDP Growth	0.08	0.12	0.05	1.00			
15. LIBOR (std.)	0.11	0.05	0.25	−0.18	1.00		
16. BRENT (ac.)	0.06	−0.18	0.37	0.20	0.12	1.00	
17. Nasdaq (std.)	0.00	−0.01	−0.38	−0.24	0.17	−0.08	1.00

5.2. Model Specification

Given the characteristics of the datasets, we have opted for the two-step binomial probit model with endogenous factors. For instance, consider a project that fails in 2016. The GDP per capita growth in 2016 may impact project outcomes due to the lack of purchasing power. However, the GDP per capita growth in 2008, the year of project design, may impact the project outcome due to wrong decisions made at the planning stage, and also distinctly impacts the GDP per capita growth in 2016 due to continuity. GDP per capita growth in 2008 is therefore an endogenous factor to GDP per capita growth in 2016. To address this intricacy, the two-step binomial model is employed, which conducts two sequential regression steps to mitigate the influence of these factors. This approach has been developed and refined by prominent econometricians such as McFadden [93], Newey [94], and Rivers and Vuong [95]. The theoretical foundations of the probit model and econometrics, which underpin our analysis, are drawn from works by Stock and Watson [96], Cameron and Trivedi [97], and Baum [98]. The STATA® command that we have employed to implement this model is specified as follows and the model specification for models 1–9 is illustrated in Table 10.

ivprobit depvar varlist1 (varlist2 = varlist_iv), first twostep

Table 10. Model Specification (Model 1–9).

Model No.	Exogenous Variables	Endogenous Variables	Supporting Literature
Model 1	• GDP per capita growth *2 years before the outcome* • Inflation *2 years before the outcome* • Net fiscal position *2 years before the outcome* • Openness *2 years before the outcome*	• GDP per capita growth *2 years before the financial closure* • Net fiscal position *2 years before the financial closure* • Openness *2 years before the financial closure* • Institutional quality: - Rule of Law - Control of corruption - Voice and accountability	[2,18,22,24,58,62–64,66,68–74]
Model 2	Model 1+ • PPP experience • MFI support • Federal or local government guarantee the contract	Same as Model 1	[11,21,26,62–67,76–79,99]
Model 3	Model 2+ • Exchange rates *1 year before the outcome* • FDI *1 year before the outcome*	Model 1+ • Exchange rates *1 year before financial closure* • FDI *1 year before financial closure*	[22,57,62–64,81–83]

Table 10. *Cont.*

Model No.	Exogenous Variables	Endogenous Variables	Supporting Literature
Model 4	Model 3+ • Interest rates *2 years before the outcome*	Same as Model 3	[22,74]
Model 5	Model 4+ • Short-term debt to exports ratio *2 years before the outcome* • Industrial raw exports *2 years before the outcome*	Same as Model 3	[2,24,58,62–64,70,71,83–85]
Model 6	Model 5 • China/U.S. GDP growth *1 year before the outcome* • U.S. GDP growth 1 year before the outcome	Same as Model 3	[22,45,57,58,89]
Model 7	Model 5+ • LIBOR fluctuations *in the year of the outcome*	Same as Model 3	[22]
Model 8	Model 5+ • Oil price *fluctuations in the year of the outcome*	Same as Model 3	[22,57,58]
Model 9	Model 5+ • Stock market fluctuations *in the year of the outcome*	Same as Model 3	[22,57,58,90–92]

Regarding the time lag of the exogenous and endogenous factors, previous empirical research studies using similar variables suggested a country-specific time lag of risk transmission, which is 2 for domestic variables and 1 for foreign variables [58,81]. The inherent shifts in financial market indicators, such as LIBOR, BRENT, and NASDAQ, occur without any inherent time lags [57,58]. The research relies on a Wald chi-square test as the model selection criterion, as noted by Campos et al. [100]. Specifically, adding each new variable should increase the Wald chi (2) statistic while ensuring that the variables in the basic model remain significant and exhibit consistent coefficient signs [101].

6. Results and Discussion

6.1. Model Effectiveness

As shown in Table 11, the effectiveness of the new models was demonstrated through the increasing Wald chi (2) test statistics resulting from the inclusion of new variables. The results indicate that upon the addition of international variables to the models, the Wald chi (2) test statistics of the two most significant models, Model 6 and Model 7, which used different metrics to quantify international economic growth, reached 112.14 and 129.58, respectively. Please note that the factors that cause success are indicated by negative signs, whereas the factors that cause failure are indicated by positive signs.

Table 11. Model results.

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
GDP p.c. growth	−0.0717	0.322	−0.538	−0.670	−1.742	−1.355	−1.585	−1.413	−1.334
Inflation	0.0725 **	0.0786 **	0.0712 **	0.0702 **	0.0533 **	0.0554 **	0.0544 **	0.0579 **	0.0539 **
Fiscal position	8.2×10^{-6} **	8.36×10^{-6} **	-3.49×10^{-5} *	-3.55×10^{-5}	-3.49×10^{-5}	-1.59×10^{-5}	-3.93×10^{-5}	-3.45×10^{-5}	-3.47×10^{-5}
Openness	0.00293 **	0.00318 **	0.00648 **	0.00641 **	0.00653 **	0.00642 **	0.00638 **	0.00656 **	0.00663 **
PPP exp.		0.374	0.183	0.166	−0.558 **	−0.675 **	−0.635 **	−0.529 **	−0.604 **
MLS		−0.0758	−0.0371	−0.0355	0.0237	0	0.026	0.0232	0.0268
Central Gov.		−0.0404	−0.204 **	−0.217 **	−0.279 **	−0.185 *	−0.224 **	−0.281 **	−0.260 **
FDI inflow			0.260 **	0.268 **	0.338 **	0.341 **	0.310 **	0.336 **	0.344 **
Exchange rate			−0.100	−0.103	−0.104 *	−0.133 **	−0.0983 *	−0.116 *	−0.105 *
Interest rate				−0.0133 *	−0.0104	−0.0151 **	−0.00566	−0.0137 *	−0.00884
Debt to exports					−0.00151	−0.00386	−0.00169	−0.00138	−0.00133
Indl. Exports					0.00384	0.00408	0.00478 *	0.00380	0.00397
China GDP						0.0170			
U.S. GDP						0.103 **			
LIBOR							0.595 **		
BRENT								−0.00231	
NASDAQ									0.000615 *
_cons	−2.379 **	−2.745 **	−2.500 **	−2.456 **	−1.614 **	−1.622 **	−1.768 **	−1.665 **	−1.726 **
	(−11.48)	(−5.49)	(−4.25)	(−4.20)	(−4.53)	(−4.65)	(−5.03)	(−4.58)	(−4.49)
N Wald chi (2)	6658	6658	4059	4059	3784	3381	3784	3784	3784
test statistic	44.17 **	69.26 **	97.19 **	97.86 **	107.80 **	112.14 **	129.58 *	107.86 **	108.30 **

Notes: T-statistics in parentheses * $p < 0.10$, ** $p < 0.05$.

In the context of a multivariate regression model, multicollinearity arises when strong correlations exist among multiple independent variables. To assess the presence of multicollinearity, this study employed the variance inflation factor (VIF) to quantify the extent to which variance in the regression coefficients has been amplified. The results, as presented in Table 12, reveal VIF values for the exogenous independent variables, with a mean VIF of 1.37 which is far below the recommended threshold of 10 [102]. This value signifies the absence of observed multicollinearity.

Table 12. Test for Multicollinearity of the Exogenous Independent Variables.

Variables	GDP p.c. Growth	Inflation	Fiscal Position	Openness	PPP exp.	Central Gov.	FDI Inflow	Exchange Rate
VIF	1.85	1.06	1.09	1.22	1.05	1.48	1.37	1.26
1/VIF	0.541	0.943	0.917	0.820	0.952	0.676	0.730	0.794
Variables	**Interest rate**	**Debt to exports**	**Indl. Exports**	**China GDP**	**U.S. GDP**	**LIBOR**	**BRENT**	**NASDAQ**
VIF	1.2	1.28	1.57	1.86	1.36	1.27	1.5	1.46
1/VIF	0.833	0.781	0.637	0.538	0.735	0.787	0.667	0.685
Mean VIF				1.37				

6.2. Analysis of the Empirical Results

Model 1–5 only exhibit the risk effect of domestic risk factors. This study finds that average GDP per capita growth does not have a significant impact on project failure. However, inflation is identified as a critical variable contributing to project failure, consistent with previous research [62]. Trade exposure, as measured by openness, consistently contributes to project failure. The analysis also found that factors such as support from multilateral development banks are not statistically significant in determining project sustainable outcomes. With regard to financial exposure, the study found that an increase in FDI net flow significantly raises the probability of project failures, highlighting the potential risks associated with foreign investment.

The study found that the involvement of the federal government in granting the contract and past PPP experiences can reduce the likelihood of project failure, possibly due to the central government's ability to manage national-level projects. MLS, indicating whether the project receives a MDB's support in the form of a political risk guarantee, also proves to be insignificant. When faced with a PPP project that is exposed to international risk, the central government has additional issues to consider, such as managing the exchange rate, interest rates, and inflation, and may need to consider infrastructure development goals, imports of raw materials, exports, and the effort required to maintain the free flow of capital when employing fiscal and monetary policy.

This study revealed that the real interest rate's influence is considerable, although not consistently evident in all models. Surprisingly, fluctuations in the exchange rate positively impact project success, challenging the common belief that a stable currency is crucial for sustaining foreign direct investments (FDIs). This phenomenon is likely because long-term investments like equity investments in PPP are less influenced by short-term exchange rate fluctuations. As much of the revenue repatriation for private partners and contractors is denominated in foreign currencies, the negative effect of currency fluctuations is relatively insignificant. Moreover, the project's resilience is enhanced by maintaining open and liquid capital markets that allow free capital flow, indicating strong institutional quality and less reliance on a single export source.

Models 6 was used to examine the relationship between global economic growth and PPP project success, using GDP growth to operationalize global real economy dynamics. While China's growth did not show a significant relationship to project outcomes, U.S. economic growth was found to be a significant factor contributing to project failure. The divergence may be attributed to the fact that China has consistently demonstrated greater resilience and independence in its fiscal and monetary policies. China's economic perfor-

mance maintains a notable degree of independence from both global and U.S. economic growth, with correlation coefficients of 0.08 and 0.07, respectively. Conversely, the U.S. economy exhibits a robust correlation with overall global economic health, reflecting a correlation factor of 0.73. Figure 9 portrays the trajectories of world GDP growth (depicted by the solid line), while the economic growth of the U.S. (represented by the dotted line) aligns closely with the global trend. In contrast, China's economic growth (indicated by the dashed line) appears largely disconnected from these trends.

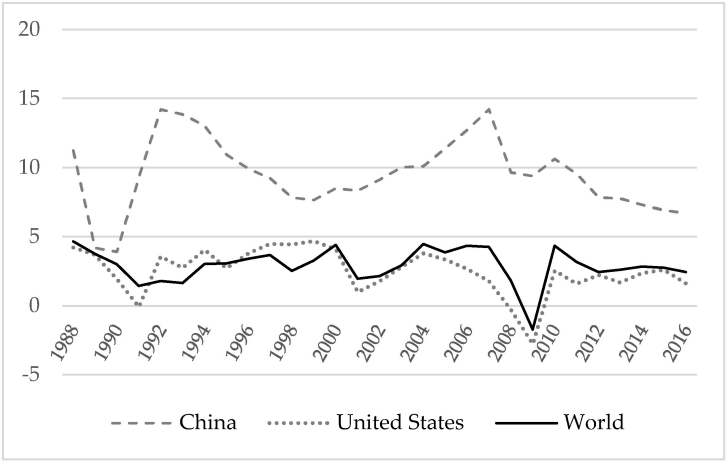


Figure 9. Trends of GDP growth in China, the U.S., and the world average.

Many investors perceive Chinese assets as a viable alternative and a safe haven during times of U.S. crises, favoring them as a means of risk evasion. The result reaffirms that the U.S. wields a dominant influence over the global real economy and financial markets. When the U.S. economy performs well, it leads to an increase in the value of U.S. assets, thereby diminishing the appeal of investing in emerging market infrastructure projects.

In Models 7–9, three financial indicators were added: standard deviations in LIBOR, average change in BRENT crude oil price, and standard deviation in the Nasdaq Composite Index. Of these indicators, only the standard deviation in LIBOR was found to have a highly significant impact, highlighting the importance of credit risk transmission in the infrastructure market. This finding may also be attributed to the fact that the infrastructure market is not as interconnected and liquid as the global financial market, suggesting that infrastructure assets have a low correlation with other asset classes. Overall, these findings suggest that financial indicators may have limited predictive power in assessing the resilience of PPP projects.

6.3. Sectoral and Regional and Project Type Differences

Infrastructure assets exhibit significant heterogeneity [103], and our database breakdown revealed distinct characteristics across various infrastructure assets. To further investigate this diversity, we conducted an empirical analysis by utilizing five sets of dummy variables: income groups, regions, sectors, revenue sources, and project types. By employing these variables, we aim to capture the varied impact of infrastructure investments on different socio-economic segments and understand the nuanced implications of such investments. Please see Appendix B for the full results.

As shown in Table 13, our findings indicate that out of the three income groups, only the low-income group exhibits a significant vulnerability to project failure. Additionally, our analysis of region-specific dummy variables has revealed that projects in Africa and East Asia are more prone to failure, whereas those in South Asia are more likely to succeed [104]. While the energy sector was the only sectoral dummy variable that proved significant, both indicators for oil price fluctuations remained insignificant. The study also found that contract periods and fiscal support from the government were not significant predictors of project success.

Table 13. Results of models with dummies.

Models with Dummies	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
LIC	0.574 **								
MIC		−0.0310							
UMIC			−0.0801						
AFR				0.306 **					
EAP					0.735 **				
ECA						−0.700 **			
LAC							0.151		
MENA								0	
SAR									−0.908 **
_cons	1.752 **	1.758 **	1.675 **	1.730 **	−2.175 **	1.948 **	1.760 **	1.615 **	1.556 **
N	3784	3784	3784	3784	3784	3784	3784	3724	3784
Models with Dummies (Cont'd)	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**
ENERGY	−0.284 **								
ICT		0.164							
TRANSPORT			0.129						
WATER				0.133					
GOVRISK					−0.0661				
MARRISK						−0.262 **			
Contract period							−0.00713		
Greenfield								−0.143 *	
Brownfield									0.0925
_cons	−1.590 **	1.765 **	1.725 **	1.741 **	1.654 **	1.723 **	−1.291 **	−1.548 **	−1.705 **
N	3784	3784	3784	3784	3784	3784	2533	(−4.26)	(−4.91)

Notes: T-statistics in parentheses * $p < 0.10$, ** $p < 0.05$.

Two noteworthy discoveries emerged from our comparison of greenfield versus brownfield projects and market/revenue-based versus government-supported projects. Contrary to popular belief, our analysis revealed that greenfield projects and revenue-based projects, which are often regarded as riskier due to demand and construction risks, are significantly more likely to succeed. Conversely, government-supported and brownfield projects, which are typically viewed as less risky, proved to be insignificant. This finding implies that our perception of project-specific risks may be altered when considering the broader global context.

6.4. Policy Implications and Recommendations

Table 14 provides a summary of the empirical findings, highlighting the impact of each variable on primary stakeholders. It becomes apparent that the government occupies a central position within the stakeholder network [105]. This centrality may be attributed to the inclusion of international variables. In light of global risk transmission, the government assumes a pivotal role in managing external risks, equipped with various financial and monetary policies at its disposal. Moreover, the Mundell–Fleming model [106,107] suggests that governments may have more fiscal flexibility when they consider external factors.

Table 14. Summary of empirical findings.

Indicators	**Impact**	**Impact on Primary Stakeholders**
Domestic variables		
Inflation	Positive	End users/Contractors
Openness/Trade Exposure	Positive	Government
PPP experience	Negative	Government/Private Partner
Federal or local government granted the contract	Negative	Government/Private Partner
FDI Inflow/Financial Exposure	Positive	Government
Exchange rate	Negative	Private Partners
International variables		
U.S. GDP growth	Positive	All stakeholders
LIBOR fluctuations	Positive	Lenders
Stock market fluctuations	Positive	Private Partners

It is crucial to recognize that while primary stakeholders are not necessarily the most impacted by risks, they may not always possess the most adept risk management capabilities. The dynamic nature of stakeholders underscores the importance of continual management, taking into account their diverse and evolving motivations. Such an approach fosters stakeholder relationship building, promotes checks and balances, and enhances overall project value. Based on these findings, the study proposes the following policy implications and recommendations:

Firstly, the study would like to reemphasize the dominant role which the government plays in the PPP initiatives of emerging economies. Government is at the center of formulating PPP-related policies and establishing an institutional environment that permits and encourages public–private partnerships [51]. Adverse actions of the government, including government interference, political instability, revocation of support, concession termination, and expropriation, have caused significant setbacks for many projects [63]. Institutional quality encompasses the quality of the country's legal and contractual environment. Equity investors and lenders require a well-defined legal and regulatory framework to establish the specific rights and responsibilities associated with private sector investments and promote private sector participation. Such a framework is crucial in increasing the certainty of long-term PPP contracts, which are essential for attracting private sector investment. The presence of clear legal and regulatory guidelines helps to provide a stable environment for private sector investment, thereby contributing to the outcomes of PPP projects [13].

Secondly, the policy implications of this study are particularly relevant to domestic monetary and fiscal policy. Both monetary and fiscal policy can stimulate output through low financing costs and lower interest rates, but at the cost of higher inflation [108]. The empirical findings suggest that lowering interest rates can reduce PPP project failure while rising inflation can increase it in the long run. Therefore, policymakers should be cautious when using monetary or fiscal policy to intervene in PPP projects, as such interventions may not always be effective [109]. In addition, the study found that variables such as GDP per capita and government support for projects were not significant predictors of success, further highlighting the limits of government intervention. These findings suggest that policymakers should consider alternative approaches to supporting PPP projects, such as improving the regulatory environment and enhancing private sector participation.

Lastly, the empirical findings suggest that while MDBs may not always be effective in supporting such projects, lower-income countries and the African region are significantly more vulnerable and require greater attention. As shown in Table 15, although MDBs do not have quotas or specific focuses on any region, income group, or sector, the study found that projects from LICs and Africa were less supported, possibly due to a lack of suitable projects in the pipeline. To address this gap, the study recommends that MDBs enhance their support for these countries and take their vulnerability to global risks into account. This could involve working closely with governments and private sector actors to identify suitable projects and facilitate their development, as well as providing targeted financial and technical assistance. Greater attention to PPP projects in lower-income countries and the African region could help to drive economic growth, reduce poverty, and promote sustainable development in these regions.

Table 15. MDB support rate.

MDB Support Rate (Supported Projects/Total Projects in That Category)					
Income Groups		**Regions**		**Sectors**	
LIC	76.8%	AFR	77.3%	Energy	85.2%
MIC	84.3%	EAP	94.6%	ICT	84.7%
UMIC	89.7%	ECA	85.9%	Transport	90.7%
		LAC	83.5%	Water and sewerage	92.3%
		MENA	74.3%		
		SAR	90.0%		

7. Conclusions

This research aimed to analyze the global determinants of risks in PPPs and investigate the mechanism of international risk transmission. A comprehensive theoretical foundation is provided by reviewing and selecting key determinants from various sources in the literature [110]. These determinants were then reorganized into a unified framework that incorporated both domestic and international variables. The framework also outlined the channels through which global risks are transmitted. This innovative framework makes a contribution to the field of PPP research, particularly in terms of analyzing risk factors and assessing their impact on project resilience. Specifically, the analysis underscores the pivotal role of the government and multilateral financial institutions in addressing risks that pose a threat to project outcomes.

First, the research findings highlight the significance of the transmission of risks from the international to the domestic level. High inflation, changes in U.S. GDP growth, as well as the fluctuations in exchange rates and the global borrowing rate (i.e., LIBOR) play significant roles in determining these outcomes. This finding highlights the systematic effects and deep roots of the impacts from the international arena on the PPP outcomes of individual countries [53]. Consequently, governments should remain attentive to the global repercussions on PPP projects during major risk events such as high global inflation or recession. Under such circumstances, it is essential for governments to provide relief measures, special financing arrangements, and credit enhancement measures to ensure sustainable development, preventing projects from failing or falling into distress due to short-term shocks from the global market.

Second, the study unveiled a noteworthy adverse effect of trade and financial exposure on PPP project outcomes, which presents a paradox considering that these factors are fundamental determinants of both PPP development and foreign engagement in emerging economies [1]. This finding underscores the importance of governments and investors being vigilant about the potential risks associated with PPP projects, even as the market becomes increasingly open to foreign interests and the potential benefits of increased infrastructure investment. It is crucial for governments to conduct a comprehensive ex ante evaluation of their country's expertise and capacity to manage risks before implementing PPP models [110]. Additionally, governments should consistently enhance the policy environment to foster sustainable outcomes. The study's results emphasize the significance of adopting a balanced approach to PPP development that takes into account both the potential benefits and risks associated with these projects.

While this study provides a valuable empirical analysis of the factors influencing global PPP resilience in the face of global risks, it is important to acknowledge its limitations. Firstly, the analysis is based on project data available only from 1990 to 2016, which may limit its relevance in understanding more recent developments such as the global COVID-19 pandemic outbreak in 2020. The global economic performance since the COVID-19 pandemic has shown that vulnerable supply chains resulting from epidemic prevention and control measures lead to dramatic increases in raw material prices and inflation, coupled with escalated oil prices due to the Russia–Ukraine conflict, causing cost overruns in numerous infrastructure projects. Additionally, stimulus measures implemented by many governments during the pandemic have led several countries to hike interest rates in response to high inflation, which further exacerbates the solvency challenges for emerging economies. The ever-evolving nature of international risk transmission requires ongoing research to capture the changing landscape. Secondly, the concept of project resilience in this study is primarily defined in terms of a binary classification of 'success' or 'failure'. However, resilience encompasses multifaceted aspects including financial sustainability, environmental sustainability, and more. The rationale behind this is rooted in the extensive scope of the World Bank PPI database, encompassing more than 7200 projects. Consequently, delving into the specific causes of failure and comprehensively outlining the outcomes for each project becomes an intricate challenge. Future research should explore these additional dimensions to comprehensively analyze the sustainability

of PPP development. Nonetheless, crafting a comprehensive database to encompass the multifaceted performance and contentment associated with infrastructure projects presents a formidable challenge, primarily due to issues related to data availability and resources. Governments may be the suitable stakeholder to initiate this considering the establishment of such an extensive database needs to capture macro-level data. This endeavor would also necessitate the development of multidimensional metrics, serving as tools to effectively gauge and operationalize the sustainability of these projects [9,109].

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Appendix A. Description of the Variables

Dependent variables

(1) Has the private investor exited (cancellation) or considered exiting (distress) the project? FAIL (discrete)—1 if the project is listed as being "distressed" or "cancelled", 0 if otherwise. Source: World Bank's PPI database.

Independent variables
Legal and institutional framework [Instrumental]

(1) Rule of Law: the extent to which agents have confidence in and abide by the rules of society; includes the quality of contract enforcement and property rights, the police, and the courts, as well as the likelihood of crime and violence: RULE (continuous)—country's average annual score for this criterion in the WGI (1996–2015 if available). Source: World Bank's WGI database. [First Stage]
(2) Control of corruption: the extent to which power is exercised for private gain; includes both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests: CORRUPT (continuous)—country's average annual score for this criterion in the WGI (1996–2015 if available). Source: World Bank's WGI database. [First Stage]
(3) Voice and accountability: the extent to which a country's citizens can participate in selecting their government; includes freedom of expression, freedom of association, and a free media: VOICE (continuous)—country's average annual score for this criterion in the WGI (1996–2015 if available). Source: World Bank's WGI database. [First Stage]

Macroeconomic—economic conditions

(1) Average rate of per capita GDP growth—this is a proxy for capacity to pay: GDP p.c. growth (continuous). Source: World Bank [Significant] [First Stage]
(2) Standard deviation in real exchange rate: Real effective ex. (continuous). Source: World Bank [Significant] [First Stage]
(3) Average of inflation rate: Inflation (continuous). Source: World Bank [Significant]
(4) Average change in real interest rate: Real interest rate (continuous). Source: World Bank [Significant]

International transfer of risk

(1) Financial Exposure: Average of change in FDI net inflows: Net FDI inflow (continuous). Source: World Bank [Significant] [First Stage]

(2) Trade Exposure: Average of the ratio of total exports plus imports divided by GDP: Openness (continuous). Source: World Bank [Significant] [First Stage]
(3) Average of short-term debt to exports ratio: St. debt to exports (continuous). Source: World Bank
(4) Average ratio of fuel and industrial exports to total exports: Ratio ind. exports (continuous). Variables for manufacturing exports ratio and agricultural exports ratio was not included due to the concern of multicollinearity, because they equal to 100% minus fuel and industrial material exports. Source: World Bank
(5) GDP growth: GDP Growth (continuous). Source: World Bank
    a. U.S. [Significant]
    b. China
(6) Financial indicators (continuous). Source: Federal Reserve Economic Data
    a. LIBOR (std.) [Significant]
    b. BRENT Crude Oil (ac.)
    c. Nasdaq Composite Index [Significant]

Project design phase

(1) Political risk guarantee: MLS (discrete)—1 if the project received a political risk guarantee from MFIs, 0 if otherwise. Source: World Bank's PPI database.
(2) Contracted with federal or local government? Central Gov. (discrete)—1 if the project was contracted with the federal government, 0 if otherwise. Source: World Bank's PPI database. [Significant]
(3) Average net lending (cash surplus or deficit): Fiscal Position (continuous). Source: World Bank [Significant]
(4) Contract period: Contract Period (continuous). Source: World Bank's PPI database.

Dummies

1. Sectoral variables (discrete)—the following variables are binary in nature; 1 if the condition is present, 0 if otherwise. Source: World Bank's PPI database.
    (1) ENERGY [Significant]
    (2) ICT
    (3) TRANSPORT
    (4) WATER
2. Country dummies (discrete)—the following variables are binary in nature; 1 if the condition is present, 0 if otherwise. Source: World Bank's PPI database.
    (1) LIC [Significant]/MIC/UMIC
    (2) AFR[Significant]/EAP/ECA/LAC/MENA
3. Time dummies (discrete)—time period between 2007 and 2008 (global financial crisis) and between 2010 and 2011 (sovereign debt crisis) are of particular interest; 1 if the condition is present, 0 if otherwise. Source: World Bank's PPI database.
    (1) D0708D if Investment Year = 2008/2009 or if Financial Closure Year = 2008/2009
    (2) D1011D if Investment Year = 2011/2012 or if Financial Closure Year = 2012/2013 [Significant]
4. Type of transaction (discrete)—the following variables are binary in nature; 1 if the condition is present, 0 if otherwise. Source: World Bank's PPI database.
    a. Brownfield
    b. Greenfield [Significant]

Appendix B. Model Results

Table A1. Model Results (with Dummies).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
GDP p.c. growth (av.)	−1.123	−0.594	−0.882	−1.088	−4.795 **	0.183	0.122	−1.178	−1.467	−1.085	−0.745	−0.863	−0.904	−0.877	−0.568	−0.0262	−1.051	−0.785
	(−0.63)	(−0.33)	(−0.50)	(−0.61)	(−2.31)	(0.10)	(0.06)	(−0.65)	(−0.83)	(−0.59)	(−0.42)	(−0.48)	(−0.51)	(−0.49)	(−0.32)	(−0.01)	(−0.59)	(−0.44)
Inflation (av.)	0.0655 **	0.0722 **	0.0652 **	0.0629 **	0.112 **	0.0830 **	0.0641 **	0.0648 **	0.0627 **	0.0633 **	0.0654 **	0.0674 **	0.0678 **	0.0647 **	0.0712 **	0.0341 *	0.0628**	0.0673 **
	(3.99)	(4.30)	(3.99)	(3.77)	(3.96)	(4.31)	(3.79)	(3.80)	(3.82)	(3.53)	(3.92)	(4.04)	(4.11)	(3.89)	(4.31)	(1.71)	(3.79)	(4.09)
Fiscal position (av.)	−0.0000579	−0.0000608	−0.0000578	−0.0000636	−0.0000924 **	−0.0000480	−0.0000491	−0.0000532	−0.0000568	−0.0000385	−0.0000579	−0.0000568	−0.0000529	−0.0000538	−0.0000638	−0.0000255	−0.0000489	−0.0000542
	(−1.38)	(−1.47)	(−1.40)	(−1.52)	(−2.00)	(−1.15)	(−1.13)	(−1.24)	(−1.36)	(−0.92)	(−1.39)	(−1.37)	(−1.25)	(−1.28)	(−1.51)	(−0.64)	(−1.17)	(−1.30)
Openness (av.)	0.00608 **	0.00612 **	0.00586 **	0.00605 **	0.00514 **	0.00779 **	0.00640 **	0.00575 **	0.00520 **	0.00566 **	0.00587 **	0.00593 **	0.00609 **	0.00587 **	0.00614 **	0.00781 **	0.00583 **	0.00603 **
	(4.85)	(4.77)	(4.63)	(4.75)	(3.95)	(5.62)	(4.81)	(4.56)	(3.97)	(4.44)	(4.67)	(4.69)	(4.82)	(4.62)	(4.85)	(6.02)	(4.60)	(4.80)
Net FDI inflow (ac.)	0.267 **	0.248 *	0.260 **	0.276 **	0.242 *	0.301 **	0.282 *	0.280 **	0.264 **	0.246 *	0.273 **	0.263 **	0.266 **	0.262 **	0.260 *	0.314 **	0.256*	0.263**
	(2.05)	(1.87)	(1.97)	(2.09)	(1.74)	(1.99)	(1.93)	(2.07)	(1.96)	(1.82)	(2.04)	(1.96)	(1.99)	(1.96)	(1.91)	(2.03)	(1.91)	(1.96)
Real effective ex. (std.)	−0.144 **	−0.148 **	−0.138 **	−0.151 **	−0.142 **	−0.135 **	−0.155 **	−0.156 **	−0.160 **	−0.145 **	−0.148 **	−0.150 **	−0.142 **	−0.147 **	−0.138 **	−0.0518	−0.145 **	−0.148 **
	(−2.47)	(−2.47)	(−2.27)	(−2.51)	(−2.34)	(−2.32)	(−2.58)	(−2.60)	(−2.46)	(−2.26)	(−2.47)	(−2.49)	(−2.37)	(−2.45)	(−2.24)	(−0.97)	(−2.40)	(−2.45)
PPP experience	−0.565 **	−0.577 **	−0.599 **	−0.594 **	−0.448 *	−0.455 **	−0.587 **	−0.622 **	−0.589 **	−0.574 **	−0.577 **	−0.558 **	−0.612 **	−0.600 **	−0.591 **	−1.146 **	−0.623 **	−0.600 **
	(−2.58)	(−2.64)	(−2.77)	(−2.73)	(−1.86)	(−1.98)	(−2.67)	(−2.73)	(−2.69)	(−2.61)	(−2.65)	(−2.54)	(−2.81)	(−2.76)	(−2.67)	(−3.63)	(−2.86)	(−2.75)
MLS	0.0345	0.0351	0.0463	0.0319	0.00827	0.0181	0.0258	0.0178	−0.00527	−0.0116	0.0350	0.0160	0.0292	0.0296	0.0438	0.0128	0.0239	0.0252
	(0.29)	(0.29)	(0.39)	(0.27)	(0.07)	(0.15)	(0.21)	(0.15)	(−0.04)	(−0.10)	(0.29)	(0.13)	(0.25)	(0.25)	(0.37)	(0.09)	(0.20)	(0.21)
Central Gov.	−0.104	−0.0791	−0.0977	−0.134	0.0281	−0.0133	−0.0530	−0.0671	−0.0634	−0.0222	−0.0752	−0.0792	−0.0546	−0.0751	−0.0739	0.0499	−0.0746	−0.0741
	(−1.07)	(−0.81)	(−0.99)	(−1.35)	(0.27)	(−0.13)	(−0.53)	(−0.69)	(−0.65)	(−0.22)	(−0.78)	(−0.82)	(−0.55)	(−0.78)	(−0.76)	(0.42)	(−0.78)	(−0.77)
Real interest rate (ac.)	−0.0128 *	−0.0136 *	−0.0125 *	−0.0127 *	−0.0174 **	−0.0164 **	−0.0137 *	−0.0131 *	−0.0129 *	−0.0139 *	−0.0129 *	−0.0134 *	−0.0130 *	−0.0131 *	−0.0122	−0.0124	−0.0132*	−0.0136*
	(−1.78)	(−1.87)	(−1.71)	(−1.76)	(−2.24)	(−2.20)	(−1.87)	(−1.79)	(−1.77)	(−1.77)	(−1.79)	(−1.86)	(−1.80)	(−1.81)	(−1.64)	(−1.58)	(−1.83)	(−1.87)
St. debt to exports	−0.00318	−0.00492	−0.00442	−0.00271	−0.00581	−0.00120	−0.00475	−0.00532	−0.00546	−0.00461	−0.00410	−0.00472	−0.00490	−0.00444	−0.00499	−0.000228	−0.00455	−0.00457
	(−0.86)	(−1.35)	(−1.20)	(−0.71)	(−1.52)	(−0.32)	(−1.27)	(−1.42)	(−1.47)	(−1.21)	(−1.10)	(−1.27)	(−1.33)	(−1.20)	(−1.34)	(−0.05)	(−1.23)	(−1.24)
Ratio ind. exports	0.00160	0.00397	0.00346	0.00283	0.00682 **	0.00279	0.00318	0.00320	0.00332	0.00426	0.00350	0.00393	0.00393	0.00357	0.00404	0.000573	0.00354	0.00361
	(0.58)	(1.52)	(1.30)	(1.07)	(2.29)	(1.06)	(1.20)	(1.20)	(1.27)	(1.61)	(1.32)	(1.49)	(1.49)	(1.35)	(1.53)	(0.18)	(1.34)	(1.37)
LIBOR (std.)	0.762 **	0.751 **	0.755 **	0.767 **	0.691 **	0.641 **	0.746 **	0.770 **	0.761 **	0.799 **	0.771 **	0.750 **	0.737 **	0.755 **	0.705 **	0.557 **	0.745 **	0.745 **
	(5.11)	(4.99)	(5.03)	(5.09)	(4.45)	(4.17)	(4.92)	(5.09)	(5.03)	(4.85)	(5.12)	(4.99)	(4.89)	(5.04)	(4.58)	(3.39)	(4.98)	(4.97)
China GDP growth	−0.00930	−0.0142	−0.00949	−0.00748	−0.0334	−0.0302	−0.0134	−0.00756	−0.00488	−0.00988	−0.00924	−0.0151	−0.0113	−0.0103	−0.0145	0.0100	−0.00991	−0.0136
	(−0.37)	(−0.56)	(−0.38)	(−0.29)	(−1.18)	(−1.12)	(−0.52)	(−0.29)	(−0.19)	(−0.39)	(−0.36)	(−0.59)	(−0.45)	(−0.41)	(−0.57)	(0.34)	(−0.39)	(−0.53)
U.S. GDP growth	0.214 **	0.208 **	0.210 **	0.216 **	0.114 *	0.159 **	0.223 **	0.222 **	0.222 **	0.217 **	0.217 **	0.209 **	0.213 **	0.215 **	0.187 **	0.227 **	0.216 **	0.210 **
	(4.37)	(4.20)	(4.26)	(4.32)	(1.76)	(3.04)	(4.39)	(4.44)	(4.37)	(4.41)	(4.36)	(4.22)	(4.29)	(4.30)	(3.61)	(4.06)	(4.33)	(4.23)
LIC	0.574 **																	
	(2.40)																	
MIC		−0.0310																
		(−0.28)																
UMIC			−0.0801															
			(−0.75)															
AFR				0.306 **														
				(1.99)														

Table A1. *Cont.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
EAP					0.735 **													
					(2.63)													
ECA						−0.700 **												
						(−3.45)												
LAC							0.151											
							(1.23)											
MENA								0										
								(omitted)										
SAR									−0.908 **									
									(−2.20)									
BRENT (ac.)										0.0144								
										(1.42)								
ENERGY										−0.284 **								
										(−3.24)								
ICT											0.164							
											(1.14)							
TRANSPORT												0.129						
												(1.43)						
WATER													0.133					
													(1.32)					
GOVRISK														−0.0661				
														(−0.81)				
MARRISK															−0.262 **			
															(−2.10)			
Contract period																−0.00713		
																(−1.46)		
Greenfield																	−0.143 *	
																	(−1.74)	
Brownfield																		0.0925
																		(0.98)
_cons	−1.752 **	−1.758 **	−1.675 **	−1.730 **	−2.175 **	−1.948 **	−1.760 **	−1.615 **	−1.556 **	−1.590 **	−1.765 **	−1.725 **	−1.741 **	−1.654 **	−1.723 **	−1.291 **	−1.548 **	−1.705 **
	(−5.06)	(−5.03)	(−4.73)	(−5.01)	(−5.21)	(−5.31)	(−4.95)	(−4.55)	(−4.43)	(−4.30)	(−5.07)	(−4.97)	(−5.01)	(−4.63)	(−4.91)	(−2.74)	(−4.26)	(−4.91)
N	3784	3784	3784	3784	3784	3784	3784	3724	3784	3784	3784	3784	3784	3784	3784	2533	3784	3784

Notes: T-statistics in parentheses * $p < 0.10$, ** $p < 0.05$.

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Identification of Various Execution Modes and Their Respective Risks for Public–Private Partnership (PPP) Infrastructure Projects

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Abstract: The public–private partnership (PPP) based model for the execution of infrastructure projects originated from Anglo-Saxon countries and was initially used in 1977 by the United Kingdom (U.K). Since then, its popularity has increased worldwide. Earlier studies by researchers and many other professional sectors and departments have introduced PPP contracts into different execution modes like Build, Operate, and Transfer (BOT); Build, Own, Operate, and Transfer (BOOT); and Build, Lease, and Transfer (BLT), etc. All definitions of PPP contracts are different but have a few common characteristics and risks. Previously, numerous pieces of literature were available on these common risks for various execution modes of PPP contracts. However, each PPP mode still has unique risks that must be identified to understand and successfully implement the PPP projects properly. This paper fills the gap mentioned above and aims to identify various commonly used PPP execution modes in infrastructure projects and their corresponding risks after placing the different PPP execution modes into four (04) different categories. Identified risks for the corresponding PPP categories were also divided into seven (07) stages of the PPP life cycle. Semi-structured interviews were conducted to gather information from thirty-four (34) PPP experts worldwide. Accordingly, interviews are transcribed and processed for thematic analysis in academic NVIVO software. These identified risks are further placed in the respective PPP category for the convenience and better understanding of the study's outcome to the users and for the subsequent prioritization and allocation of these identified risks accordingly to the PPP parties during the finalization of the PPP execution mode.

Keywords: public–private partnership (PPP); infrastructure projects; risk identification; PPP execution modes; public and private sectors; NVIVO hierarchy charts

1. Introduction

The PPP is a venture between the public and private sectors based on the expertise of each partner to accept the respective risk for the successful execution of the projects traditionally provided by the public sector [1]. The private sector can earn a long-term contractual relationship with the public sector to improve the company's reputation. In contrast, the public sector can take the monetary benefits and use the exposure to the latest technology through the execution of PPP projects [2].

It is a fact that PPP modalities are used for the execution of infrastructure projects under uncertain environments despite their experience has reached almost at maturity

level in the UK and other developed countries like France and Germany, which have now accepted it as a traditional execution method has not produced desirable output of project performance regardless of extreme care taken at early stages of the projects [3]. The PPP-based model originated from Anglo-Saxon countries [4] and was initially used in 1977 by the UK. Since then, its popularity has increased worldwide, and in the current years, it is spreading swiftly in China [5] and other countries in Asia, Africa, and Australia on a large scale [4]. PPP regime has now spread to around 134 developing countries with 15–20% of the total investment cost of infrastructure projects [6]. PPP has now become a vital part of public procurement due to budgetary constraints, deficient technological expertise, less risk acceptability by the public sector organizations, less PPP exposure, untrained human resource, gaps in demand and supply, and political pressure for improving public services projects [7]. The PPP procurement approach is widely used for various sectors of infrastructure projects such as highways, residential colonies, health care facilities, water treatment plants, etc. [8]. Considering the complexity of the PPP procurement approach, it is essential to identify its related risks comprehensively throughout the life cycle of the PPP projects arising from the multiple dimensions [9]. It is also imperative to identify the risks of the respective modality of PPP contracts to properly allocate risks when developing the risk allocation matrix of PPP projects [10].

Earlier studies by researchers and many other professional sectors and departments have introduced PPPs in various execution modes in multiple countries like BLT, BTO, BOT, BOOT, BOO, PFI, BTL, CAO, etc. [11–13], wherein all definitions are different but have few standard features [12]. For example, in BTL, the private sector builds the infrastructure facilities, the ownership is transferred to the public sector after the completion of the project, and rights of operation of that infrastructure facility are given to the public sector. In the BTO contract, the private sector quotes the operations charges to recoup its cost from user levy charges. Both Build and Transfer are the same in these modes, but the infrastructure facilities are leased to the public sector by the BTL private sector. In such cases, the public sector pays the lease amount and the operational cost to the Concessionaire. BTL mode is usually employed for non-profit works or services such as sewer, housing infrastructure, and other dormitories [13].

A risk is an unanticipated event or state that, if triggered, has positive or negative consequences on one of the project objectives, which can be termed as opportunities or threats, respectively [14]. Famous tools and techniques used to identify risks are interviews, meetings, brainstorming, SWOT analysis, checklist items, and meetings. PPPs are more vulnerable in terms of uncertain events happening and carry various and critical risks as compared to the traditional types of public contracts, including outsourcing services and works [5]. The objectives of the study are to identify the various execution modes of PPP infrastructure projects and their corresponding risks pertaining to the respective categorized PPP execution modalities.

2. Literature Survey

The Transaction Cost Theory [15] best explains private partnerships in PPP infrastructure projects. The theory is related to the degree of risks the private party accepts depending on the future benefits and privileges in return for taking risks. Moreover, Agent Theory or Principal-Agent theory [6] also describes that the public sector must establish an environment that not only corrects the moral hazard related to the prospective private partner but also provide a conducive and attractive environment for the private partner.

In the last twenty (20) years, the research interest of scholars has increased in the PPP domain, especially in European countries [16]. The growth of PPP and its role in various projects is not a fresh concept, but it is experiencing renewed curiosity in the study of PPP as a tool for better development planning. Outstanding public debt and financial constraints are placing pressure on the state and governments around the globe for the participation of the private sector in various socio-economic development programs [17]. Moreover, it rearranges services related to the public sector by considering private sector worth and

good practices to achieve better project performance than traditional procurement methods of delivering public services [18]. Current studies locate PPP as a partnership of cooperation and contractual obligation among the state, government, and private sector to share risks, opportunities, and costs to accomplish some responsibilities and activities to accomplish a collective objective [19] as described in Transaction Cost Theory above.

Different stakeholders involved in any project under PPP procurement modes have different perceptions regarding risk assessment. As a result, disagreements may arise among stakeholders that affect the project performance [20]. Thus risk identification, followed by its allocation, is an ambiguous task [21]. Moreover, stakeholder relationship leads to a viable long-term method for improving social linkages, enlightening the value of public means, and creating a better use of taxpayer collection [20]. Intensive efforts have been placed on the improvement of ways by which the public and private sectors can strengthen corporations to provide goods and services traditionally provided previously by the public sector only. The different perceptions of the stakeholders may produce the best and fair results; that is, the outcome that reduces the possibility of bad performance [21]. The reviewed literature on different forms of PPP projects shows that most of the studies are conducted on PPP infrastructure projects. The title of most of the studies belongs to critical success factors of PPP, risk related to PPP, and the BOT tendering process for bringing value for money [22].

Every PPP agreement is differently structured, and therefore the type of risks are different for each stakeholder due to the diversity in each PPP modality [23]. Assessing all risks is key for proper project management at various stages of the project life cycle period [24]. This leads to suitable risk allocation and sharing, which is inevitable for negotiation [5] and brings transparency, fairness, and value for money to PPP projects [25]. Inconsistency in risk assessment and management is one of the barriers to the successful execution of the PPP project [26]. Lack of readiness to accept risk by either of the stakeholders delays the project [23]. Risk aversion by the stakeholders during the entire life cycle of the PPP projects due to the improper risk allocation in PPP projects was highlighted in past studies [27].

World Bank manages a facility for technical support that is known as Public–Private Infrastructure Advisory Facility (PPIAF) [13]. It summarizes the modes and types of PPP in accordance with the main attributes and characteristics of various definitions of PPP, as shown in Figure 1 PPIAF (2012, May) [28]. In this figure, PPP modalities in existing assets are surrounded by concession, operations and maintenance, management, and service contracts. PPP modalities are surrounded by BOOT, BTO, and turnkey contracts.

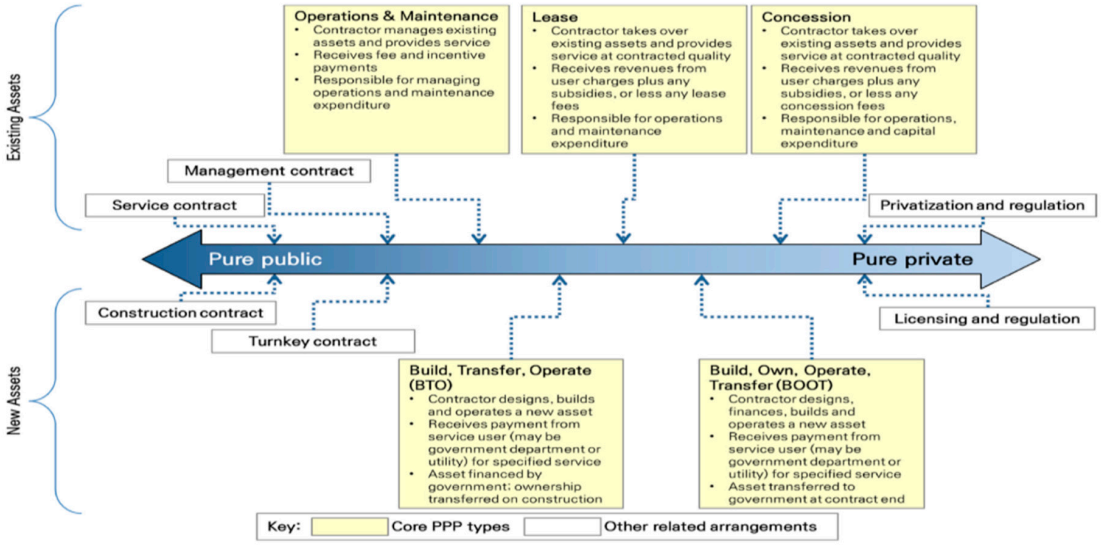

Figure 1. Core PPP contract types and categorization Public–Private Infrastructure Advisory Facility (PPIAF).

The BOT execution mode of PPP is widely and commonly used in the world, especially for greenfield projects [29]. Economic theorists consider this model as the conical form of PPP infrastructure projects due to its greatest attraction and theoretical interest [30]. BOT type of PPP modality has a positive impact on the growth of the countries and is commonly used where the public sector lacks the resources to build large-scale infrastructure facilities [31]. BOT is a contractual type whereby the private sector arranges the financing and undertakes the construction of infrastructure facilities and the operation and maintenance thereof. The private sector operates the facilities over a fixed period of time during which it is permitted to collect from the users of that project facilities in terms of appropriate tariffs, fees, levies, tolls, rentals, or charges, as agreed in the bid not exceeding those proposed rates of the bid [32] described in the agent cost theory above. The private sector then transfers the facilities to the public sector at the contract ends. BOT (Toll), BOT (annuity), DBFOT, hybrid BOT mode (toll + grant) [33], DOT, ROT, and BOR execution modes are almost similar, with slight variations in concession agreements. In BOR, the private sector has the right to make a request to negotiate for the revision of the concession at the end of the term [32]. DBFOT mode also includes the investment of private sectors to construct, design, finance, operation, and maintenance of a venture for public usage for a certain period of time and then transfer the facilities to the public sector after the expiry of the ownership period. The Concessionaire is able to collect the revenues or user levy from the facility users. The private entity collects the fee from the users as quoted in the bid submission stage. The expectations of the private sector are to collect sufficient revenues to recoup its investment in the project [34]. A similar PPP mode DBFO with no transfer phase is more efficient in terms of cost and time for PPP infrastructure projects [35]. Notable examples of projects executed on BOT or DBFOT mode in Pakistan are the Lahore Ring Road (Southern Loop) project and the Lahore–Sheikhupura–Faisalabad Dual Carriageway [36]. In order to address the failure of demand forecast, attract investors and promote privatization and investment by the private sector, BTO (risk sharing) and BTO (adjusted) modes were introduced and adopted by the Korean Government for the construction and rehabilitation of railway-related projects. Both public and private sectors share the revenues and operating costs in the BTO-rs mode of PPP infrastructure projects [13]. However, in BTO (Adjusted), the risk sharing in revenue loss is adjusted as agreed by the parties [37]. AP-PPP also falls under the BTO-PPP types of contracts [38]. One of the types or modalities of PPP contracts is the present value of revenues contract (PVR), which is an example of a flexible contract in order to minimize the demand risks of the revenues [39]. Flexibility in contracts provides various options for the public and private sectors to compensate for the risks in accordance with the concession agreement. A minimum revenue guarantee, which is also termed a minimum income guarantee or minimum demand guarantee, could be a possible inclusion in the agreement. The public sector shares the demand risk partially in infrastructure projects [13].

In the Republic of Korea, the PPP procurement types are based on whether the project facilities are to transfer back to the public sector or not on the completion of facilities of PPP projects. The foremost type is also called the revertible type, which includes BOT, BLT, BT, BTO, etc., and the other is called the non-revertible type, which includes BOO, DBFO, etc. On the basis of the collection of user fees, PPP infrastructure projects are categorized as whether to collect directly from the users or through operations and management rights, i.e., BTO, or from ownership rights, i.e., BOOT, BOO, etc. [37]. The BOO execution model is akin to complete privatization, and the private sector has no obligation to transfer the project facility assets to the public sector [29]. This execution modality is used when the private sector wants to keep ownership of the assets even after the contract ends [29]. One of the disadvantages of this mode is that the private sector uses the project's public facility throughout its life period. The public sector should create an interface between the old and new operators of the venture by making sure that the new party takes care of the system's features and that personnel are well-trained [40]. Some notable examples of projects executed in BOO mode are the Shuweihat-2 Power and Desalination Plant,

United Arab Emirates, and the Manila Water Supply and Sewerage System, Philippines. BOOT mode is also similar to BOO PPP mode, with the responsibility that the infrastructure facility is transferred back to the public sector after the pre-determined concession period [41]. BOOT is a significant PPP execution mode for the development growth of infrastructure projects. This modality is now being practiced in many developed and developing countries like Australia, the USA, Canada, the UK, India, the Philippines, Malaysia, etc. [42]. Notable examples of executed projects in BOOT mode include the Sydney Airport Link in Australia [42].

BLO execution mode includes that facility ownership remains with the private party who leases the facility to the public sector for a longer period of time without any transfer of assets responsibility. The public sector is responsible for the operations and maintenance, renewal, and replacement of assets and gives attention to maintaining the interface between the construction phase and the operation phase [40]. A few notable examples of projects executed in BLO mode are the Mount Signal Solar Project in the United States and the Delhi International Airport in India. In the BLT execution mode, the private sector leases the completed facility to the public sector or others for a concession period until it recovers its investment before transferring the facility owner to the public sector [43]. Moreover, the Concessionaire finances builds and maintains the project for a predefined period and leases the assets to the public sector for fixed revenue payment and rental payment of these assets [44].

In the LOT execution mode of PPP, the existing infrastructure facility is for efficient operation to the private sector for a certain period of time. After the completion of the predefined concession period, the facility is transferred back to the public sector [41]. Transfer–Operate–Transfer (TOT) is a PPP mode that is suitable for brownfield projects, and the facility is transferred to the public sector after the contract ends [29]. Other renowned PPP execution modalities are the SC, the MC, and outsourcing-like contracts wherein the ownerships lie with the public sector and investment responsibilities lie with the private sector. Management contracts have a slightly longer duration than service contracts [33]. Sewage treatment plants in China are mainly operated through the PPP modalities, which include BOT, BOO, ROT, OM, TOT, BOT + TOT, and others. BOT is selected for most of the cases, up to 83.7 percent of total sewage treatment projects in China [2].

In the BOLT execution mode, the private party builds and expectedly designs the infrastructure project and leases the facility to the public sector. After the end of the concession period, the facilities are returned back to the public sector. Most of the PPP modalities are suitable for transportation projects with revenue collection, but this mode is equally suitable for other social projects [41]. BLOT and BLMT execution modes of PPP are similar, with a slight difference in terms of operational responsibility in the first case and maintenance responsibilities in the second case lying with the private sector over the concession period [2]. Quite a few infrastructure projects have been executed in China on these modes since the inception of the PPP regime in the country [45].

In the Philippines, BOT law exists, which includes various PPP modalities, including BT, CAO, DOT, and ROT execution modes [37]. BT is a PPP execution mode whereby the private sector arranges finances and undertakes the construction of the infrastructure project facilities and, after its successful completion, transfers back to the public sector. The public sector maintains, operates, and recovers the investment cost from the users as per the agreed schedule. Operations and maintenance phase risks lie with the public sector due to security or strategic reasons. Whereas, in BT + LUF, the public sector recovers the finances of the project through land use by real estate developers [46]. Moreover, DBB is the PPP execution mode whereby the public sector retains a designer to deliver the whole design part and, after then, publishes an advertisement for the award of construction works separately, keeping in view the completed bidding construction documents of the designer. DB, DBO, DBOM, and DBOFM are akin with slight variations in the contractual arrangements [47]. Various projects around the world are executed on DBOFM mode, and notable examples include the Hong Kong–Zhuhai–Macau Bridge and the Tappan

Zee Bridge Replacement Project in New York. CAO is a PPP modality with a contractual arrangement wherein the Private sector develops and expands existing infrastructure facilities leased by the public sector. The private sector operates the developed facility and collects the user charges to recover his investment cost over the agreed period. Transfer facilities may or may not be linked with this type of PPP modality by the private sector [11].

Apart from the previously mentioned PPP execution modalities, BBO and DBL modes also exist for the execution of PPP projects in Indonesia and other countries but are very uncommon. The assets are built and acquired by the private party for effective management in this particular PPP mode for infrastructure projects [37]. The extent of public and private participation in various PPP types of agreement is described in the Figure 2 below.

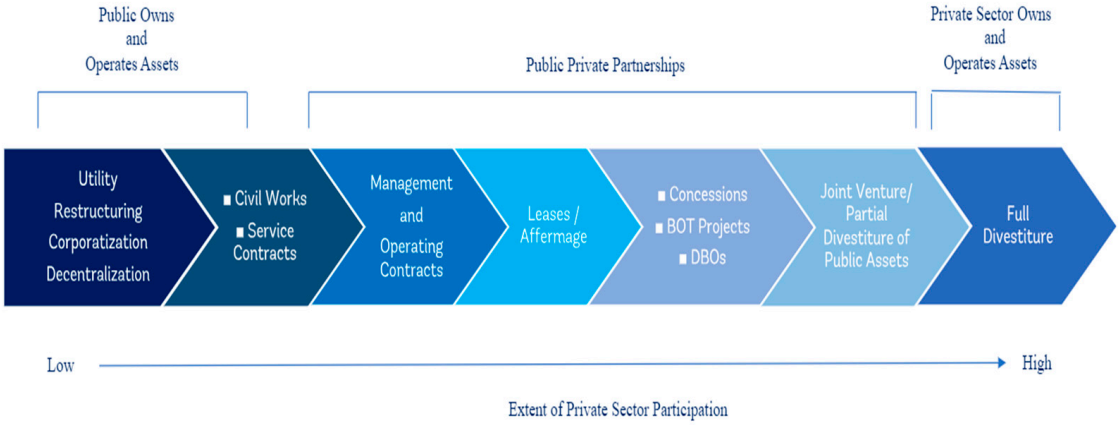

Figure 2. The extent of public and private participation (https://ppp.worldbank.org/public-private-partnership/agreements (accessed on 3 March 2020).

Moreover, most of the time is consumed for contract negotiation in PPP/PFI projects due to the uncertainty in the proper identification of risk at the initial stages, which ultimately drives the prospective bidders to quote expensive bids [25]. Researchers identified the critical success factors for PPP projects, including stable macroeconomic variables, responsibility sharing among stakeholders of the project, a stable environment politically and socially, transparency and efficiency in the procurement process, and judicious government control [48]. PPP projects normally follow the base case scenario at the time of the award of the contract, and to make it flexible, overwrite clauses in the contract agreement are included to cope with volatility in the macroeconomic variables. For dealing with such risks, the government retains most of the risks and explores different forms of PPP agreement, simulating different possibilities by the public departments to extract the risk threshold values for retaining risks. The surplus revenue generated through the approach of a flexible contract is retained with the Concessionaire, but the handsome contribution also goes to the public entity [49]. Researchers also report the results of a comparative analysis of the preference for risks in PPP projects [50]. It is broadly acknowledged that risk assessment is fundamentally required for the successful execution of PPP projects [9]. At the early stages of the PPP procurement process, public clients present the identified risk to the private party for bidding purposes, and during negotiations, these risks are allocated to the party best suitable to manage the risks [25].

3. Research Methodology

Research methodology is a source of guidance for researchers to conduct research from start to end [51]. Qualitative type interviews followed by an extensive literature review and desktop data were conducted in order to fill the gap of deficiency in the existing literature [3]. Semi-structured formats for in-depth exploratory research were developed for the identification of various modes and respective risks of PPP infrastructure projects because the goal was not to generalize the results of the study but to explore from the thorough

participation of the respondents [52]. Initially, the questionnaire was distributed to the respondents, which was revised from interview to interview, considering their suggestions for improvement from the informants [53]. Open and close-ended questions were asked in the questionnaire to give the liberty to the informants beyond the protocols as mentioned in Appendix A of the study to establish related useful additional information [54].

Most of the questions were from the interview protocol; however, additional questions were also asked from the interviewee for the sake of obtaining extra information. The current study includes the representation of informants from all over the world. Most of the respondents are from public, private, or advisory sectors, as shown in Figure 1. The list of informants has fifty (50) people. Hard and soft copies of the questionnaire were sent to them at their official addresses, email addresses, or through other electronic means. Forty (40) people responded to the questionnaire and agreed to give interviews to share their perspectives regarding the identification of various PPP modes and respective risks. Interviews are conducted in their offices, and some of them agreed to record their interviews after their consent on the Zoom meeting link. According to [55], the data saturation was completed with 30 informants. However, four more interviews were added to the study to ensure that any further information could be added to the study. Thirty-four (34) informants included twenty-five (25) male and nine (09) female PPP experts. Interviews were conducted with the personnel of various organizations, which include the public and private sectors, the Independent consultants and advisors, and the Concessionaire (SPV) organizations, as shown in Figure 3 below.

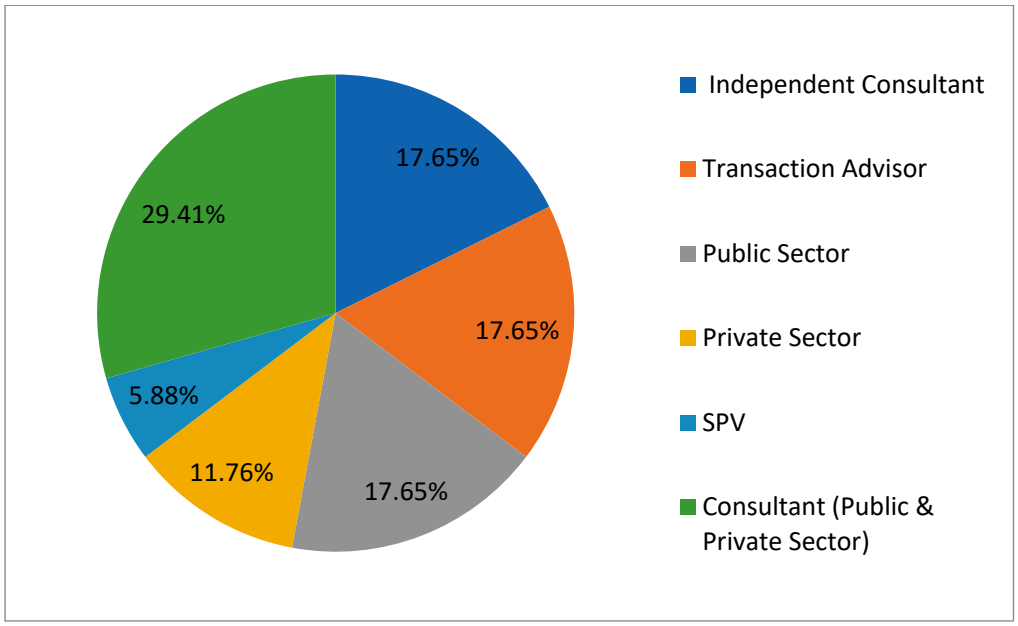

Figure 3. Organizational type.

The top-level experts and the middle-level experts from various organizations were approached through various references telephonically, zoom meetings, or meeting at their places for the interview purposes, with the range of their experiences varying from five (05) years to twenty-five (25) years, as shown in Figure 4 below.

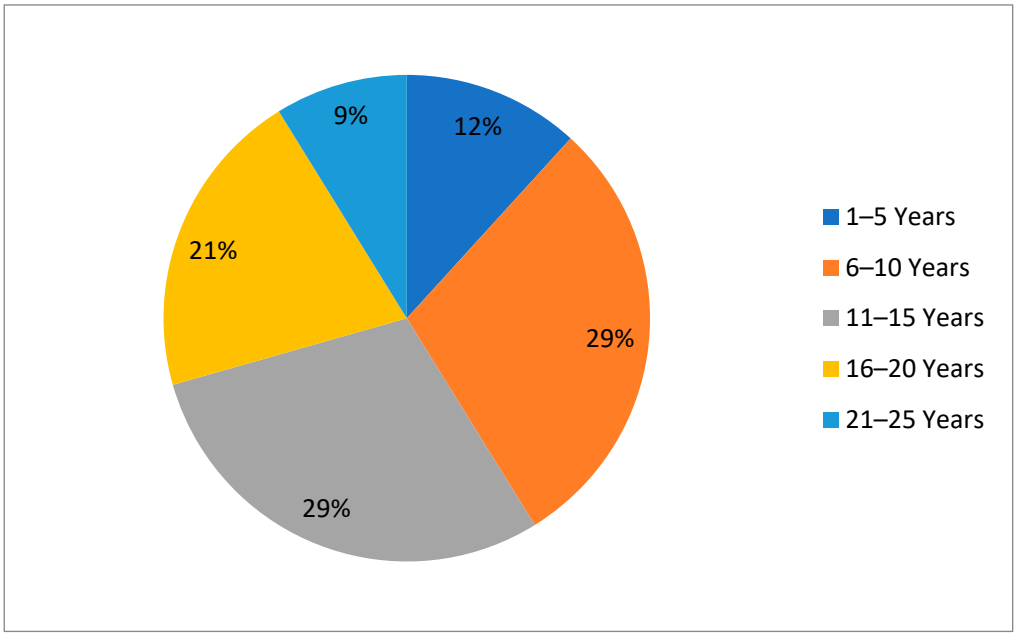

Figure 4. Experience of respondents in years.

The educational background of the respondents is shown in Figure 5 below. The duration of the interview was thirty (30) to forty-five (45) mins depending upon the satisfaction of the researchers.

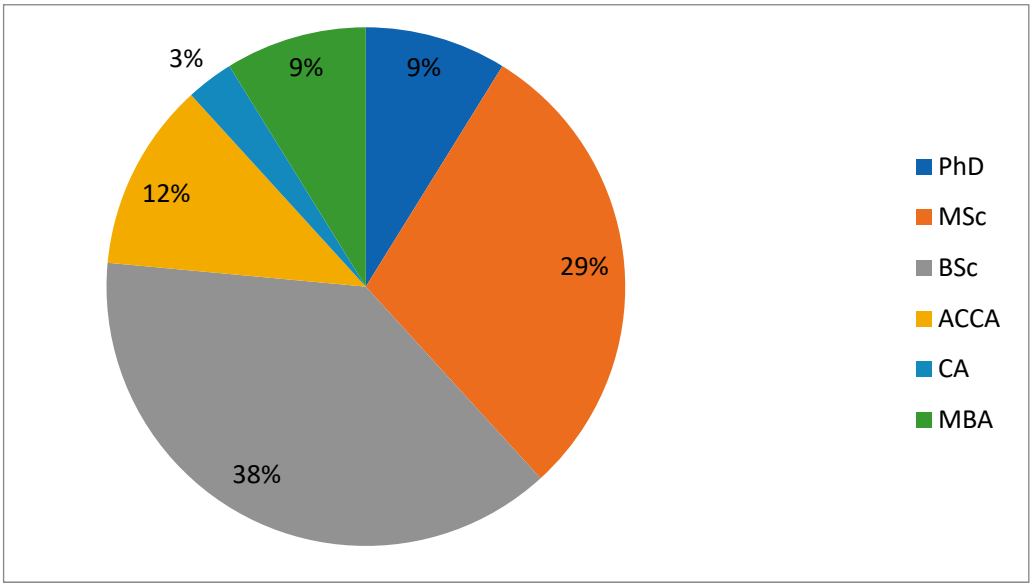

Figure 5. Educational background.

The research methodology is shown in the following Figure 6.

Six steps of thematic analysis [56] were performed for the identification of PPP modes and their respective risks. These steps are data familiarization, generation of the primary theme, searching of theme, reviewing of themes, naming of themes, and result generation. The coding method was used both for deductive and inductive reasoning, and the former started with a basic structure for coding.

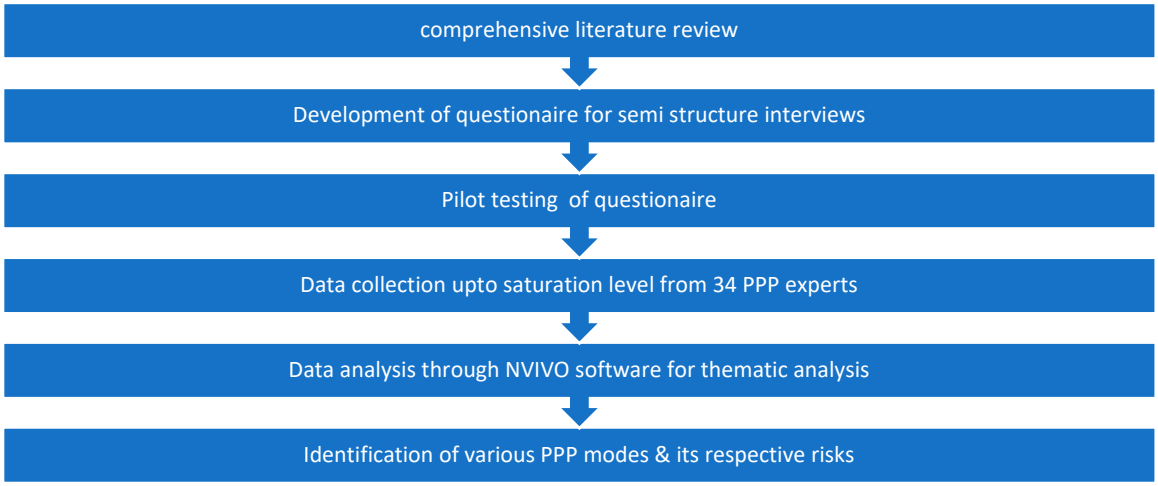

Figure 6. Research methodology.

It was performed through the NVIVO academic software, which allows for performing analysis of unstructured and qualitative data. It is also helpful for classification and rearranging the data for the users. Parent codes were created by the authors on the basis of four (04) categorizations of PPP infrastructure projects, i.e., the DBFOT-BOT type of PPP contracts, the lease–affermage BLT type of PPP contracts, ownership-BOOT type of PPP contracts, and the services, operations, and maintenance type of PPP contracts. Child nodes are grouped with mode "name". Child nodes were further divided into their respective risks identified by the interviewees after reviewing the transcribed data and labeling the codes with the names mentioned by the practitioners. The overall coding exercise in NVIVO is shown in Figure 7.

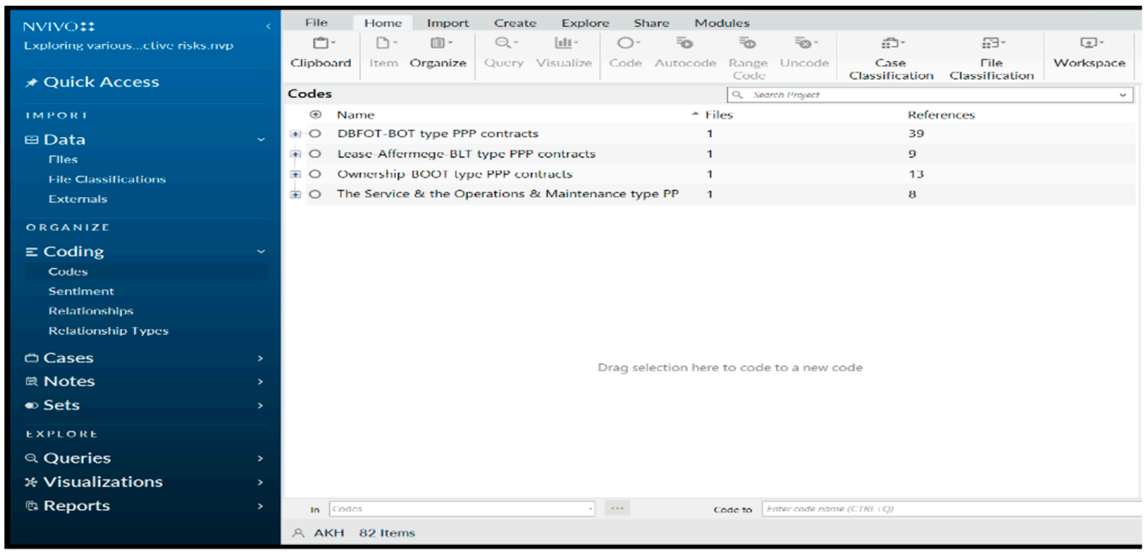

Figure 7. The NVIVO coding and the hierarchy chart.

4. Research Results and Discussion

The study identifies the various execution modes of PPP infrastructure projects adopted around the world and also the identification of associated risks of these PPP modalities. Subsequently, interview data were gathered in the form of partial audio recordings after soliciting the consent of the respondents and partially from the interview notes taken from the informant's interviews in their offices or places. Data analysis was performed on NVIVO academic software, and developed the parent codes and child codes, as

mentioned in Figure 7 above. NVIVO created the overall coding for the transcribed data, a purview of it as under;

Figure 8 shows the overall coverage of PPP modes and their respective risks by the respondents on the basis of data collected for the study. The data taken from the previous literature were also discussed with the respondents, and the concept of each perspective was supported accordingly. The world cloud shown in Figure 9 highlights the importance of each identified factor according to the perspective of the experienced personnel.

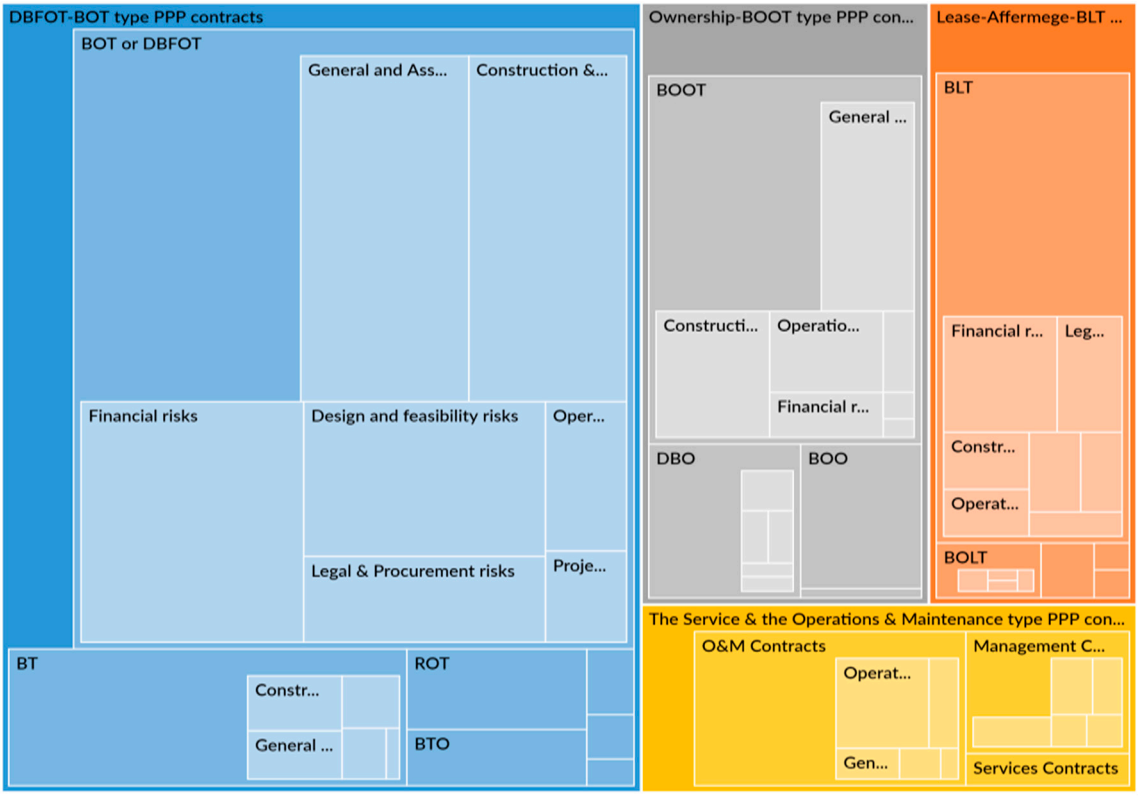

Figure 8. The purview of overall NVIVO coding of transcribed data.

Figure 9. NVIVO word cloud.

Figure 10 shows the analysis of the first category, i.e., DBFOT-BOT type PPP contracts, which include BOT or DBFOT; both modes are akin with different nomenclature according to most of the researchers, BT, BTO, DOT, DBOFT, CAO, TOT, and ROT. Most of the respondents talk about the BOT or DBFOT mode in this category along with their respective risks, which shows the importance of the BOT modality in the construction and execution of infrastructure projects around the world, especially in tolled roads and highway projects. The importance of mode under this category can be seen in Figure 10 [44]. Phang categorized the PPP risks related to infrastructure projects into the planning, design, and feasibility risks; the financial risks; the legal and procurement risks; the construction and execution risks; the operations and maintenance risks; the general and project environment risks; and the completion and transfer of assets risks. In the BOT mode of construction, the importance of the general and transfer of assets risk, the financial risks, the construction and execution risks, and the design and feasibility risks is highlighted in the following hierarchy chart.

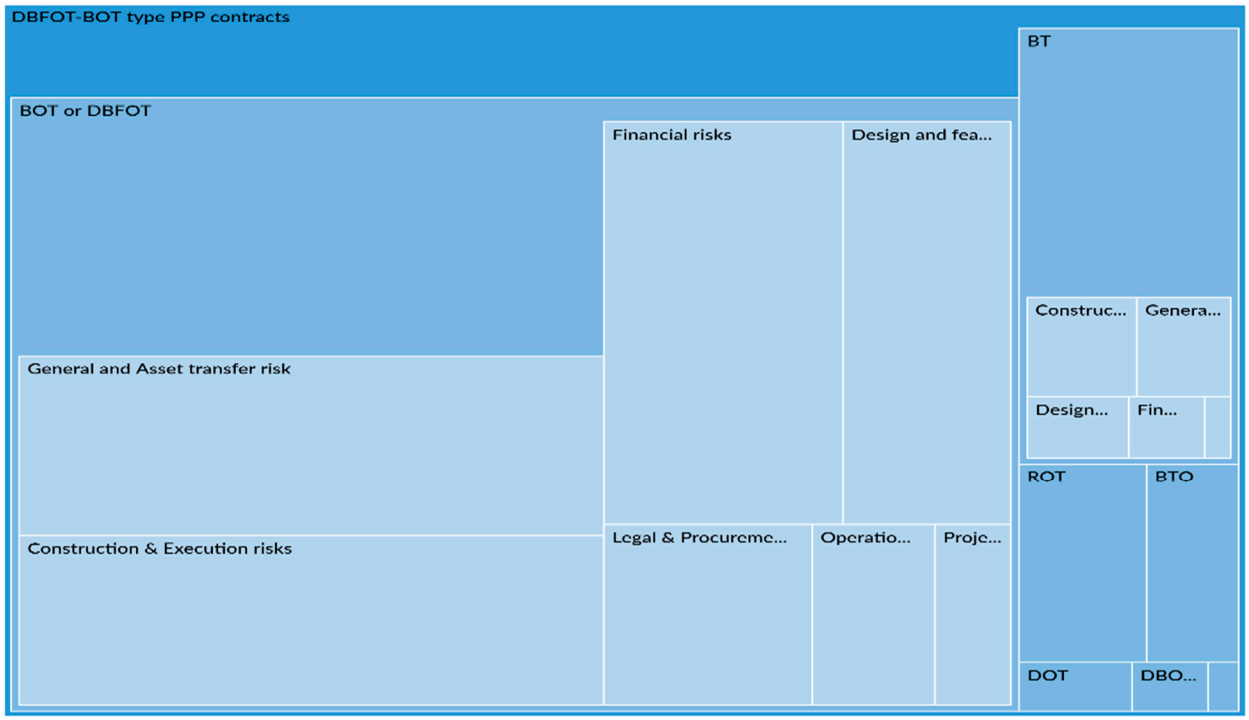

Figure 10. NVIVO coding of DBFOT-BOT Types of PPP contracts.

Broadly, two types of PPP road infrastructure projects are known as greenfield and brownfield projects. New construction, building, and developing a project is placed in greenfield type of projects, whereas rehabilitation, renovation, restoration, or upgradation of existing infrastructure facilities comes under brownfield or grey-field types of PPP projects. The earlier one is also expressed as Private Finance Initiative (PFI) in the UK, and the latter one is also termed the integrated PPP approach [57]. BOT with availability-based payment is usually conducted in social types of infrastructure projects. BT is a PPP execution mode where the public sector has two assets where either of the assets is capable of earning revenue, and the other is not. The mode of payment is managed through annuity-based or availability payments [33].

The provision of drinkable water from sea water in Saudi Arabia is being planned, where the public sector provides the annuity to the Concessionaire for recoupment of his investment in the project. Developing countries with no PPP experience have inherent risks attached to them due to a lack of experience/talent and limited competency and resources to undergo PPP projects, which vary from country to country [58]. The inherent risk, the poor cost estimation risk, the unproven engineering techniques risk, the soil contamination

risk, the poor geotechnical investigation risk, and land availability or acquisition risk are significant risks coded under the planning, design, and feasibility risks NVIVO code.

Cost estimation risk in greenfield projects is a prevalent risk. Huge differences in cost estimation at the feasibility stage of the project and at the completion stage of the project can be faced due to this risk in different PPP projects around the world. Poor geotechnical investigation is one of the reasons for inaccurate cost estimation [59]. A similar kind of risk in the shape of soil contamination was faced in one of the PPP infrastructure projects in Australia, where poor estimation added around 15% extra to the cost of the project. The contractor blamed the public sector, and vice versa, and the matter went to court. Consequently, stoppage of work was an option for private entities on that specific portion of work until the time of its resolution amicably. The extra cost was divided between the three parties by the court, and the executor bore the most part of the cost because the whole project was to be managed for a longer duration. In comparison, the design and estimation of infrastructure project is usually available for brownfield ROT types of infrastructure projects. There will be more Brownfield ROT types of PPP infrastructure projects in the future due to the deteriorated conditions of the roads and other infrastructure facilities [60].

A few significant risks related to legal and procurement risks include the insolvency of the concession company, the provision of encumbrance-free land risk, the condition precedents risks, the change in law risks, the regulatory risks, the ownership risks, and the imports and supply chain risks.

Figure 11 highlights the PPP modalities and their risks under the lease–affermage BLT type of PPP contracts. BLT, BOLT, BLOT, BTL, BLMT, BLO, DBLOT, and LOT are the PPP modalities placed under this category. The importance of each execution mode with respect o the responses of the respondents can be seen in Figure 11. In BLT mode, the Concessionaire builds and constructs the project assets and hands them over or leases them to the public sector for the recoupment of investments of the investors of the project [43]. BLOT and BLMT are alike modalities of PPP with a slight difference in the shape of separate responsibilities, i.e., the management responsibility or the responsibility of the operations, or both. For example, in the development and construction of an industrial estate, Concessionaire builds the infrastructure and leases out the residential and commercial plots to the public sector for a certain period of time, whereas the operations and maintenance responsibilities shall remain with the private sector.

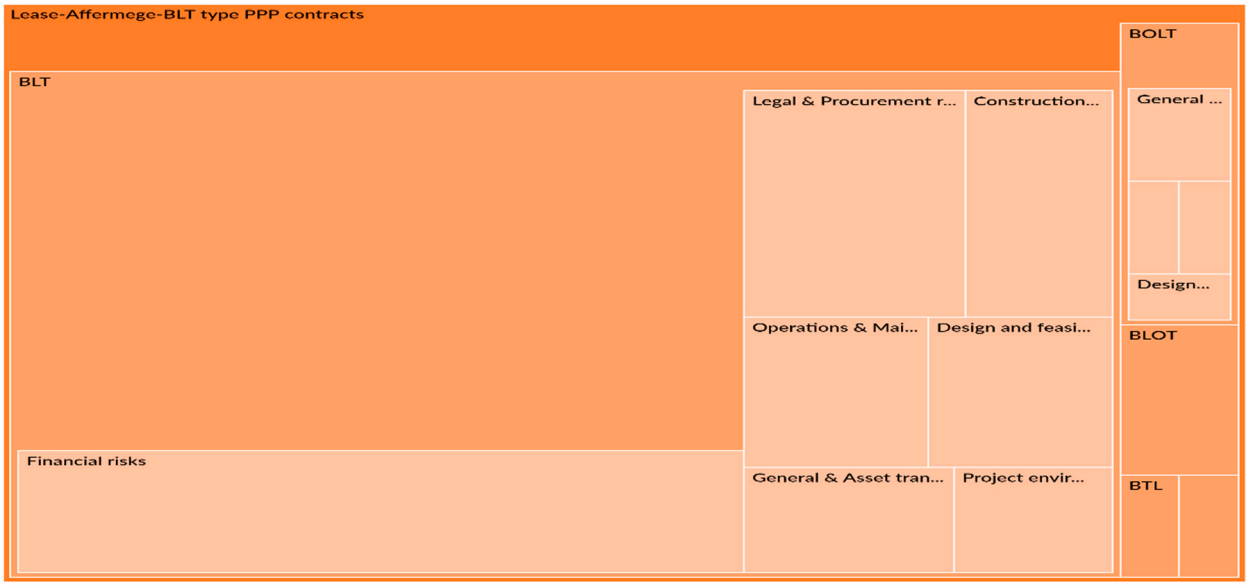

Figure 11. NVIVO coding of lease–affermage BLT types of PPP contracts.

Another major risk in PPP infrastructure projects is the availability of finance. Most of the projects failed due to this risk because, at the stage of feasibility study/initial stage, this

risk is not fully assessed by the stakeholders. Another potential risk is price escalation risk, which triggers the commonly known cost overrun risk, especially in developing countries. As the said risk is covered in the traditional types of contracts, therefore it should be covered in PPP greenfield projects by considering its severity and multifold consequences [57]. At present, there is an unprecedented price hike and currency devaluation, and ultimately, it is the responsibility of the Concessionaire to take the burden of these risks during execution. The compounding effect of these parameters is too much. Inflation risk and foreign exchange risk are also major risks in the current scenario of the world's economy and should be properly addressed at the time of developing the transaction structure of PPP infrastructure projects. Foreign currency exchange-type risks are predominantly seen in independent power producer (IPP) contracts. Developing countries are facing balance payment crises, and they have to go to the international monetary Fund (IMF); therefore, the private sector is receiving delayed payments, but in the end, they are unable to obtain foreign exchange from the market and unable to provide the dividends to the shareholders. Interest rate risk is available in all types of PPP modalities. Few transactions of PPP are available where the government can take up this risk, but in developing countries, it is unheard of where the government can take up this particular risk. After achieving financial close, the public sector leaves you with your buyers or other stakeholders. But, this is not the case in developed countries of the world. The importance of revenue loss risk, demand risk, tariff risk, commitments with financial institutes, and financial close risk cannot be ignored [50]. The competing routes risks and the force majeure risks cannot be ignored during the current COVID-19 pandemic period. Construction materials and prices of other goods have increased too much due to COVID-19; the global supply chain has been disturbed, which had severe effects on the PPP projects, where the countries are dependent a lot on imports. All these risks are placed under the financial risk NVIVO code.

A few typical risks specifically belonging to the lease–affermage BLT type of PPP contract category are explored by the practitioners the tenant/lease risks, the revenue shortfall risk, the property-related risk, and the market risks. Some of these risks are a new addition to the existing literature. However, the existing literature does not bifurcate these typical risks for this category, which create difficulty for the executors to properly identify and allocation of these risks to the concerned stakeholders.

Figure 12 elaborates on the PPP modalities and their respective risks of the ownership-BOOT type of PPP contracts. This category includes BOO, BOOT, DBO, DB, DOO, and DBOOT PPP modalities. The importance of each execution mode with respect to the responses of the respondents can be seen in Figure 12.

PPP modality wherein ownership of assets belong to the private party, i.e., BOOT types of projects, risks related to land acquisition can be easily managed by the public sector because the ownership responsibility is shifted to the private sector [37]. Also, BOOT is popular in the power sector because technology related to the power sector obsoletes, especially in a long concession period, i.e., 25 years; therefore, the public sector does not want to take ownership of assets being useless after the concession period. Asset management risks due to lack of research and development in PPP projects, depreciation risks, residual value risks, obsolescence risks, disposal risks, maintenance risks, interconnectivity with other roads, and partnership risks are typical examples of risks pertaining to ownership-BOOT type of PPP contracts.

Thus, the completion and asset transfer risks phase have more coverage in this particular category, as shown in Figure 12 above, which includes the asset maintenance risks, market demand risks, residual value of asset risks, obsolescence of asset risks, transfer of assets risks, ground condition, the conditional survey of assets risks, and the ownership of assets risks. After general and asset transfer risks, the construction and execution risks have more coverage, as shown in the above figure. This section includes vital risks like construction disputes and strike risks, construction cost overrun risks, quality risks, availability of manpower and material risks, site availability risks, schedule risks, shifting of utility risks, and scope creep risks. Corruption risks, regime change risks, political risks,

environmental permit risks, lack of R&D in PPP, and ground and weather conditions are significant risk factors of the general and environmental risks phase of PPP projects.

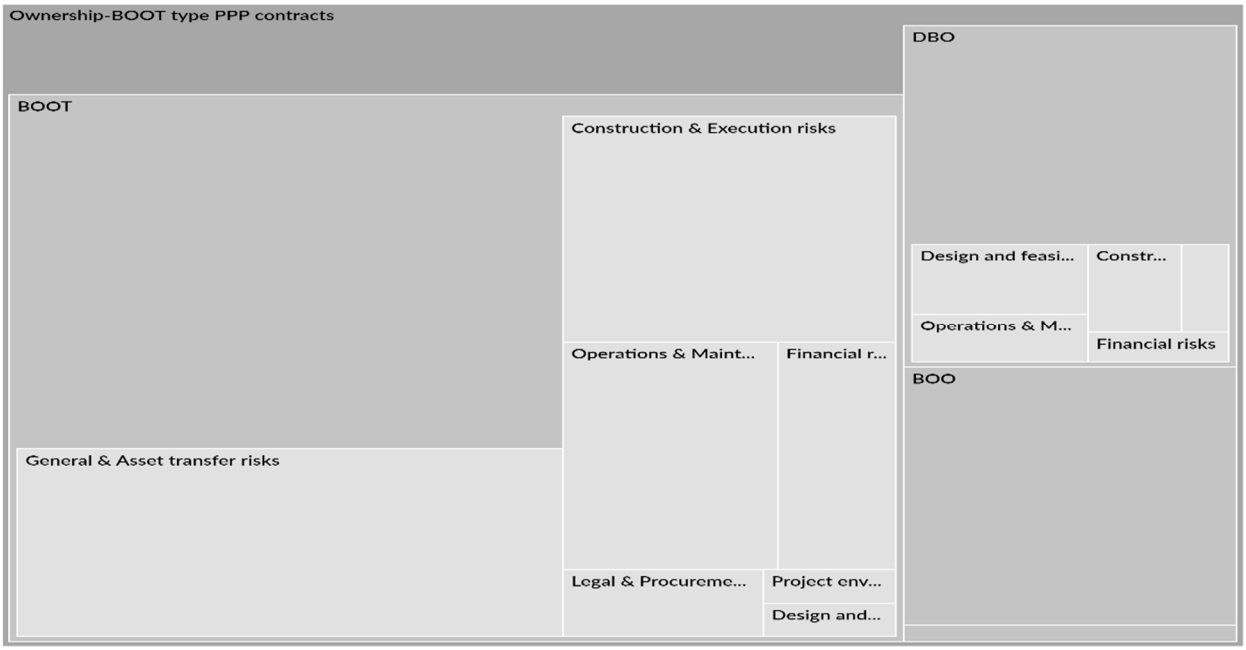

Figure 12. NVIVO coding of ownership-BOOT type of PPP contracts.

The last category of PPP modalities is the services and the O&M type of PPP contracts, which includes the O&M contracts, the management contracts, and the services contracts. In the service and the O&M type of PPP contracts, the private sector accepts the payment risk. Real estate developers, hospitals, and educational institutes are examples of the services and the O&M type of PPP contracts. Operations and maintenance risks have high weightage in this category, including performance risks; the operator's default risks, the low operating productivity risks, the low operational quality risks, and the operational cost overrun risks are prominent risks.

The deductive coding of the data was further assessed inductively by the researchers. It was found that BOT or DBFOT, BOOT, BLT, BT, BOLT, BOO, and the BOOT modalities are the most commonly used modalities around the world for the execution of the PPP projects, but BOT or DBFOT mode has a huge contribution for the execution of PPP projects around the world, especially in tolled roads and highways related infrastructure PPP projects. This is quite clear in the following Figure 13, where the NVIVO nodes are shown horizontally, and the percentage coverage of their corresponding transcribed data is shown vertically.

Finally, the identified PPP modalities for the execution of infrastructure projects were categorized, and the risks were identified along with their definitions for the respective categories summarized in Appendix B of the study and developed risk register by using both primary and secondary data [61,62]. The public sector offers a minimum demand guarantee (MDG) and minimum revenue guarantee (MRG) to attract private investment in PPP projects to cater to most of the risks in the risk register of Appendix B [63–70]. Moreover, a suitable Concessionaire for efficient project delivery is also an essential aspect of coping with these risks [18]. Due to the evolution in PPP, a slight shift from the traditional approach of PPP in the shape of revenue-based payments like BOT to availability-based payments like DBFM is also being used for the procurement of infrastructure PPP projects [51].

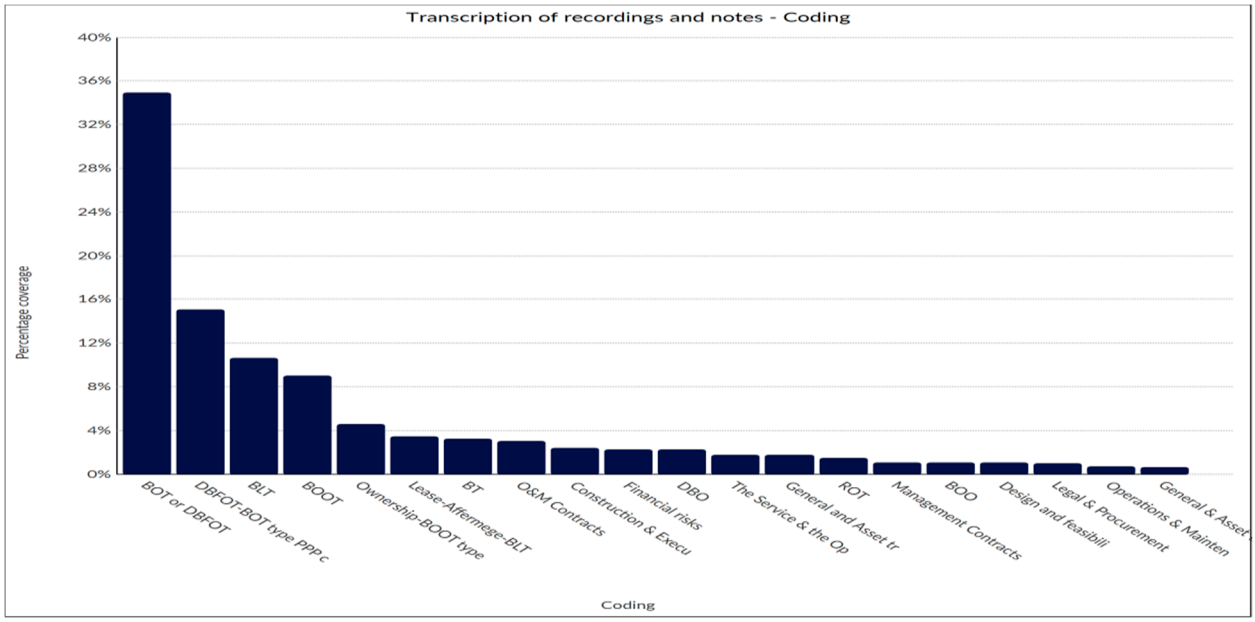

Figure 13. Percentage coverage of transcribed data.

5. Conclusions

The basic purpose of the study was to identify the various execution modes of PPP infrastructure projects and categorization of similar PPP modalities for a better understanding of the identification of risks to the respective categories. Various PPP modes were identified, and prominent modes of each category were extracted through thematic analysis on NVIVO software. BOT modality is a very commonly used mode around the world, especially in tolled roads and highways PPP projects, followed by BLT, BOOT, and O&M PPP contracts. On the basis of the difference in the arrangement of the PPP structure of these modes, the corresponding risks are also different, and the significance of each risk varies from mode to mode. This study concluded the desired results through a thematic analysis of NVIVO software and highlighted the importance and risks for each category. Four (04) categories are developed, and various modes of PPP infrastructure projects like BOT, DBFOT, BTO, BT, CAO, ROT, TOT, DBOFT, and DOT are placed under BOT-DBFOT type of PPP contracts. BLT, DBLOT, LOT, BLO, BLOT, BOLT, and BLMT are placed under lease–affermage BLT type of PPP contracts. BOOT, BOO, DBO, DOO, and ROOT are placed under the ownership-BOOT type of PPP contracts. O&M, the services, and the management contracts are placed under the services and the O&M type of PPP contracts. The respective risks of these categories are identified through literature review and data gathering approaches and placed in seven (07) stages of the PPP projects life cycle as the planning, design, and feasibility risks; the financial risks; the legal and procurement risks; the construction and execution risks; the operations and maintenance risks; the project environment risks; and the general and transfer of assets risks, except for the last category.

Previously, identified risks were not categorized in this way, and thus confusion remains there for the readers to identify and subsequently prioritize and allocate the risks to the stakeholders on the basis of risk significance, which varies from one PPP modality to another. For example, the significance of the transfer of assets risks, revenue risks, asset obsolescence, market demand risks, and productivity risks varies in BOT, BLT, BOOT, and O&M contracts. The comparison of which was made in the NVIVO hierarchy charts above. A few typical risks that specifically belong to the lease–affermage BLT type of PPP contract category are tenant/lease risks, the revenue shortfall risk, the property-related risk, and market risks. Similarly, asset management risks due to lack of research and development in PPP projects, depreciation risks, residual value risks, obsolescence risks,

disposal risks, maintenance risks, interconnectivity with other roads risks, and partnership risks are typical examples of risks pertaining to the ownership-BOOT type of PPP contracts.

The corruption risks, the political risks, and the regime change risks are the biggest threat to all types of PPP projects in developing countries and also have considerable impacts in developed countries. Researchers can prioritize the identified risks for their subsequent better allocation during the finalization of the PPP execution modality for all four categories to assess how the priority of risks changes in each category. Due to a large number of PPP execution modalities opted for the PPP infrastructure projects, it is difficult to find experts worldwide with hands-on experience in each modality, which was the limitation of the study. Therefore, these execution modalities are categorized into four (04) different categories.

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Abbreviations

PPP	Public–Private Partnership
BOT	Build, Operate, and Transfer
BTO	Build, Transfer, and Operate
DBOM	Design, Build, Operate, and Maintain
DBFOT	Design, Build, Finance, Operate, and Transfer
DBFOM	Design, Build, Finance, Operate, and Maintain
DBOO	Design, Build, Own, and Operate
DCMF	Design, Construct, Manage, and Finance
O&M	Operations and Maintenance
DBO	Design–Build–Own
BLT	Build, Lease, and Transfer
BOOTT	Build, Own, Operate, Train, and Transfer
CAO	Contract, Add, and Operate
PPIAF	Public Private Infrastructure Advisory Facility
TOT	Transfer–Operate–Transfer
DOOT	Develop, Own, Operate, and Transfer
BLO	Build, Lease, and Own
BT	Build–Transfer
AP	Availability Payment
BLMT	Build, Lease, Maintain, and Transfer
DBFM	Design, Build, Finance, and Maintain
DBL	Design, Build, and Lease
PFI	Private Finance Initiative
BBO	Build–Buy–Operate
ROT	Rehabilitate/Renovate, Operate, and Transfer
BLOT	Build, Lease, Operate, and Transfer
BOO	Build–Own–operate
BOOT	Build, Own, Operate, and Transfer
BOOM	Build, Own, Operate, and Maintain
ROOT	Rehabilitate, Own, Operate, and Transfer
DOT	Develop, Operate, and Transfer
SC	Service Contract
MC	Management Contract
BOLT	Build, Own, Lease, and Transfer
SWOT	Strength, Weakness, Opportunity, Threat
DBOFT	Design, Build, Operate, Finance, and Transfer
LOT	Lease, Operate, and Transfer
DBB	Design, Bid, and Build
LUF	Land Use Fee
BOR	Build, Operate, and Renewal
PVR	Present Value of Revenues
DB	Design–Build
BBO	Build, Buy, and Operate

Appendix A. Questions Related to the Interview Protocol

First Part (Introduction)	• Please mention your name, position, education, and experience. • Please state the name of your company/organization. • What is the type of your organization? ○ Contractor/private entity, ○ Consultant (public sector) ○ Consultant (private sector) ○ Financier/sponsor, ○ Client/government entity/public sector, ○ Concessionaire/special purpose vehicle, ○ Independent consultant ○ Other (please mention your role)
Second Part (PPP Modes)	• How long have you been working on PPP infrastructure projects? • What modes of PPP infrastructure projects have you been involved in? • What other PPP modalities do you know in addition to the modalities mentioned in the above question?
Third Part (Associated risks)	• What are the major associated risks you have come across on various PPP modes? • What other critical risks on PPP infrastructure projects do you want to mention?

Appendix B. Identified Risks in Four (04) Different Categories along with Definitions

Risks	PPP Modalities			
	DBFOT/BOT Type PPP Contracts	**Lease/Affermage/BLT Type PPP Contracts**	**Ownership/ BOOT Type PPP Contracts**	**The Services and the O&M Type PPP Contracts**
(a)	**Planning, design, and feasibility risks**			Efficiency enhancement
1	Improper design and technical study **Definition:** Poor design team responsible for carrying out the technical studies			Unavailability of Investor
2	Land acquisition and compensation **Definition:** Difficulties faced by both client and consultant regarding route alignment for land acquisition and subsequently stay orders from the owners of the land during the compensation phase			Productivity Risks
3	Required initial approvals for a feasibility study **Definition:** Unnecessary delay in approvals from the concerned agencies at the initial stages of the project			Social Challenges
4	Improper preliminary survey **Definition:** Poor survey team responsible for reconnaissance survey			Reputation Risks
5	Inherent risks to conceiving PPP projects **Definition:** Incompetency or lack of experience in adopting the PPP modality, especially in developing countries			Performance Risk
6	Multilateral agencies and stakeholders' involvement **Definition:** PPPs have many stakeholders and agencies as compared to the traditional approach of executing projects			
7	Poor cost estimation **Definition:** Poor quantification of project items, including soil contamination and other construction items at the time of the planning stage			

Risks	PPP Modalities			
	DBFOT/BOT Type PPP Contracts	**Lease/Affermage/BLT Type PPP Contracts**	**Ownership/ BOOT Type PPP Contracts**	**The Services and the O&M Type PPP Contracts**
(b)	**Financial risks**			
8	Macroeconomic variables **Definition:** This includes inflation, GDP, Government fiscal policies, national income, international trade, and interest rate, etc.			
9	Availability of finance **Definition:** Adequate funds are available to the contractor during the construction of the PPP project phase			
10	Fulfillment of commitments with financial institutes **Definition:** This includes debt repayment to the financial institutes in an efficient manner as committed during financial closure			
11	Revenue shortfall **Definition:** Shortfall in revenues, user levies, and availability-based payments			
12	Financial rate of returns on investment Definition: Internal rate of return (IRR), return on investment (ROI), payback period, and net present value (NPV), etc., are the indicator of the risk.			
13	Financial insolvency of the host government **Definition:** The host government could not remain financially stable and became bank corrupt			
(c)	**Legal and procurement risks**			
14		Ownership of assets **Definition:** Concessionaire is fully responsible for projects assets		
15	Change in Law **Definition:** Post-bid changes in any existing law by the government that affects any of the project objectives			
16	Insolvency of the public or private sector **Definition:** Insolvency of either public or private sector			
17	Third-party reliability **Definition:** Any unexpected disagreement arising from the third party regarding the fulfillment of contractual obligations			
18	Institutional nature arrangement **Definition:** Poor institutional nature arrangement for execution of PPP Projects			
19	Encumbrances of land Definition: Illegal encumbrances cause litigation and invoke legal repercussions			
20	Legally weak partnership or strategic alliance **Definition:** PPPs are all about partnerships between the public and private sectors, which should be legally and contractually strong for durable intra-consortium counterparty			
21	Inefficient procurement process **Definition:** The procurement process should be efficient, economical, effective, and transparent, which brings value for money			

Risks	PPP Modalities			
	DBFOT/BOT Type PPP Contracts	**Lease/Affermage/BLT Type PPP Contracts**	**Ownership/ BOOT Type PPP Contracts**	**The Services and the O&M Type PPP Contracts**
22		Tenant risks **Definition:** Risks related to the leaseholder for efficient operations		
23	Lack of flexibility in contracts Definition: PPPs are complex contractual arrangements; therefore, they should be flexible enough to safeguard the interests of both parties			
24		Market demand for assets **Definition:** The project's assets are market-driven for desired revenue collection		
25		Legal aspects of the property **Definition:** lessor should lease the land to the lessee, which is legally protected against all types of litigations		
26			Expropriation **Definition:** risks of taking property or assets by the state from the owner	
(d)	**Construction and execution risks**			
27	Poor quality **Definition:** Maintaining the desired quality standards on the project during the construction and execution phase			
28	Unproven engineering techniques **Definition:** Using untested technology and inadequate engineering exposure for the construction and execution of the infrastructure projects			
29	Unforeseen construction cost overruns **Definition:** Construction cost overrun resulting from poor planning and measurements of the quantities			
30	Availability of land for use **Definition:** encumbrance free right of way is available for construction			

Risks	PPP Modalities			
	DBFOT/BOT Type PPP Contracts	**Lease/Affermage/BLT Type PPP Contracts**	**Ownership/ BOOT Type PPP Contracts**	**The Services and the O&M Type PPP Contracts**
31	Scope creep **Definition:** extensive change orders during the construction phase			
32	Inadequate health and safety measures **Definition:** Non-adoption of required health and safety requirements as per standards			
33	Delay in a construction period **Definition:** Noncompliance with construction timelines adequately			
34	Availability of labor and material **Definition:** Shortage of resources due to inadequate supply chain management of the organizations			
35	Protection of geological and historical objects **Definition:** Sometimes slight variations are required during the construction phase for the protection of geological and historical objects			
36	Shifting of utilities **Definition:** Shifting of utilities like power lines, gas lines, and other underground cables			
(e)	**Operations and maintenance risks**			
37	Operation and maintenance **Definition:** Concessionaire is responsible for the operation and maintenance of the project	Operation and maintenance **Definition:** Public sector is responsible for operations, and Concessionaire is responsible for maintenance activities	Operation and maintenance **Definition:** Concessionaire is responsible for the operation and maintenance of the project	
38	Demand and revenue shortfall **Definition:** Revenue collection is less than the forecasted demand			
40	Frequency of maintenance Definition: Major maintenance involves high cost; therefore, the frequency of maintenance matters			
41		The uncertainty in rent prices **Definition:** Uncertainty lies with the lessee to cope with the decrease in rent prices		Operational Technology
				Operational Efficiency risks
42	Toll slippages **Definition:** Week operational measures and control			
(f)	**General and project environment risks**			
43	Corruption **Definition:** Kickbacks, unjust rewards, and corrupt officials			
44	Political instability Definition: Regime change and other political chaos in the country			
45	Environmental permits Definition: Permits required from the environmental protection agencies for project approvals			

Risks	PPP Modalities			
	DBFOT/BOT Type PPP Contracts	**Lease/Affermage/BLT Type PPP Contracts**	**Ownership/ BOOT Type PPP Contracts**	**The Services and the O&M Type PPP Contracts**
46	Ground and weather conditions **Definition:** Unexpected or poor ground or weather conditions			
47	Lack of R&D in the PPP regime **Definition:** Poor R&D in the field of PPP domain			
48	Natural disasters or force majeure events **Definition:** The circumstances which are out of the control of any stakeholder reach			
49	Transfer of technology **Definition:** International bidders are the source of the transfer of technology			
50	Inherent risks **Definition:** Limited competencies and experience available for the execution of PPP projects, especially in developing countries			
(g)	**Completion and transfer of assets risks**			
51	Project transfer risks **Definition:** Transferring the project assets to the public sector as per requirements			
52			Residual value risks **Definition:** Unable to transfer the assets in normal working condition	
53			Depreciation of asset **Definition:** Devaluation of the asset at the time of transferring of assets	
54	Completion of project **Definition:** Non-fulfilment of the contractual requirement regarding the completion of the project			
55			Asset obsolescence Definition: due to long concessions of PPP, the project's assets or technology may be obsoleted	
56			Asset maintenance Definition: due to ownership of assets, asset maintenance is the prime responsibility of the private sector to properly handover	
	[42,44,58,63–123]			

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Evolutionary Mechanism of Trust for Public–Private Partnership Projects with Public Participation

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Abstract: Trust plays a pivotal role in sustaining cooperative relationships and serves as the cornerstone of successful cooperation among participants in public–private partnership (PPP) projects. A decline in trust can result in unethical behavior, fractured relationships, and even project failure. Despite its critical importance, there is an insufficiency of research exploring the evolutionary dynamics of trust, particularly from the perspective of public participation. To address this, an evolutionary game model is constructed to analyze the evolution of behavioral strategies and identify their stable state from a dynamic perspective. The model examines the influence of trust levels and public participation on cooperation, revealing that trust asymmetry negatively impacts collaborative outcomes in PPP projects. There is an optimal trust level: trust positively influences cooperation up to a certain peak, beyond which excessive trust becomes detrimental and hinders cooperative outcomes. When trust levels are equal, the selection of behavioral strategies is influenced by the initial willingness of participants. A threshold exists for this initial willingness, above which cooperation is more likely to succeed. Additionally, public participation is found to significantly enhance cooperation. These conclusions advance the theoretical advancements of trust in PPP projects and offer valuable insights for policymakers and stakeholders in addressing trust-related challenges, thereby fostering sustainable collaboration.

Keywords: public–private partnership (PPP) projects; trust; public participation; evolutionary game

1. Introduction

In recent years, rapid economic development has significantly increased the demand for infrastructure. Relying on financial investments from the government can no longer meet the substantial investment required for current infrastructure construction. This situation promotes the development of the PPP model. PPP advocates a non-confrontational working mode [1,2]. Compared with the traditional model, the introduction of private sector investment in the PPP model can not only alleviate the financial pressure but also improve the quality of public services and better serve the public [3]. In the partnership of PPP projects, trust serves as the soft environment for the cooperation between the government and private sector, and it is the bond that maintains the relationship. Studies have shown that trust is the core element of improving cooperation and is crucial for

achieving project objectives [4]. Scholars have also proved that trust can enable both parties to maintain full expectations for cooperation, reduce project implementation costs, and improve project performance [3,5]. Moreover, trust helps to mitigate barriers, promoting better cooperation and giving full play to their strengths [6]. Trust in PPP projects is not a static phenomenon but evolves through interactions and learning [7]. To form a stable cooperative relationship, the government and private sector need to engage in multiple games and cooperation. In the long-term evolutionary game process, how can we effectively enhance the trust levels between the government and private sector and reveal the evolutionary mechanism of trust? It is a problem that needs attention and resolution.

The primary goal of PPP is to provide high-quality services to the public [8]. Public participation serves as the fulcrum for maintaining balance within partnerships, making effective engagement of the public essential for the success of the PPP projects [9]. The government encourages the public to actively participate in PPP projects, which can improve transparency and further supervise the behavior [10]. However, the unequal distribution of interests within PPP arrangements often leads to the marginalization of public rights [11]. To better implement the PPP model and to avoid potential adverse effects, encouraging public participation is essential [12].

Previous research has primarily focused on the determinants and functions influencing interorganizational trust, alongside the critical role of public participation in PPP projects. However, studies on how trust evolves under the perspective of public participation remain limited. To address this issue of trust between the government and private sector in PPP projects, an evolutionary game model is established that considers the government, the private sector, and the public in PPP projects. Based on this model, this study explains the process of behavioral evolution and the final stable state of strategies from a dynamic perspective. Moreover, it explores the influence of trust levels and public participation on the cooperative outcomes in PPP projects. It makes a new contribution to solving the trust problem in PPP projects and provides new analytical tools for PPP project management practice.

This paper explores the dynamics of trust in PPP projects, emphasizing the interplay between trust levels, public participation, and cooperative behavior. It begins with a review of relevant literature to establish the theoretical foundation for this study. The methodology is then developed to describe the problem, construct an evolutionary game model, and identify stable states of trust and cooperation. Numerical simulations illustrate the evolutionary pathways and the effects of the trust level and public participation on evolutionary strategies. Section 5 compares these findings with prior research and offers practical recommendations for enhancing trust and collaboration in PPP projects, summarizing the research contributions, implications for practice, and limitations and highlighting areas for future exploration.

2. Literature Review

The research on trust problems usually divides trust into three types: interpersonal trust, interorganizational trust, and trust between individuals and organizations. In project management, interorganizational trust is defined as the trust level that organization members have in the organization collectively [2]. Interorganizational trust has been confirmed as a key to the efficient operation of projects and is essential to ensure project success [13]. Jiang et al. [14] explored the relationship between trust between owners and contractors and project success and found that interorganizational trust positively impacts project success. On the contrary, distrust leads to negative impacts on projects, potentially even leading to project failure [3], which emphasizes the important role of interorganizational trust in project success. Further research has found that trust between partners not only

enhances mutual trust but also reduces opportunistic behaviors [15]. In other words, trust can make cooperation between transaction partners more efficient [16]. Specifically, interorganizational trust can promote information sharing, reduce transaction costs, and improve organizational performance [17,18]. For example, Wu et al. [19] proposed that interorganizational trust can reduce the demand for complex contracts and thus reduce the pre-transaction cost. Pavlou et al. [20] found that interorganizational trust can increase satisfaction, improve cooperation willingness, and enhance project performance by facilitating technology sharing, goal achievement, and timely problem-solving. In addition, by improving governance methods for informal relationships, interorganizational trust can also promote shared planning and significantly improve flexibility in project delivery and performance improvement [21,22].

Trust represents a potential psychological condition induced by behaviors or decisions, which subsequently impacts future behaviors or decisions. Therefore, trust is not a static phenomenon but a dynamic evolutionary process. Understanding and mastering this dynamic evolution process of trust is the key to revealing the relationship between parties [23]. Wang et al. [24] argued that advanced technologies could be used to stimulate the awareness and initiative of the public. Most studies agree that the dynamic nature of trust involves its level either increasing or decreasing over time; the evolution of trust is a dynamic process that moves from a lack of trust to initial trust and eventually to sustained trust [6]. Le et al. [25] highlighted the presence of an optimal trust level in engineering project management, noting that this level minimizes the transaction costs for both owners and contractors. Fu et al. [26] argued that trust among industrial clusters is inherently dynamic. This optimal trust would evolve through various stages of the cluster. Xiao et al. [27] analyzed the two-stage game between firms through the Cournot model to explain the formation mechanism of interorganizational trust and pointed out that the game theory provided a new perspective for trust research.

Evolutionary game theory combines game theory analysis with dynamic evolutionary processes, which has great potential in the simulation analysis of realistic problems [28]. Different from classical games, the core of evolutionary game theory is to combine participants' strategies with natural selection, allowing them to continuously adjust their strategies over time, thereby more accurately reflecting the dynamic balance of the game behaviors [29]. In PPP projects, the government and private sector form a cooperation based on trust. The government, private sector, and the public cannot make the optimal decision instantaneously. Instead, they form a stable equilibrium state through continuous trial and error and imitation. Therefore, the evolutionary game method has been widely used in trust research for PPP projects. Zhang et al. [30] developed a trust evolution model and confirmed that interorganizational trust in PPP projects was influenced by a historical trust level and viewpoint similarity. Ren [31] studied the evolutionary behavior of stakeholders in PPP projects, summarizing stable strategies of trust evolution and identifying the key factors influencing trust behaviors, thereby advancing the sustainable development of PPP projects. Li et al. [32] established an evolutionary game model of trust between investment companies and supply chains in the PPP supply chain network, analyzing the evolutionary mechanism of trust, which is of great significance for PPP supply chain participants to cooperate.

In summary, existing studies have analyzed the importance of trust for cooperation among participants and the dynamics of trust in PPP projects. However, they have not investigated the evolutionary mechanism of trust between the government and private sector from the perspective of public participation. Therefore, this study introduces the public as a third-party regulatory subject, analyzes the evolutionary mechanism of trust based on evolutionary game theory, and provides support for the government to formulate strategies.

3. Methodology

3.1. Problem Description

Currently, research on the enthusiasm and mode of public participation has extensively applied to PPP projects. Previous studies have argued that advanced technologies could be used to stimulate the awareness and initiative of the public [33]. Scholars have confirmed a preference among the public for participation in decision-making through internet platforms [34]. Additionally, Song et al. [9] investigated the boundary conditions of cooperation by analyzing the evolutionary paths. The results showed that public participation played a role in modulating the partnership. Therefore, as the direct beneficiaries of PPP projects, the public can directly or indirectly participate in PPP projects to improve supervision and ensure the smooth operation of the projects.

Due to the different interests pursued by the government and private sector through cooperation, as well as the long duration and large scale of PPP projects, there is a trust game between the government and private sector, and it is difficult to find an equilibrium strategy under uncertain conditions. In addition, since the public is the direct beneficiary of PPP projects operated by the private sector, there is also a game between the public and private sectors. While it is difficult for the government, private sector, and the public to find the best strategy in the early stages, all three continuously learn and adjust, as well as optimize their initial strategies through trial and error. Therefore, the strategy choices made by the three parties and the equilibrium states are a game process of constant adjustment and dynamic evolution. Evolutionary game theory emphasizes the dynamic adjustment of strategies through learning and simulation, which not only describes the dynamic evolution process of strategy selection but also explains the formation process of equilibrium strategies [35]. Therefore, in PPP projects, the behavior strategies of the government, private sector, and the public align with the analytical framework of evolutionary game theory.

3.2. Evolutionary Game Model Construction

Based on the evolutionary game model, this study reveals the evolutionary mechanisms of trust from the perspective of public participation. Firstly, according to the basic assumptions, the payoff matrix of the tripartite strategy behavior is obtained, reflecting the profit value or loss value of the participants under different strategy combinations. Secondly, using Friedman's theory, we analyze the equilibrium solution and the stable strategies. Finally, through simulation, we analyze not only the evolutionary paths of each participant but also the influence of trust level and public participation on the evolutionary strategies. The detailed flow chart is shown in Figure 1, which outlines the methodology of this research.

3.2.1. Analysis of Participant Behavior Characteristics

In PPP projects, participants share the same goal, but each pursues its own interests. Ideally, the government and private sector trust each other completely, and they keep promises and avoid opportunism. The government attracts the private sector to take part in PPP projects to reduce financial pressure. The private sector gains profits, enhances the brand's value, and achieves a win–win. However, in the operation of PPP projects, the private sector often suffers losses due to legal changes, damaged government reputation, and market volatility, and the failure of the private sector to finance can lead to project failure. At the same time, there is information asymmetry between the government and private sector, as well as an unreasonable distribution of excess profits. These problems lead to distrust. The public is the direct beneficiary of PPP projects. The operation of PPP projects affects the daily quality of life of people. For their own interests, the public can regulate the opportunistic behavior of the private sector through public opinions and

media reports while also supervising government actions. However, due to the lack of related policies and information, the enthusiasm of the public to participate in supervision can be affected, thus resulting in a tendency not to participate in supervision.

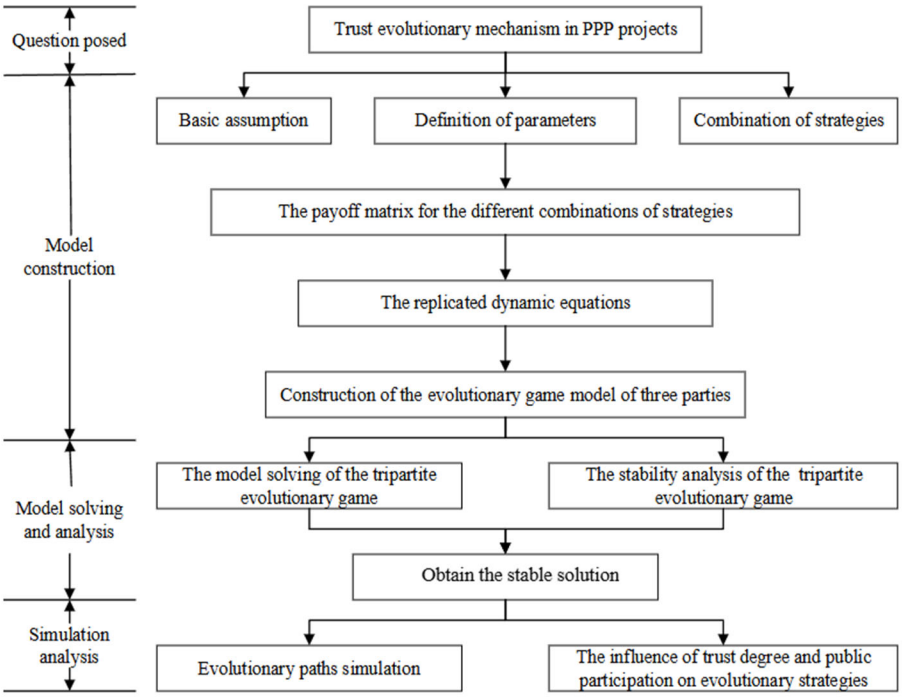


Figure 1. Flow chart outlining the methodology of this research.

3.2.2. Basic Assumptions

To construct a scientific and objective evolutionary game model, the following assumptions are made:

Assumption 1: Based on the analysis of the behavior characteristics of the three parties, the strategy space of the government is $S1$ = (trust and distrust), with the probability of adopting trust and distrust being x and $1 - x$, respectively. The strategy space of the private sector is $S2$ = (cooperation and opportunism), and the probability of cooperation and opportunism is, respectively, y and $1 - y$. The strategy space of the public is $S3$ = (participation and non-participation), and the probability of taking participation and non-participation is z and $1 - z$, respectively; $x\ y\ z, \in [0, 1]$.

Assumption 2: It is assumed that trust exists objectively and that the trust level is quantifiable. Let α and β denote the trust levels of the government and private sector, respectively.

Assumption 3: When the strategy combination is (distrust and opportunism), the benefits are, respectively, U_1 and U_2. When the public participates in supervision, the fines paid by the government and private sector are denoted as M_1 and M_2, respectively, the compensation of the private sector is W, and the loss caused to the public by the opportunistic behavior of the private sector is L.

Assumption 4: When the government and private sector actively cooperate, meaning the strategic combination is (trust and cooperation), the increased benefits of the government and private sector include not only performance rewards P_1 and P_2 but also intangible benefits (such as reputation, praise, credibility, etc.) αC_1 and βC_2. For public participation in supervision, the reward given to the public by the government is Q.

Assumption 5: The phenomenon that one party acts to maximize their own utility at the expense of others is termed moral hazard [36]. In PPP projects, if one party adopts an active strategy while the other chooses a passive cooperation, it results in certain moral hazard benefits for the passive party. When the government chooses a passive strategy, that

is, the strategy combination of the government and private sector (distrust and cooperation), the moral hazard benefits for the government increase by R_1, the increased benefit for the private sector is βC_2, and the penalty paid by the government is M_1. When the private sector chooses a passive strategy, meaning the strategy combination is (trust and opportunism), the private sector increases the moral hazard benefits R_2, and the government increases the benefits αC_1. The penalty paid by the private sector is M_2. When the public reports the opportunistic behavior of the private sector, the reward given by the government is Q, the compensation from the private sector is W, and the loss caused to the public by the opportunistic behavior of the private sector is L. The parameters of the model and their meanings are shown in Table 1.

Table 1. Parameters description.

Parameters	Meaning
U_i	The benefits of government and private sector choosing passive strategies, i = 1, 2
C_i	The costs of active cooperation, i = 1, 2
P_i	The performance rewards of active cooperation, i = 1, 2
R_i	The moral hazard benefits of government and private sector, i = 1, 2
Q	The reward given by the government for participating in regulation
C_3	The cost of public participation in regulation
M_1	The penalty to be paid by the government due to distrusting behavior
M_2	The penalty to be paid by the private sector due to the opportunistic behavior
W	The compensation given by the private sector to the public
L	The loss to the public due to the opportunistic behavior of the private sector
α	The trust level of the government in PPP projects
β	The trust level of the private sector in PPP projects

3.2.3. Model Construction

Based on the above assumptions, a tripartite evolutionary game model of the government, private sector, and the public is constructed. The payoff matrix under different strategy combinations is shown in Table 2.

Table 2. Payoff matrix of the different strategy combinations.

	The Public, Participation, z	
	The Government, Trust, x	**The Government, Distrust, $1-x$**
private sector, cooperation, y	$U_1-(1-\alpha)C_1+P_1-Q$ $U_2-(1-\beta)C_2+P_2$ $Q-C_3$	$U_1-M_1+R_1$ $U_2-(1-\beta)C_2$ $-C_3$
private sector, opportunism, $1-y$	$U_1-(1-\alpha)C_1-Q$ $U_2-M_2-W+R_2$ $Q-C_3+W-L$	U_1-M_1 U_2-W-M_2 $W-C_3-L$
	The Public, Non-Participation, $1-z$	
	The Government, Trust, x	**The Government, Distrust, $1-x$**
private sector, cooperation, y	$U_1-(1-\alpha)C_1+P_1$ $U_2-(1-\beta)C_2+P_2$ 0	U_1+R_1 $U_2-(1-\beta)C_2$ 0
private sector, opportunism, $1-y$	$U_1-(1-\alpha)C_1$ U_2+R_2 $-L$	U_1 U_2 $-L$

Based on Table 2, the expected benefits and replication dynamic equations of the government, private sector, and the public under various strategies can be obtained.

(I) The expected benefits of the government when choosing trust U_{11} are:

$$U_{11} = yz(U_1 - (1-\alpha)C_1 + P_1 - Q) + y(1-z)(U_1 - (1-\alpha)C_1 + P_1) + (1-y)z(U_1 - (1-\alpha)C_1 - Q) + (1-y)(1-z)(U_1 - (1-\alpha)C_1) \quad (1)$$

The expected benefits for the government when choosing distrust U_{12} are:

$$U_{12} = yz(U_1 - M_1 + R_1) + y(1-z)(U_1 + R_1) + (1-y)z(U_1 - M_1) + (1-y)(1-z)U_1 \quad (2)$$

Referring to the expected benefits of the government under the two strategies, the government's average expected benefits $\overline{U}_1$ are:

$$\overline{U}_1 = xU_{11} + (1-x)U_{12} \quad (3)$$

Therefore, the replication dynamic equation for the government is:

$$F(x) = \frac{dx}{dt} = x(U_{11} - \overline{U}_1) = x(1-x)(-(1-\alpha)C_1 + (P_1 - R_1)y + (M_1 - Q)z) \quad (4)$$

(II) The expected benefits of the private sector when it adopts cooperation U_{21} are:

$$U_{21} = xz(U_2 - (1-\beta)C_2 + P_2) + x(1-z)(U_2 - (1-\beta)C_2 + P_2) + (1-x)z(U_2 - (1-\beta)C_2) + (1-x)(1-z)(U_2 - (1-\beta)C_2) \quad (5)$$

The expected benefits of the private sector when it adopts opportunism U_{22} are:

$$U_{22} = xz(U_2 - M_2 - W + R_2) + x(1-z)(U_2 + R_2) + (1-x)z(U_2 - W - M_2) + (1-x)(1-z)U_2 \quad (6)$$

According to the expected benefits of the private sector under the two strategies, the average expected benefits of the private sector $\overline{U}_2$ are:

$$\overline{U}_2 = yU_{21} + (1-y)U_{22} \quad (7)$$

Then, the replication dynamic equation for the private sector is:

$$G(y) = \frac{dy}{dt} = yU_{21} + (1-y)U_{22} = y(1-y)(-(1-\beta)C_2 + (P_2 - R_2)x + (M_2 + W)z) \quad (8)$$

(III) The expected benefits of the public's participation strategy U_{31} are:

$$U_{31} = xy(Q - C_3) + x(1-y)(Q - C_3 + W - L) + (1-x)y(-C_3) + (1-x)(1-y)(W - C_3 - L) \quad (9)$$

The expected benefits of the public's non-participation strategy U_{32} are:

$$U_{32} = x(1-y)(-L) + (1-x)(1-y)(-L) \quad (10)$$

According to the expected benefits of the public under the two strategies, the average expected benefits of the public $\overline{U}_3$ are:

$$\overline{U}_3 = zU_{31} + (1-z)U_{32} \quad (11)$$

Then, the replication dynamic equation for the public is:

$$H(z) = \frac{dz}{dt} = zU_{31} + (1-z)U_{32} = z(1-z)(W - C_3 + Qx - Wy) \quad (12)$$

By combining Equations (4), (8) and (12), the replicated dynamic equations of the government, private sector, and the public can be obtained as follows:

$$\begin{cases} F(x) = x(1-x)(-(1-\alpha)C_1 + (P_1 - R_1)y + (M_1 - Q)z) \\ G(y) = y(1-y)(-(1-\beta)C_2 + (P_2 - R_2)x + (M_2 + W)z) \\ H(z) = z(1-z)(W - C_3 + Qx - Wy) \end{cases} \tag{13}$$

3.3. The Stability Analysis of the Equilibrium Strategy

In order to explore the evolutionary stable strategies (ESS) of the government, private sector, and the public, in Equation (13), by setting $F(x) = G(y) = H(z) = 0$, the local equilibrium points are $E_1(0,0,0)$, $E_2(1,0,0)$, $E_3(0,1,0)$, $E_4(0,0,1)$, $E_5(1,1,0)$, $E_6(1,0,1)$, $E_7(0,1,1)$, and $E_8(1,1,1)$. Then, in all the above local equilibrium points, we also need to analyze their evolutionary stability to find the evolutionary stable strategy (ESS) in the system. According to Friedman's [37] stability theory, a system can be considered stable when all eigenvalues of the Jacobian matrix have negative real parts. The Jacobian matrix of the system is

$$J = \begin{bmatrix} \frac{\partial F}{\partial x} & \frac{\partial F}{\partial y} & \frac{\partial F}{\partial z} \\ \frac{\partial G}{\partial x} & \frac{\partial G}{\partial y} & \frac{\partial G}{\partial z} \\ \frac{\partial H}{\partial x} & \frac{\partial H}{\partial y} & \frac{\partial H}{\partial z} \end{bmatrix} \tag{14}$$

where

$$\begin{gathered} \frac{\partial F}{\partial x} = (1-2x)(-(1-\alpha)C_1 + (P_1 - R_1)y + (M_1 - Q)z) \\ \frac{\partial F}{\partial y} = x(1-x)(P_1 - R_1) \\ \frac{\partial F}{\partial z} = x(1-x)(M_1 - Q) \\ \frac{\partial G}{\partial x} = y(1-y)(P_2 - R_2) \end{gathered}$$

$$\begin{gathered} \frac{\partial G}{\partial y} = (1-2y)(-(1-\beta)C_2 + (P_2 - R_2)x + (M_2 + W)z) \\ \frac{\partial G}{\partial z} = y(1-y)(M_2 + W) \\ \frac{\partial H}{\partial x} = z(1-z)Q \\ \frac{\partial H}{\partial y} = -z(1-z)W \end{gathered}$$

$$\frac{\partial H}{\partial z} = (1-2z)(W - C_3 + Qx - Wy)$$

When the local equilibrium point is $E_1(0,0,0)$, the Jacobian matrix is:

$$J_1 = \begin{bmatrix} -(1-\alpha)C_1 & 0 & 0 \\ 0 & -(1-\beta)C_2 & 0 \\ 0 & 0 & W - C_3 \end{bmatrix}$$

From J_1, it can be concluded that the three eigenvalues are $\lambda_1 = -(1-\alpha)C_1$, $\lambda_2 = -(1-\beta)C_2$, and $\lambda_3 = W - C_3$. By analogy, the remaining equilibrium points are substituted into Equation (14), and the corresponding eigenvalues are calculated, respectively. However, due to the multitude of game players, the cumbersome parameters, and the complex evolution process, it is not possible to determine the stability of each Nash equilibrium solution based on the existing conditions. Therefore, to facilitate the analysis of the signs of the eigenvalues without loss of generality, the following constraints are set:

(I) In PPP projects, whether the public participates or not, the government and private sector have opportunistic behaviors. It is assumed that the benefits of trust strategy adopted by the government are greater than those of distrust strategy, and the benefits of private

sector cooperation are greater than those of opportunistic behavior. Hence, the constraints (15) and (16) apply to the government and private sector, respectively:

$$-(1-\alpha)C_1 + M_1 - Q - R_1 > 0 \tag{15}$$

$$-(1-\beta)C_2 - R_2 + M_2 + W > 0 \tag{16}$$

(II) It is assumed that the benefits from public participation in regulation are greater than those of non-participation. That is, a constraint (17) applies to the public:

$$Q - C_3 > 0 \tag{17}$$

According to the above two sets of constraints, the signs of the eigenvalues can be determined, and then the stability of the equilibrium point can be judged. When all eigenvalues have negative real parts, the equilibrium point is an evolutionary stable point [37]. The eigenvalues and attributes of each equilibrium point are presented in Table 3.

Table 3. The eigenvalues and attributes of equilibrium points.

Equilibrium Point	Eigenvalues of the Jacobian Matrix			Stability
	λ_1	λ_2	λ_3	
$E_1(0,0,0)$	$-(1-\alpha)C_1(-)$	$-(1-\beta)C_2(-)$	$W - C_3(\pm)$	Uncertain
$E_2(1,0,0)$	$(1-\alpha)C_1(+)$	$(1-\beta)C_2(+)$	$W - C_3 + Q(+)$	Unstable
$E_3(0,1,0)$	$-(1-\alpha)C_1 + P_1 - R_1(\pm)$	$(1-\beta)C_2(+)$	$-C_3(-)$	Unstable
$E_4(0,0,1)$	$-(1-\alpha)C_1 + M_1 - Q(+)$	$-(1-\beta)C_2 + M_2 + W(+)$	$-W + C_3(\pm)$	Unstable
$E_5(1,1,0)$	$(1-\alpha)C_1 - P_1 + R_1(\pm)$	$(1-\beta)C_2 - P_2 + R_2(\pm)$	$-C_3 + Q(+)$	Unstable
$E_6(1,0,1)$	$(1-\alpha)C_1 - M_1 + Q(-)$	$-(1-\beta)C_2 + P_2 - R_2 + M_2 + W(+)$	$-W + C_3 - Q(-)$	Unstable
$E_7(0,1,1)$	$-(1-\alpha)C_1 + P_1 - R_1 + M_1 - Q(+)$	$(1-\beta)C_2 - M_2 - W(-)$	$C_3(+)$	Unstable
$E_8(1,1,1)$	$(1-\alpha)C_1 - P_1 + R_1 - M_1 + Q(-)$	$(1-\beta)C_2 - P_2 + R_2 - M_2 - W(-)$	$C_3 - Q(-)$	ESS

According to Table 3, it can be determined that $E_2(1,0,0)$, $E_3(0,1,0)$, $E_4(0,0,1)$, $E_5(1,1,0)$, $E_6(1,0,1)$, and $E_7(0,1,1)$ are non-stable points, and point $E_1(0,0,0)$ cannot determine the stable state. Point $E_8(1,1,1)$ is the equilibrium point where the trust evolutionary game model attains a stable state; the corresponding evolutionary strategies are (trust, cooperation, and participation). Therefore, the stable strategies of the evolutionary game are discussed in two scenarios below.

Scenario 1: When $W - C_3 > 0$, it indicates that the compensation received by the public for reporting the opportunistic behavior of the private sector exceeds the cost of public participation. Table 4 reveals that all eigenvalues of the Jacobian matrix corresponding to equilibrium point $(1,1,1)$ have negative real parts. Consequently, in this scenario, the system has a stable point $(1,1,1)$, and its corresponding evolutionary strategies are (trust, cooperation, and participation).

Scenario 2: When $W - C_3 < 0$, the compensation received by the public for reporting the opportunistic behavior of the private sector is less than the cost of public participation. From Table 4, the eigenvalues of the Jacobian matrix corresponding to equilibrium points $(0,0,0)$ and $(1,1,1)$ are less than zero. Thus, in this scenario, the system has two stable points, $(0,0,0)$ and $(1,1,1)$, with the corresponding evolutionary strategies being (distrust, opportunism, and non-participation) and (trust, cooperation, and participation).

Table 4. Equilibrium point stability analysis (Scenario 1, 2).

Equilibrium Point	Scenario 1				Scenario 2			
	λ_1	λ_2	λ_3	Stability	λ_1	λ_2	λ_3	Stability
$E_1(0,0,0)$	−	−	+	Unstable	−	−	−	ESS
$E_2(1,0,0)$	+	+	+	Unstable	+	+	+	Unstable
$E_3(0,1,0)$	±	+	−	Unstable	±	+	−	Unstable
$E_4(0,0,1)$	+	+	±	Unstable	+	+	±	Unstable
$E_5(1,1,0)$	±	±	+	Unstable	±	±	+	Unstable
$E_6(1,0,1)$	−	+	−	Unstable	−	+	−	Unstable
$E_7(0,1,1)$	+	−	+	Unstable	+	−	+	Unstable
$E_8(1,1,1)$	−	−	−	ESS	−	−	−	ESS

4. Numerical Simulation and Discussion

4.1. Evolutionary Paths Simulation

In order to show the evolutionary process of the government, private sector, and public in different scenarios, numerical simulations are conducted on the evolutionary paths. The parameter values in this paper mainly consider the impact of the changes in relevant variables on the strategies of government, private sector, and public strategy. Each parameter value does not represent the actual payment or profit in reality [38]. Based on the above constraints, the initial values of the variables are set, as shown in Table 5. Two groups of values evolved 100 times from different initial strategy combinations; the results are presented in Figure 2, where the x-axis represents the willingness of the government to trust, the y-axis represents the willingness of the private sector to cooperate, and the z-axis represents the willingness of the public to participate.

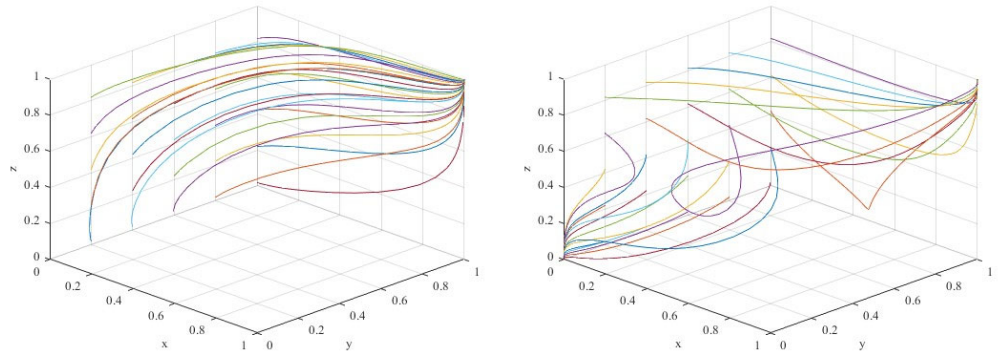
Table 5. Parameter settings for evolutionary path simulation.

Parameter	C_1	C_2	P_1	P_2	R_1	R_2	Q	C_3	M_1	M_2	W	L	α	β
Array 1	4	6	8	7	2	3	4	3	9	8	9	4	0.5	0.5
Array 2	4	6	8	7	2	3	4	3	9	8	2	8	0.5	0.5

Array 1 satisfies the conditions of scenario 1. The penalty for distrusting the behavior of the government is greater than the sum of the government's reward for public participation in supervision and the moral hazard benefits from the passive strategy of the government ($M_1 > Q + R_1$). The penalty for opportunistic behavior by the private sector exceeds the difference between the moral hazard return when the private sector adopts a negative strategy and the compensation paid by the public for reporting the private sector ($M_2 > R_2 - W$). Furthermore, the cost of public participation is lower than the compensation obtained when reporting the opportunistic behavior of the private sector, and it is also lower than the reward for participating in regulation ($C_3 < W$ and $C_3 < Q$). Figure 2a shows that there is an evolutionary stable point $(1,1,1)$ in the system; that is, the strategy combination (trust, cooperation, and participation) is an evolutionarily stable strategy set. The higher penalties for choosing passive strategies encourage evolution towards trust by the government and cooperation by the private sector. Moreover, the reward for public participation in supervision exceeds its cost, promoting active public participation in supervision.

Array 2 satisfies the conditions of scenario 2. The penalty for distrusting the behavior of the government is greater than the sum of the government's reward for public participation in supervision and the moral hazard benefits from the passive strategy of the government ($M_1 > Q + R_1$). The penalty for opportunistic behavior by the private sector

exceeds the difference between the moral hazard return when the private sector adopts a negative strategy and the compensation paid by the public for reporting the private sector ($M_2 > R_2 - W$). Moreover, the cost of public participation in supervision is between the compensation obtained when reporting the opportunistic behavior of the private sector and the reward for participating in supervision ($W < C_3 < Q$). Figure 2b indicates that there are two evolutionary stable points, $(0, 0, 0)$ and $(1, 1, 1)$, meaning the strategy combinations (distrust, opportunism, and non-participation) and (trust, cooperation, and participation) are two evolutionary stable strategy sets. In this scenario, the government, private sector, and the public either actively cooperate to facilitate the operation of PPP projects or hold a negative attitude, which is detrimental to the achievement of the PPP project goal.



(**a**) (**b**)

Figure 2. Results of 100 evolutions: (**a**) the result of 100 evolutions of array 1; (**b**) the result of 100 evolutions of array 2.

4.2. The Influence of Trust Level on Evolutionary Strategies

The trust level has a significant impact on the strategy selection [39]. Therefore, this section analyzes the influence of the trust level on the evolution of behavior strategies. The parameter settings of the numerical simulation are shown in Table 6. In PPP projects, there are different levels of trust. And one party's trust level is certain, while the other party's trust level changes over time. In addition, there may also be phenomena where there is no trust or complete trust. The above possible situations are simulated to analyze the impact of the trust level on the evolution of behavior strategies. The results are presented in Figures 3–7, where the x-axis represents time, and the y-axis represents the initial willingness.

(I) The influence of different trust levels on the evolution of behavior strategies. In PPP projects, the trust levels can be categorized into three cases: (i) $\alpha > \beta$, (ii) $\alpha < \beta$, and (iii) $\alpha = \beta$, with (i) and (ii) representing the trust asymmetry. Assuming the trust levels are $\alpha = 0.8$, $\beta = 0.4$; $\alpha = 0.4$, $\beta = 0.8$; $\alpha = 0.4$, and $\beta = 0.4$, using $\alpha = 0.4$, $\beta = 0.4$ as the control group, the willingness of the government to trust is set at $x = 0.5$, the willingness of the private sector to cooperate is set at $y = 0.5$, and the willingness of the public to participate is set as $z = 0.5$. The evolutionary trends of behavior strategies are presented in Figure 3.

When $\alpha > \beta$, indicating trust asymmetry, the government has greater trust in the private sector; the evolutionary results are shown in lines 4, 5, and 6 of Figure 3. The government evolves toward trust, the private sector evolves toward cooperation, and the public chooses to participate. For the government, comparing line 4 (trust asymmetry with $\alpha = 0.8$, $\beta = 0.4$) with line 7 (trust symmetry with $\alpha = \beta = 0.4$), it is observed that the trust asymmetry slows down the government's evolution towards trust. Regarding the private sector, comparing line 5 (trust asymmetry with $\alpha = 0.8$, $\beta = 0.4$) with line 8

(trust symmetry with $\alpha = \beta = 0.4$), it is found that trust asymmetry also slows down the evolution of the private sector towards cooperation.

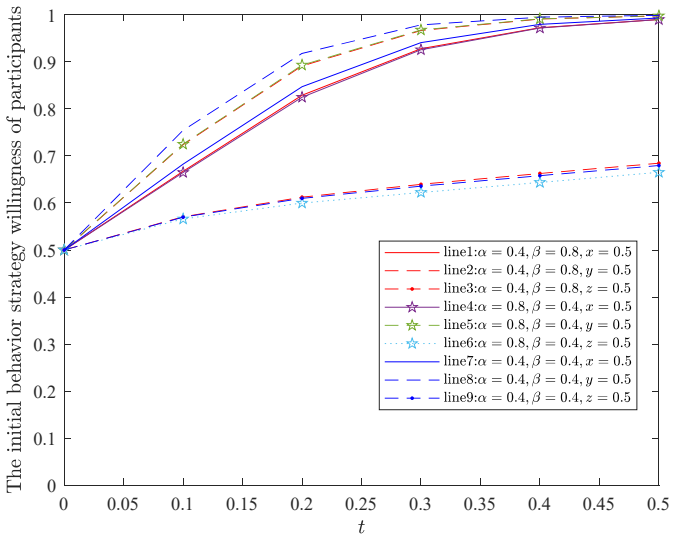


Figure 3. The influence of different trust degrees between government and private sector on the evolution of behavior strategies.

Table 6. Parameter settings.

Parameter	C_1	C_2	P_1	P_2	R_1	R_2	Q	C_3	M_1	M_2	W	L
Value	2	4	8	7	2	3	4	3	11	8	9	4

When $\alpha < \beta$, indicating trust asymmetry, the evolutionary results are shown in lines 1, 2, and 3 of Figure 3. Similarly, comparing line 1 (trust asymmetry with $\alpha = 0.4$, $\beta = 0.8$) with line 7 (trust symmetry with $\alpha = \beta = 0.4$) and line 5 (trust asymmetry with $\alpha = 0.4$, $\beta = 0.8$) with line 8 (trust symmetry with $\alpha = \beta = 0.4$) shows that trust asymmetry slows down the evolution of the government towards trust and the private sector towards cooperation.

Overall, trust asymmetry will reduce the exchange efficiency of information and resources between the government and private sector, ultimately leading to a negative effect on cooperation.

(II) The influence of the trust level on the evolution of behavioral strategies when one party has a certain level of trust. There are two scenarios: when the trust level of the government is constant, the influence of the private sector's trust level on the evolution of behavioral strategies is examined; when the trust level of the private sector is constant, the influence of the government's trust level on the evolution of behavioral strategies is considered. Assuming that the willingness of the government to trust is set at $x = 0.5$, the willingness of the private sector to cooperate is set at $y = 0.5$, and the willingness of the public to participate is set at $z = 0.5$. The evolutionary trends of the behavioral strategies are shown in Figures 4 and 5.

From Figure 4, when the trust level of the government is constant ($\alpha = 0.5$), by comparing line 1 ($\beta = 0.2$) with line 4 ($\beta = 0.5$), it is found that with an increase in the trust level of the private sector, the government's evolution toward a trust strategy speeds up. Compared with line 4 ($\beta = 0.5$) and line 7 ($\beta = 0.8$), it can be seen that with an increase in the trust level of the private sector, the government's evolution towards trust strategy slows down. Regarding the private sector, comparing line 2 ($\beta = 0.2$) with line 5 ($\beta = 0.5$), it is derived that as the trust level of the private sector increases, the evolution speed of the private sector towards cooperation accelerates. By comparing line 5 ($\beta = 0.5$) with line

8 ($\beta = 0.8$), it is found that as the trust level of the private sector increases, the evolution speed of the private sector towards cooperation slows down.

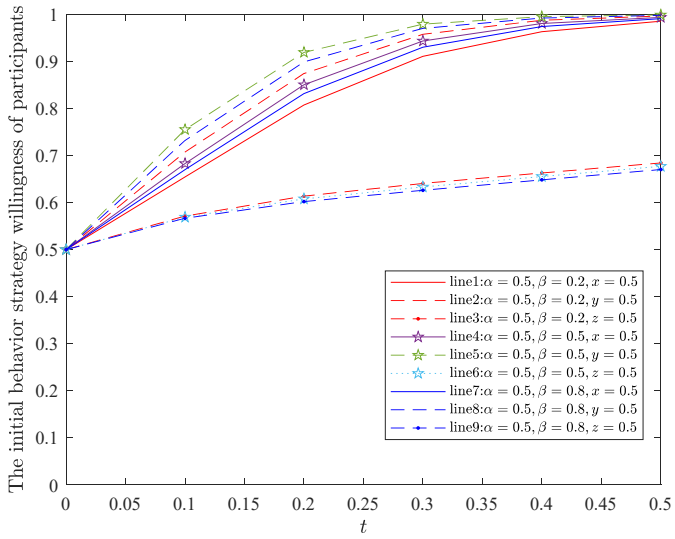


Figure 4. The influence of the private sector's trust level on the evolution of behavioral strategies when the trust level of the government is constant.

When the trust level of the private sector is constant ($\beta = 0.5$), according to Figure 5, it can be seen that the evolutionary trends of the government and private sector are not significantly different from those in Figure 4. The trust level of government increases from 0.2 to 0.5, and the evolution of government towards trust and the private sector towards cooperation speeds up. However, when the trust level of government increases from 0.5 to 0.8, the evolution of government to trust and the private sector to cooperation slows down.

In summary, neither the trust level of the government nor the trust level of the private sector is the more, the better. Excessive trust is not good for individuals and the implementation of PPP projects. In PPP projects, there exists an optimal level of trust in order to achieve the maximum probability of cooperation. The trust level before this optimal point has a positive effect on the cooperation while exceeding the peak level of trust leads to a negative effect on cooperation.

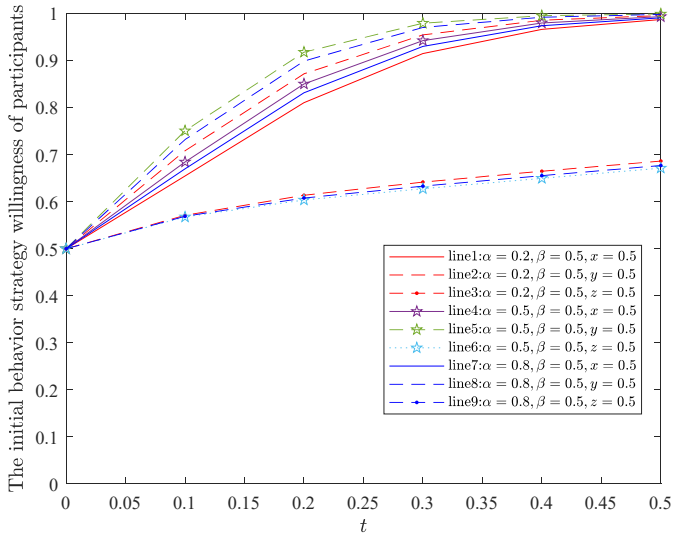


Figure 5. The influence of the government's trust level on the evolution of behavioral strategies when the trust level of the private sector is constant.

(III) There are two scenarios: no trust $(\alpha = \beta = 0)$ and complete trust $(\alpha = \beta = 1)$. The evolutionary trends of behavior strategies are shown in Figure 6.

When there is no trust ($\alpha = \beta = 0$), assuming the willingness of the government to trust is $x = 0.8$, the willingness of the private sector to cooperate is $y = 0.8$, and the willingness of the public to participate is $z = 0.8$, which indicates that the initial willingness of all parties is high. The evolutionary results are shown in lines 1, 2, and 3 of Figure 6. Although there is no trust, due to the high initial willingness, the government, private sector, and public evolve to trust, cooperation, and participation, respectively.

When there is complete trust ($\alpha = \beta = 1$), assuming (i), the willingness of the government to trust is $x = 0.4$, the willingness of the private sector to cooperate is $y = 0.4$, and the willingness of the public to participate is $z = 0.4$; the evolutionary results are shown as lines 7, 8, and 9 in Figure 6. The government, private sector, and the public evolve to distrust, opportunism, and non-participation, respectively. (ii) The willingness of the government to trust is $x = 0.5$, the willingness of the private sector to cooperate is $y = 0.5$, and the willingness of the public to participate is $z = 0.5$; the evolutionary results are shown as lines 4, 5, and 6 in Figure 6. At this time, the government, private sector, and the public evolve to trust, cooperation, and participation, respectively.

This indicates that when there is complete trust and no trust, the evolutionary trends of behavioral strategy are closely related to their initial willingness; that is, the selection of behavioral strategies mainly depends on their initial willingness in the game process. Moreover, there is a threshold of initial willingness, above which more cooperation can be brought about.

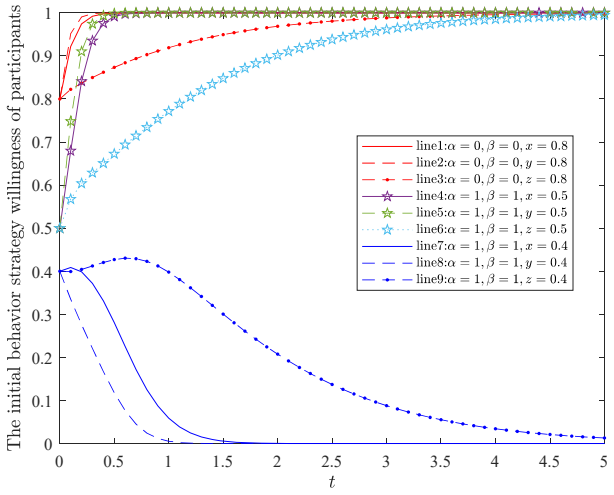


Figure 6. The influence of no and complete trust on the evolution of behavior strategies.

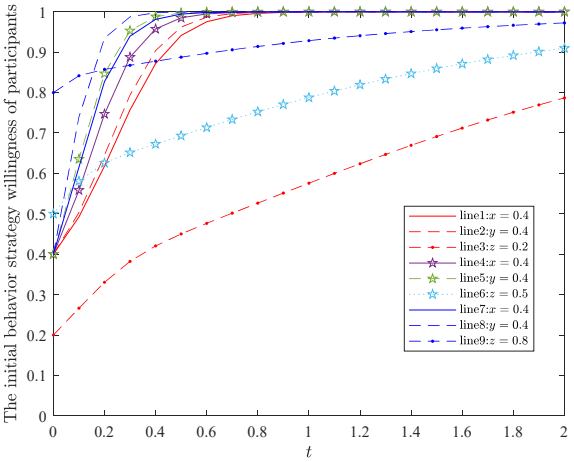


Figure 7. The influence of public participation on the evolution of behavior strategies.

4.3. The Influence of Public Participation on Evolutionary Strategies

As the direct beneficiaries of PPP projects, the public has become an important participant. This section studies the influence of public participation on the evolution of government and the private sector. Assuming the trust level of the government is $\alpha = 0.5$, the trust level of the private sector is $\beta = 0.5$, the willingness of the government to trust is $x = 0.4$, the willingness of the private sector to cooperate is $y = 0.4$, and the willingness of the public to participate is $z = 0.2,\ 0.5,\ 0.8$. The simulation results are shown in Figure 7. The x-axis represents time, and the y-axis represents the initial willingness.

As far as the government is concerned, by analyzing line 1 ($x = 0.4,\ z = 0.2$), line 4 ($x = 0.4,\ z = 0.5$), and line 7 ($x = 0.4,\ z = 0.8$), it is evident that the government gradually accelerates the evolution of trust as the willingness of the public to participate increases. Similarly, with regard to the private sector, it is also apparent that as the willingness of the public to participate increases, the evolution of the private sector to cooperate also speeds up.

This indicates that the public, as a stakeholder, influences strategic selection to a certain extent, which promotes active cooperation between the government and private sector. In other words, public participation has a positive effect on cooperation.

5. Discussion

In this paper, we analyze the evolutionary mechanism of trust from the perspective of public participation. Considering the complexity of PPP projects and the dynamics of trust, this paper constructs an evolutionary game model of the government, the private sector, and the public. The model is solved using the Jacobian matrix to analyze the stability of equilibrium points. Then, the possible scenarios are categorized to analyze the evolutionary paths. Finally, a numerical simulation is conducted to discuss the influence of the trust level and public participation on cooperation. The results show that trust asymmetry negatively affects cooperation. The trust level has a peak value, with levels below the peak positively motivating cooperation, while levels above the peak have a negative effect, which hinders cooperation. When there is complete trust and no trust, the selection of behavior strategies depends on the initial willingness, and there is a threshold of the initial willingness, above which more cooperation can be brought about. Public participation positively influences cooperation between the government and the private sector, leading to more cooperative behavior.

The trust level plays a crucial role in the evolution of behavioral strategies. Trust is a key factor in promoting cooperation, reducing transaction costs, and enhancing project execution efficiency [40,41]. In PPP projects, the trust level of the government is often influenced by capital strength, reputation, and historical performance, while the private sector is also wary of the government due to political risks and management efficiency, leading to differences in the trust level, that is, trust asymmetry [2,42]. In Section 4.2, it is found through simulation experiments that the evolution speed of the government to trust and the private sector to cooperation slows down when $\alpha > \beta$ or $\alpha < \beta$. This is because trust asymmetry may lead to the party with a higher trust level being exploited by the party with a lower trust level, resulting in various losses. It can also exacerbate the uncertainty and risk in project implementation and operation. Moreover, trust asymmetry may also lead to opportunism, which is not conducive to project implementation and operation. This is consistent with previous research. Wang et al. [43] and Graebner [42] found that trust asymmetry had negative effects on cooperation. Specifically, trust asymmetry reduces the efficiency of resource exchange, increases friction and conflict during cooperation, and is not conducive to stable and lasting cooperation. These findings further highlight the importance of building and maintaining mutual trust in PPP projects. Especially in the early

stages, the government and private partners need to establish effective communication and monitoring mechanisms to mitigate trust asymmetry. Additionally, the government and private partners can also develop transparent risk-sharing mechanisms to promote mutual trust and improve efficient cooperation, ensuring the smooth implementation of projects and long-term sustainable cooperation.

Secondly, previous studies have shown that trust could promote communication and coordination, thus playing a positive role in reducing transaction costs and promoting cooperation [44,45]. However, from the perspective of an evolutionary game, this study further discusses the influence of the trust level on cooperation. Section 4.2 presents the simulation experiments, demonstrating that when $\alpha = 0.5$, an increase in β from 0.2 to 0.5 accelerates the evolution of government trust and social capital cooperation. However, when β further increases from 0.5 to 0.8, this evolution slows down. Similarly, when $\beta = 0.5$, increasing α from 0.2 to 0.5 accelerates this evolution, while a further increase of α from 0.5 to 0.8 causes it to slow down. These findings reveal that a higher level of trust is not always better at promoting cooperation. There is a nonlinear relationship between trust levels and cooperation; that is, the trust level has a peak value, and the levels below the peak positively incentivize cooperation, where increasing the trust levels is beneficial for enhancing cooperation, willingness, and improving cooperation efficiency. Conversely, once the trust level exceeds this peak, it has a negative effect on cooperation, leading to excessive trust. This not only increases dependence but also leads to unconditional trust. Under such circumstances, trust may become an obstacle to cooperation. Therefore, the government and private partners should carefully manage trust levels and maintain an optimal trust level. This facilitates efficient communication and coordination, ensuring balanced decision-making and sustainable partnerships. In addition, a dynamic trust assessment system and adaptive risk-sharing mechanism can also be introduced in cooperation to achieve dynamic regulation of trust levels, thereby improving project performance and stabilizing cooperative relationships.

In addition, this study deeply analyzes the relationship between the evolutionary trends of behavioral strategies and their initial willingness when the trust level is equal. At the beginning of PPP projects, the government and private sector usually form an initial willingness to cooperate based on reputation and capability. All parties can adjust their initial willingness to reach cooperation. The initial willingness also plays a crucial role in facilitating cooperation. It is not only a fundamental factor in the initial stage of the project but also significantly influences the evolution of the entire cooperation process. Compared with previous studies that discussed the factors affecting PPP projects through qualitative analysis, such as technological innovations and legal regulations [46,47], this study reveals the uniqueness and complexity of initial willingness as a dynamic factor. As demonstrated in Section 4.2, simulation experiments reveal that when $x = y = z = 0.4$, the government, private sector, and the public evolve to distrust, opportunism, and non-participation, respectively. In contrast, when $x = y = z = 0.5$, the government, private sector, and the public evolve towards trust, cooperation, and participation, respectively. More importantly, it identifies a threshold value for initial willingness. When the initial willingness exceeds this threshold, it is more likely to establish a positive, cooperative relationship, thereby favoring the achievement of project goals. These findings offer significant practical implications for PPP projects; namely, participants can design targeted strategies to increase the initial willingness during the early stages, thereby improving project success and promoting long-term cooperation.

Finally, by introducing the public as a third-party regulator, this study not only extends the understanding of PPP project management mechanisms but also provides effective insights on how to improve project management efficiency and service quality. Different

from previous studies that focused on trust [48], this paper considers the impact of public participation on interorganizational trust. In Section 4.3, simulation experiments find that as public participation willingness increases $(z = 0.2, 0.5, 0.8)$, the evolution of government to trust and the private sector to cooperation gradually speeds up. The results show that as the direct beneficiaries of PPP projects, the increase in public participation can significantly promote cooperation efficiency and enhance the quality of infrastructure and public service. Boyer et al. [49] found that public participation could improve project performance, and they emphasized the central and crucial role of public participation in PPP projects, which is consistent with the results. However, Luo et al. [34] found that under the current PPP model, public participation is generally low, and they even lack the power to articulate their needs through face-to-face conversation, let alone effective supervision. This situation limits the potential value of public participation and weakens the efficacy and efficiency of PPP projects in delivering public services. To address these challenges, governments and the private sector can establish institutionalized mechanisms for public participation, such as improving public communication platforms and providing convenient channels for the public. Furthermore, the government should incorporate public feedback into the decision-making process, ensuring public opinions have a real impact on project management through reasonable mechanisms. Through effective public participation, PPP projects are more likely to realize their full potential to deliver high-quality public services.

To ensure the smooth implementation of PPP projects, this study proposes the following suggestions:

In PPP projects, the government and private sector should pay attention to trust, and the cooperation of mutual trust remains a direction requiring efforts. Secondly, the public, as the direct beneficiaries of PPP projects, plays an important role that cannot be overlooked. All participants should strive to cooperate in an environment of mutual trust and reciprocity and fully leverage advantages and strengths to gain more cooperation benefits.

(I) Establish and maintain trust mechanisms. In PPP projects, it is essential to establish and maintain bilateral trust. Specific measures to achieve this goal include developing reasonable contractual arrangements, enhancing transparency and open communication, and implementing effective risk-sharing mechanisms. Furthermore, trust can be further strengthened by regularly releasing project progress reports and audit results. These measures can not only ensure the efficiency and effectiveness of cooperation but also maintain a long-term and stable development of cooperation while actively responding to public concerns.

(II) Attach importance to initial willingness and early consultation. The success of PPP projects largely depends on a clear consensus on the expectations, goals, and acceptable risks in the initial stage, which can ensure that the initial intention is consistent. Moreover, it is crucial to adopt a joint decision-making mechanism for key project decisions. And this can not only ensure all stakeholders have sufficient participation and belonging but also lay a solid foundation for the smooth implementation of the project.

(III) Enhance public participation. Increasing public participation is an important strategy to improve the social support of PPP projects. Through legislation or policy measures, the government should clarify the rights and mechanisms for public participation in PPP projects, which can ensure that the public has a voice in the process of project planning and implementation. In addition, the government offers appropriate rewards to those who actively participate. Simultaneously, to establish a long-term mechanism and collect public opinions and needs, the government and private sector should work together to create public participation platforms, such as public hearings and online feedback systems. These measures not only enhance social acceptance and support for the project but also promote the social and economic benefits of PPP projects.

(IV) Establish dynamic adjustment and feedback mechanisms. In order to adapt to changes in the external environment and updates of internal goals, all parties should establish dynamic adjustment mechanisms for periodic evaluation and review of the project. Additionally, effective feedback mechanisms are essential to ensure a timely analysis of the information collected from all parties (government, private sector, and the public) to improve project execution and management. This dynamic adjustment and feedback mechanism helps PPP projects flexibly respond to challenges, achieve continuous optimization, and ultimately achieve project goals.

6. Conclusions

This study explores the evolutionary mechanism of trust from the perspective of public participation. The main conclusions are as follows: (i) When there is trust asymmetry between the government and private sector, the party with a higher trust level may be exploited by the one with a lower trust level, which is not conducive to cooperation. (ii) The trust level is not the more, the better, and there is a peak value. The trust level has a positive effect on cooperation before the peak, while exceeding the peak leads to a negative effect, which is detrimental to cooperation. (iii) When the trust level is equal, whether they cooperate depends on their initial willingness. There is a threshold of initial willingness, above which it is conducive to cooperation; the higher the initial willingness, the more cooperation occurs when exceeding the threshold. (iv) Public participation has a positive effect on cooperation and helps to bring more cooperation.

The theoretical contributions are as follows: (i) It emphasizes the nonlinear nature of trust levels and their bidirectional moderating effect on cooperation. These findings enrich the theoretical framework of research on trust and cooperation in PPP projects. (ii) This paper introduces a threshold of initial willingness. This conclusion not only offers a new perspective for the preliminary preparation and negotiation but also provides a theoretical basis for understanding and guiding the strategy selection of partners in PPP projects. (iii) It emphasizes the important role and value of the public in PPP projects. These results expand the perspective of PPP project management and provide theoretical support and practical guidance for introducing public participation in PPP projects.

This study still has limitations that can be improved with further research. The evolutionary game theory model used in this study simplifies the complexity of problems for the sake of analytical and computational feasibility, such as assuming limited participants, simplified strategy spaces, and stable environments. While such simplifications facilitate theoretical analysis, they may limit the adaptability and explanatory power of the theory to real problems. Future research could test these theoretical models in more complex scenarios. Additionally, this study is influenced by specific cultures and institutions and focuses solely on PPP projects in China. Trust mechanisms in PPP projects are strongly influenced by cultural habits and institutional frameworks, which can vary significantly across countries and regions. For example, highly collectivist cultures may differ from individualistic cultures in trust mechanisms. Differences in legal frameworks and governance structures can also have an impact on trust. Future studies can explore the impact of cultural and institutional diversity on trust mechanisms through cross-country or cross-regional comparative analyses to provide broader research perspectives and practical guidance.

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The Impact of Multi-Dimensional Incentives on the Performance of Rail Transit PPP Projects

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Abstract: This study investigates how different types of incentives impact the performance of rail transit PPPs, focusing on their construction and operational phases. By surveying 121 practitioners working in the Chinese rail transit industry, we propose a new classification of incentives (i.e., control-oriented, neutrality-oriented, and recognition-oriented incentives) based on psychological theories to broaden the categorization of "positive" (rewards) and "negative" (punishment) incentives. We further explore how these multi-dimensional incentives influence project performance by surveying another 256 industry professionals. Our findings reveal that (1) in addition to punishments, performance-based payment/bonus, credit ratings, and reputation mechanisms are newly recognized as control-oriented incentives, which can restrain the autonomy of the private sector; (2) control-oriented incentives positively influence project performance in the construction phase where clear, measurable goals are available, but their impact diminishes in the operational phase; (3) recognition-oriented incentives enhance project performance in both construction and operational phases (especially the latter), fostering long-term sustainability; and (4) neutrality-oriented incentives focus on risk allocation and collaboration between public and private sectors, showing a modestly positive effect in the operational phase. As such, the study provides decision-makers in the rail transit industry with valuable insights to enhance project performance effectively when implementing incentive policies.

Keywords: rail transit; public–private partnerships; incentive; key performance indicator

1. Introduction

Performance management has been and continues to be a key to the success of public–private partnerships (PPPs), as it ensures the delivery of quality public services and protects public interests [1]. Traditionally, the performance of PPPs was measured against a range of quantitative and qualitative metrics (pre-defined) such as cost, time, quality, environmental and social impact, and contractual compliance [2]. They aimed to ensure that projects realize their goals and deliver value for money [3,4]. However, as PPPs typically feature significant risk transfer to the private sector, various stakeholders, and long-term contracts (e.g., 30 years), traditional performance management is faced with more and more challenges. For example, Grimsey and Lewis [5] revealed the complex and contentious nature when allocating risks between the public and private sectors. According to Cui et al. [6], consistent funding is problematic because of the potential shortage of public or private financial

resources, especially in long-term projects. Furthermore, Domingues and Zlatkovic [7] argued that disputes over contract interpretation or performance can be costly and time-consuming. These challenges of performance management become more conspicuous in rail transit PPPs [8–10]. In the construction phase, the integration of various technical systems, including civil work, track laying, power supply, signaling, rolling stock, and infrastructure and property development around stations, presents additional complexity in delivering rail transit PPP projects [9,11]. In the operational phase, rail transit PPPs, which serve the daily travel needs of citizens, typically face stringent safety regulations and service standards [8,9,11]. Throughout their life-cycle, rail transit PPPs have historically struggled to achieve profitability, relying heavily on government subsidies, land value capture, and fare revenue recovery to reach financial viability [9]. As a result, incentives have been widely implemented to address such specific performance challenges of rail transit PPPs [12–14]. There are differences between the incentives utilized in rail transit PPPs and other infrastructure PPPs. For example, due to the travel services provision nature, incentives may include the patronage change payment regarding the ridership growth, penalties for failing to run on-time services, or other service quality-based payment (e.g., overall customer satisfaction) [8,12]. Additionally, given the interconnectivity of rail transit systems within cities and the high potential impact of safety incidents on urban mobility, incentives are often designed to uphold high safety standards [11,13], such as penalties for safety breaches and bonuses for exemplary safety performance [15]. In comparison, incentives for other infrastructure PPPs, such as energy PPPs, could be more tied to production targets, cost control, and innovation in energy production or distribution [16].

Despite the widespread implementation of incentives within rail transit PPPs, their impact on project performance sometimes remains ambiguous and ineffective. Generally, incentives can exert dual effects: (1) "positive incentives" (e.g., subsidies, tax reduction/exemption) are designed to improve PPP performance, but not always be able to bring the expected performance improvement [17]; and (2) "negative incentives" (e.g., punishments and penalties) can sometimes be more effective than "positive incentives" in ensuring the performance of PPPs [18,19]. Most existing research attributes this dual impact of incentives to the opportunistic behaviors of the private sector [14,20], and explores multiple influencing factors such as the information asymmetry between the public and private sectors [14,20,21], poorly designed evaluation metrics combined with incentives [12], and the loss of scarcity and exclusiveness of incentives [17]. Therefore, the principal–agent model [20–22], Stackelberg game theory model [18,19,23], and evolutionary game model [17] have been widely applied to study the impact of different incentives on PPP performance and maximize the utility of incentives.

While existing research has touched on the mechanisms of how incentives affect the performance of PPP projects, the current explanations are still inadequate [17]. Most research focuses narrowly on financial outcomes, neglecting broader dimensions of PPP performance such as quality, social welfare, and long-term sustainability. Additionally, despite some studies exploring different types of incentives, the literature predominantly examines financial incentives such as subsidies, performance-based payments, or tax adjustments [17–19,23]. Moreover, relatively few studies account for how the impact of incentives varies across different phases of a project. In order to address the aforementioned gaps, the scope of this paper is to examine the impact of different incentive measures on the performance of PPP projects across different project stages within the context of rail transit PPPs in China. And, we aim to address the following research questions:

Research question (1): Why could both "positive incentives" and "negative incentives" exert dual impacts on rail transit PPPs' performance?

Research question (2): Do incentives have different influences on rail transit PPPs' performance across different stages?

By doing so, the contributions of this study are twofold. First, we provide a deeper understanding of why incentives would have dual effects on project performance by integrating psychological theories from the perspective of the private sector. Second, we broaden the types of incentives in rail transit PPPs, moving beyond the traditional "positive" and "negative" incentives and offering a stage-specific analysis of how they impact project performance, which has the potential to provide a meaningful contribution to the literature and inform practice and policy.

The remainder of this paper is structured as follows: In Section 2, an overview of the relevant literature on rail transit PPPs' performance and incentives is presented, followed by the formulation of research hypotheses. Section 3 describes the methods deployed to address the research questions. Section 4 presents the results on how different types of incentives impact PPP performance across different project phases. Section 5 presents the discussion of the findings, and Section 6 concludes the study.

2. Literature Review and Hypotheses

2.1. PPP Project Performance

The concept of performance originates from business management, encompassing three perspectives: results, behaviors, and a combination of behaviors and results. From the result-oriented perspective, performance refers to the documented outcomes achieved in a particular task or activity within a designated time frame [24]. In the behavior-oriented view, performance is defined as a collection of actions aligned with the objectives of the job or the organization, and should be distinguished from the outcomes [25,26]. From the comprehensive perspective, performance combines both behaviors and results [27,28]. Behaviors are not only a medium for achieving results but are also considered directly as results (the result of mental and physical effort applied for tasks) [29]. In the context of PPPs, the definition of performance remains elusive and subjective because of different value claims, interests, and perceptions of project success from various stakeholders [3,30]. Nevertheless, PPP performance often focuses on both the behaviors and results [31], considering input, process, output, and outcomes [32] from the perspective of each stakeholder.

For effective PPP performance management, performance objectives serve as valuable tools for assessing the strengths and weaknesses of PPPs, and are expected to be fulfilled through the life-cycle of PPPs [3]. Prior studies tend to develop comprehensive frameworks of performance indicators to measure the performance of PPPs against predefined performance objectives [10,33–36]. Quality, cost, time, and value for money remain traditional performance indicators [37–39]. Ahmad et al. [40] identified 10 key performance indicators (KPIs) to achieve an accurate analysis of performance for different stakeholders, including the additional aspects of service delivery, collaboration between organizations, socio-economic impacts, sustainability, etc. Moreover, life-cycle and phase-based perspectives have been considered in combination with KPIs or balanced scorecards (BSCs) to measure PPP performance [32,41–44]. One popular life-cycle perspective incorporates performance at the phases of initiation and planning, procurement, and partnership (such as construction, operation, and maintenance) [42,45,46]. Adopting this view, Liu et al. [46] proposed a performance management system (PMS) supported by a performance prism.

While comprehensive performance goals and indicator systems may be established, fostering long-term trust and cooperation between the private and public sectors in the actual operation of PPPs, and aligning their efforts toward common performance objectives, remains a significant challenge [3]. In this context, the inclusion of well-designed incentives (rewards and penalties) regarding already defined performance indicators in the initial contract, coupled with ongoing performance monitoring, is crucial for the successful delivery of PPP projects [12].

2.2. Incentives for PPP Projects

Incentives are methods designed by organizations to stimulate and assimilate employees' behaviors through appropriate forms of reward ("positive incentives") and punishment ("negative incentives") [47,48]. They can be material/explicit incentives (e.g., salary, benefits, bonuses, and prizes) and non-material/implicit incentives (e.g., honor, autonomy, and recognition) [49]. In PPPs, governments often utilize such incentives as financial incentives, punishments, reputation incentives, and other policy incentives. For example, financial incentives, attributed to "positive incentives", are the most common incentives used in PPPs, providing such as performance-based payment [12], subsidies [19], equity investment and loan guarantees [50], etc. Punishments, regarded as "negative incentives", can be increased taxes, direct penalties, or disqualifications when the private sector is in breach of contract [17–19,51]. Reputation incentives are mostly implicit, such as improving the private sector's image by recognizing rail-transit projects as nationally high-quality [14].

The dual impact of government incentives on PPP projects has been extensively studied. On the one hand, "positive incentives" do not always result in the expected performance improvement, whereas could even have perverse effects. For example, the private sector may deliberately slack on the level of efforts to save costs or not fully disclose their revenues to obtain more subsidies under the incentive of minimum revenue guarantee [18]. Another example is deflated performance manipulation by the private sector to ensure high scores on performance measurement or to avoid unreasonable measurement standards under the incentive of performance-based payment [12]. Yang et al. [17] attribute the side-effect of these "positive incentives" to the loss of scarcity and exclusiveness during the implementation based on the reinforcement theory. On the other hand, "negative incentives" can be particularly effective in supervising the private sector to act in the best interest of the project. By creating a strong deterrent against the private sector's poor performance or unethical behaviors, the addition of punishments into awards can mitigate the governments' risk of exposure to the high transaction costs associated with implementing incentives [12].

The existing research has touched on the dual impacts on rail transit PPP performance, most of which are looking for external reasons, such as ill-designed KPIs chosen to award incentives and/or penalties, lax regulation and tracking of actual performance, and the natural conflicts of interests and information asymmetry between governments and private sectors. However, a significant gap remains in analyzing the internal and underlying reasons from the perspective of the private sector. Therefore, our research aims to examine the real perceptions of incentive measures among private sectors from a psychological view, thus addressing research question (1).

2.3. Theories and Hypotheses

According to Deci and Ryan [52], the self-determination theory (SDT) proposes that individuals are inherently driven to develop and evolve by fulfilling their fundamental psychological needs for competence, autonomy, and relatedness. This motivation can be extrinsic or intrinsic. Extrinsic motivation refers to engaging in an activity primarily for

external rewards or to avoid punishments, closely aligning with the concept of explicit incentives applied in PPPs [53]. In contrast, intrinsic motivation is more closely associated with implicit incentives, driven by internal satisfaction and personal fulfillment [54]. SDT classifies extrinsic motivation into autonomous and controlled motivations. Autonomous extrinsic motivation occurs when individuals engage in an activity for external reasons, but still feel a sense of choice and alignment with their personal goals and values (i.e., the activity is personally meaningful and their engagement is more self-determined) [55]. In contrast, controlled extrinsic motivation occurs when individuals feel pressured or coerced into engaging in an activity due to external factors. This undermines their sense of autonomy and can lead to less sustained effort and satisfaction. According to SDT, tangible rewards such as bonuses, subsidies, and bounties based on performance could also become controlled motivation [52], which differs from their traditionally perceived encouraging nature. This SDT view may explain why some "positive incentives" do not generate expected performance improvement, as they might be perceived as controlling instead of truly inspiring. Therefore, this paper defines incentives which convey autonomy-supportive information and are perceived as motivating by individuals as recognition-oriented incentives. Incentives that convey mandatory information and are perceived as a form of control are considered as control-oriented incentives. Those incentives that fall between recognition- and control-oriented are classified as neutrality-oriented incentives.

However, the negative effect of control-oriented incentives based on SDT might be a little biased. For example, SDT cannot explain why some "negative incentives" can be particularly effective in supervising private sectors to maintain high performance. Hence, the motivated information processing (MIP) theory is introduced to study the underlying mechanisms. Under the MIP theory, the information processing and outcomes within groups are co-affected by two forms of motivation: epistemic motivation (ranging from low to high) and social motivation (from pro-self to pro-social) [56]. Variables like the need for cognition, affiliation, and agreeableness generally lead to high epistemic motivation [57], which is the same as the autonomy-supportive social contexts in SDT. But it is not enough to ensure a high group performance result, because MIP posits that group members encounter a combination of both cooperative and competitive scenarios (corresponding to the relationships between governments and private sectors): the cooperative situation will make members focus on collective outcomes thus lead to pro-social motivation, whereas the competitive situation focuses on pro-self motivation [58], which might lead to selfish behavior, lazy compromising, deception, etc., resulting in low group performance [57]. This MIP view may explain why some "negative incentives" can be particularly effective, as they force the private sector to place more weight on pro-social instead of pro-self behaviors even if their needs for autonomy are not satisfied.

Once the classification of incentives is determined, we consider their respective influence on rai transit PPP performance across different stages to address the research question (2). Given that incentives discussed here are implemented in PPPs, the ultimate effect of an incentive shall depend on (1) the relative salience of whether the private sector perceives the incentive as recognition-oriented or as a control-oriented incentive, and (2) the implementation scenario of the incentive during different phases of the project [23,59].

In the construction phase, basic indicators such as schedule, quality, cost, and safety management of PPP performance are given more priority and assessed by specific and quantitative metrics for the successful built-up of rail transit assets [3], which generally needs strict regulation and the supervision of control-oriented incentives such as punishments, performance-based payment [60]. Even though controlled motivation makes individuals feel pressured or coerced, it can monitor the private sector's behaviors according to the established clear performance objectives and restrain it from speculation caused

by pro-self motivation. Furthermore, the private sector faces a strain of cash flow as its profitability outlook or operating capability remains unclear at this phase [61]. In this case, recognition-oriented incentives, such as governments' aids in financing, hold the potential for the private sector to expand their financing sources, improve cash flow management, sustain financial stability, and attract investors [62]. In terms of other recognition-oriented incentives (supposing reputation awards and titles for high-quality projects), both SDT and MIP affirm their positive effects on inspiring individuals. Therefore, we propose the following hypotheses 1, 2, and 3 for the construction phase:

Hypothesis 1. *Control-oriented incentives positively influence rail transit PPP project performance in the construction phase.*

Hypothesis 2. *Recognition-oriented incentive measures positively influence rail transit PPP project performance in the construction phase.*

Hypothesis 3. *Neutrality-oriented incentive measures positively (H3a) or negatively (H3b) influence rail transit PPP project performance in the construction phase.*

For the operational phase, KPIs are gradually transferring priority from the schedule, quality, and cost of construction to fare revenues, safety, public clients' satisfaction with the rail transit service, and sustainability for the sustainable delivery of rail transit services [63,64]. In addition, as projects proceed to the profitable phase, the private sector could play a more independent role and concentrate on its own profits [65]. Implementing financial incentives like performance-based payment/bonuses under the circumstances might breed opportunistic behaviors caused by ambiguous performance measurement metrics [18]. Moreover, excessive punishments might aggravate the private sector's reverse psychology, and hurt their cooperating attitude22 Regarding recognition-oriented incentives, both SDT and MIP affirm their positive effects. For example, the government's positive attitude towards cooperation can encourage the private sector to improve public clients' satisfaction with the rail transit service through various innovative ways [66]. Therefore, we propose the following hypotheses 4, 5, and 6 for the operational phase:

Hypothesis 4. *Control-oriented incentive measures negatively influence rail transit PPP project performance in the operational phase.*

Hypothesis 5. *Recognition-oriented incentive measures positively influence rail transit PPP project performance in the operational phase.*

Hypothesis 6. *Neutrality-oriented incentive measures positively (H6a) or negatively (H6b) influence rail transit PPP project performance in the operational phase.*

Finally, as indicated by the proven interaction effect among performance indicators of PPP projects [35,44], PPP project performance in the construction phase generally provides a guaranteed project management capacity for the later operation. We, therefore, propose the following Hypothesis 7, and develop the hypothetical model in Figure 1.

Hypothesis 7. *PPP project performance in the construction phase positively influences PPP project performance in the operational phase.*

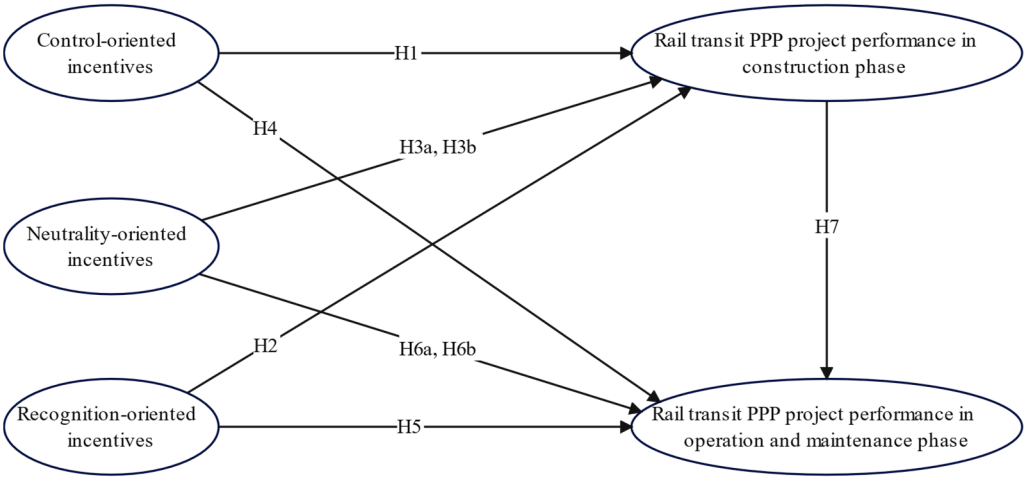

Figure 1. The hypothesized model. Note: H = hypothesis.

3. Research Methods

A quantitative approach was adopted to test the above hypothesized model based on SDT and MIP (Figure 1) [67,68]. Specifically, structural equation modeling (SEM) was selected to validate the hypothesized model because SEM's ability to model complex relationships between the observed and latent variables allows for a precise analysis of how incentives influence performance outcomes over time [69]. By incorporating both direct effects and multiple observed variables into a unified framework, SEM provides a robust analysis that accounts for the intricate dependencies and potential measurement errors within the dataset [70]. The research process was as follows: (1) A life-cycle performance evaluation framework consisting of eight KPIs and an incentive framework consisting of 16 incentive measures for rail transit PPP projects were established based on the existing literature. (2) The incentive framework was further developed to categorize the 16 incentive measures into control-oriented, recognition-oriented, and neutrality-oriented types. This was conducted by using data from 121 questionnaire surveys and the K-Means statistical analysis. (3) The different effects of three types of incentives on PPPs' performance across their life-cycle were tested and verified by structural equation modeling (SEM) using another 256 questionnaire surveys. By doing so, research questions (1) and (2) were addressed.

3.1. Identifying Incentives and Indicators for PPP Project Performance

A total of 16 incentives (Table 1) implemented on rail transit PPPs have been identified from the previous literature, comprising financial incentives, punishments, reputation incentives, and other policy incentives.

From the life-cycle perspective (i.e., construction, operation, and maintenance) [46], 8 KPIs (Table 2) were identified from the existing literature to evaluate rail transit PPP project performance. In the construction phase, KPIs encompass schedule management (PC1), quality management (PC2), cost management (PC3), and safety management (PC4) to assess the project's adherence to the requirements of time, standards, budget, and safety protocols, respectively. Transitioning to the operation and maintenance phase, KPIs are modified to include ongoing cost management (PO1), safety management (PO2), public satisfaction with the service (PO3), and management efficiency and innovation of organizations (PO4), which are crucial for assessing the project's ability to manage substantial operational costs and financial risks while maximizing fare revenue, maintaining high safety standards in complex urban environments, ensuring public satisfaction with transit

services, and fostering continuous innovation and efficiency in organizational management to address the unique challenges of rail transit PPP projects.

Table 1. The incentives used in rail transit PPP projects.

No.	Incentives	Explanation	References
1	Assistance in Financing	The government facilitates access to funding, such as bridging loans or partnerships with financial institutions.	[71,72]
2	Business Performance Bonus	Monetary bonuses are awarded for achieving specific business milestones or innovations.	[73,74]
3	Credit Rating and Reputation Mechanism	Implementation of a credit evaluation system that tracks and publicly reports the reputation of project partners.	[74–76]
4	Government's Positive Attitude towards Cooperation	The government demonstrates a collaborative stance through regular communication and mutual respect in project partnerships.	[75,77]
5	Logistical Support	Provision of essential services such as transportation, accommodation, or on-site facilities to project teams.	[78]
6	Other Performance Bonuses	Monetary bonuses are awarded for outstanding achievements in additional performance areas, such as cultural or recreational contributions.	[19,79]
7	Penalties	Financial or contractual penalties are imposed for failure to meet agreed-upon performance standards or deadlines.	[80]
8	Performance-Based Payment	Payments to the private sector are adjusted based on project delivery metrics and performance benchmarks.	[74,81]
9	Policy Support	The government enacts policies such as land-use adjustments or expedited regulatory approvals to facilitate project development.	[8,82]
10	Priority Honor Titles	Titles or distinctions such as "Model Worker" or "High-Tech Enterprise" are awarded to recognize excellence.	[8,21]
11	Revenue Sharing	The private sector is given a share of revenues from secondary sources, such as advertising or property operations.	[8,83]
12	Project Awards	The government supports project applications for prestigious awards like the Luban Award, enhancing industry recognition.	[8,21]
13	Revenue Subsidies	Financial subsidies, such as fare subsidies, are provided to support the financial stability of the project.	[9,84]
14	Risk Sharing	The government takes on specific risks, such as policy change risks, that are beyond the private sector's control.	[82,85]
15	Simplified Approval Process	The government streamlines regulatory approvals, coordinating multiple departments to expedite project timelines.	[86,87]
16	Tax Incentives	Tax relief measures, such as partial exemptions or deferrals, are granted to reduce the financial burden on the private sector.	[88,89]

Table 2. The performance evaluation framework for rail transit PPP projects.

Phase	Code	KPIs	Explanation	References
Construction	PC1	Schedule management	Assesses adherence to the construction timeline, considering delays from various factors such as resources and funding.	[40,90,91]
	PC2	Quality management	Ensures construction meets specified quality and technical standards as per regulations.	[40,90,91]
	PC3	Cost management	Evaluates the effectiveness of budget planning and cost control to enhance project profitability.	[40,90,91]
	PC4	Safety management	Monitors safety practices to prevent accidents and ensure personnel safety, especially in complex or hazardous conditions.	[90,91]
Operation and Maintenance	PO1	Cost management	Focuses on managing operational costs efficiently to maximize fare revenue and maintain financial stability.	[35,91,92]
	PO2	Safety management	Ensures the implementation of safety measures to prevent accidents during operations.	[35,41,90]
	PO3	Public clients' satisfaction with the rail transit service	Measures public satisfaction regarding service quality, punctuality, and overall performance.	[40,91,93]
	PO4	Management efficiency and innovation of organizations	Evaluates efficiency and innovation in management practices and processes to improve organizational performance.	[35,92,94]

3.2. Classification of PPP Project Incentive Measures

A questionnaire survey was designed to investigate the attributes of the initial 16 incentive measures in Table 1. A purposive sampling strategy was employed for data collection as it helped focus on identifying in-service operational staff and project managers working in major private partner companies, such as CRRC Corporation and CSCEC Corporation, which are large suppliers of rail transit PPP infrastructures [95]. Specifically, project managers who assume substantial work experience in rail transit projects and their incentive mechanisms were approached via emails due to their familiarity with the authors. This selection ensured that the participants had knowledge of government incentives and could contribute to the classification of such incentive measures [96]. They were then requested to share the survey within their network to attract wider participation. As a result, 130 responses were received between May and June 2023 among which 121 were deemed valid. Nine responses were discarded due to incomplete or irrelevant information, such as missing critical data or inconsistent answers [97]. The demographic information of the participants is summarized in Table 3. It shows that the majority of them (83.48%) worked in the private sector of rail transit PPPs while the others worked in government bodies (2.48%), research institutions (8.26%), and consulting companies (5.79%), respectively.

The attributes of incentive measures include control-oriented, neutrality-oriented, and recognition-oriented aspects. Control-oriented means the respondent feels the incentive conveys a controlling context that pressures them to think, feel, or behave in specific ways. Recognition-oriented means the respondent feels the incentive could satisfy their competence need, autonomy need, or enhance their intrinsic motivation, internalization,

and psychological well-being. Neutrality-oriented means the respondent feels the incentive has little impact on them [52]. The respondents rate each incentive measure on a scale of 1 to 5, where 1 represents control-oriented, 2 indicates less control-oriented, 3 is neutrality-oriented, 4 indicates less recognition-oriented, and 5 denotes recognition.

Table 3. Demographic information of the first survey respondents (N = 121).

Demographic Variable	Category	Frequency	Percentage (%)
Gender	Male	93	76.86
	Female	28	23.14
Age	Below 30	31	25.62
	30–40	74	61.16
	41–50	14	11.57
	51–60	1	0.83
	Above 60	1	0.83
Education background	High school or below	1	0.83
	Specialized postsecondary college	2	1.65
	Bachelor's degree	69	57.02
	Master's degree	47	38.84
	Doctorate	2	1.65
Years of work or research in infrastructure management	Less than 3 years	21	17.36
	4–6 years	45	37.19
	7–9 years	36	29.75
	10–12 years	16	13.22
	Over 12 years	3	2.48
Type and nature of respondents' work units	Government departments or related public institutions	3	2.48
	Universities or scientific research institutions	10	8.26
	Private sector (state-owned enterprises)	82	67.77
	Private sector (private enterprises)	18	14.88
	Private sector (foreign enterprises)	1	0.83
	Others (consulting firms, financial institutions, etc.)	7	5.79
Job type	Operational staff	43	35.54
	Project junior managers	59	48.76
	Project middle managers	17	14.05
	Project senior managers	0	0.00
	Others	2	65

The mean value of ratings for each incentive measure was obtained and then segmented into clusters using the K-means algorithm on IBM SPSS Statistics 27.0. The K-means algorithm is a widely used technique to cluster data into distinct groups based on similarities between data points [98]. After the first iteration, the deviation distances from initial class center points were 6.609 (control-oriented), 5.878 (recognition-oriented), and 7.087 (neutrality-oriented), respectively. Rapid convergence was achieved after the second iteration, evidenced by the minimal variation in cluster centers, as reflected in the negligible maximum absolute coordinate change of zero [99]. The distances between the final class centers were 33.085 (control-oriented and recognition-oriented), 22.765 (control-oriented and neutrality-oriented), and 11.699 (recognition-oriented and neutrality-oriented). The mean value of each 16 incentives from the survey and the results of the subsequent K-means clustering analysis are shown in Table 4.

Table 4. K-means clustering results of incentive measures.

No.	Incentive Measure	Pre-Clustering Mean Value	Assigned Cluster	Distance from Cluster Centroid
1	Policy support	3	Neutrality	7.776
2	Simplified approval process	3.033	Neutrality	7.157
3	Tax incentives	3.992	Neutrality	7.548
4	Assistance in financing	4.041	Recognition	6.872
5	The government's positive attitude towards cooperation	4.579	Recognition	5.793
6	Risk sharing	3.041	Neutrality	7.051
7	Revenue subsidies	3.934	Neutrality	7.051
8	Priority honor titles for project companies and their employees	4.388	Recognition	5.878
9	Performance-based payment	1.413	Control	7.272
10	Business performance bonus	1.512	Control	5.628
11	Other performance bonuses	2.008	Control	8.202
12	Penalties	1.364	Control	6.609
13	Revenue sharing	3.901	Neutrality	6.342
14	Project awards	3.893	Neutrality	7.464
15	Credit rating and reputation mechanism	1.463	Control	6.007
16	Logistical support	3.223	Neutrality	7.087
Average score		3.049		

Based on the clustering results from Table 4, 16 incentive measures were divided into three clusters: control-oriented, neutrality-oriented, and recognition-oriented. Further adjustments were made based on the nature of the incentives. For instance, the incentives related to government support that go beyond obligatory duties but reflect a positive cooperation attitude (incentive 14 and incentive 16) were reclassified from neutrality-oriented into the recognition-oriented category based on the principle that a good cooperative attitude is founded on the government's recognition of effective actions by the private sector. The final categories of incentives for the rail transit PPP project are shown in Table 5.

Table 5. Framework of categories of incentives for rail transit PPP project.

Category	Code	Incentive Measures
Control-oriented	A1	Performance-based payment
	A2	Business performance bonus
	A3	Other performance bonuses
	A4	Penalties
	A5	Credit rating and reputation mechanism
Neutrality-oriented	B1	Policy support
	B2	Simplified approval process
	B3	Tax incentives
	B4	Risk sharing
	B5	Revenue subsidies
	B6	Revenue sharing
Recognition-oriented	C1	Assistance in financing
	C2	The government's positive attitude towards cooperation
	C3	Priority honor titles for project companies and their employees
	C4	Project awards
	C5	Logistical support

3.3. Impact of Incentives on Rail Transit PPP Performance

A second questionnaire survey was conducted to gather data for the primary SEM analysis shown in Figure 1. Similarly to the first survey, a purposive sampling method was used to ensure that participants had knowledge of government incentives and could contribute to understanding the impact of these incentives on the performance of rail transit PPPs [96]. There were some overlaps in the participants between the two rounds of the survey, which is common as large rail transit companies are limited. Additionally, due to the trust and reputation established from the first survey, the second survey successfully recruited 256 valid responses between July and August 2023. The demographic information of the participants is summarized in Table 6, which shows that the second survey included more experienced respondents, with 45.3% having 7–9 years of experience in infrastructure management or research, as well as managers in higher positions. Moreover, given that 88.7% of the respondents in the survey were male, due to the current working status in the construction industry, an independent sample t-test was performed to determine if there are significant differences in the impacts perceived by the male and female respondents. The results indicated no significant differences between the two genders across all the test variables ($p > 0.05$).

Table 6. Demographic information of the second survey respondents (N = 256).

Demographic Variable	Category	Frequency	Percentage (%)
Gender	Male	227	88.7
	Female	29	11.3
Age	Below 30	29	11.3
	30–40	145	56.6
	41–50	70	27.3
	51–60	8	3.1
	Above 60	4	1.6
Education background	High school or below	2	0.8
	Specialized postsecondary college	4	1.6
	Bachelor's degree	178	69.5
	Master's degree	66	25.8
	Doctorate	6	2.3
Years of work or research in infrastructure management	Less than 3 years	16	6.3
	4–6 years	60	23.4
	7–9 years	116	45.3
	10–12 years	36	14.1
	Over 12 years	28	10.9
Affiliation type	Government departments or related institutions	4	1.6
	Efficient or scientific research institutions	14	5.5
	Social capital (state-owned enterprises)	187	73.0
	Social capital (private enterprises)	45	17.6
	Others (consulting firms, financial institutions, etc.)	6	2.3
Job type	Operational staff	35	13.7
	Project junior managers	155	60.5
	Project middle managers	46	18.0
	Project senior managers	8	3.1
	Others	12	4.7

Secondly, based on their experiences, the participants were requested to indicate the degree of impact of control-oriented, recognition-oriented, and neutrality-oriented incentives (Table 5) on enhancing rail transit PPPs' performance through a 16-item scale. For instance, under control-oriented incentives, 'How significant do you think performance-based payment can enhance rail transit PPP project performance?' was asked (A1 in Table 5)). This significance was rated using a 5-point Likert scale ranging from 1 (slight impact), 2 (moderate impact), 3 (significant impact), 4 (very large impact) to 5 (extremely large impact). Similarly, the impact of items A2–5 (control-oriented incentives), B1–6 (neutrality-oriented incentives), and C1–5 (recognition-oriented incentives) of Table 5 were evaluated.

Thirdly, the participants were requested to indicate the degree of impact of incentives on enhancing rail transit PPP project performance in the construction phase and performance in the operation and maintenance phase (Table 2) through an 8-item scale. For instance, in terms of performance in construction, 'How significant do you think the performance indicator—the project schedule in construction phase would be affected by incentive measures?' (PC1 in Table 2). This significance was rated using a 5-point Likert scale ranging from 1 (slight impact), 2 (moderate impact), 3 (significant impact), 4 (very large impact) to 5 (extremely large impact). Similarly, the impact of items PC2-4 (performance in construction) and PO1-4 (performance in operation and maintenance) of Table 2 were evaluated.

Finally, several analytic techniques were employed to process the collected data. First, IBM SPSS Statistics 27.0 was utilized to calculate Cronbach's alpha values, assessing the reliability of the measurement scales [100]. IBM SPSS AMOS 28.0 was employed to evaluate the structural validity of our measures through a series of confirmatory factor analyses (CFA) [70]. Second, IBM SPSS Statistics 27.0 was applied to conduct correlation analyses and generate descriptive statistics for the study [101]. Lastly, all the effects hypothesized in hypotheses 1, 2, 3, 4, 5, 6, and 7 were examined by establishing SEM in IBM SPSS Statistics 27.0.

4. Results

4.1. Reliability, Validity, and Descriptive Analysis

As shown in Table 7, the value of Cronbach's alpha for each construct is greater than the acceptable threshold of 0.6 [102]. Next, the results of CFA indicated good construct validity of the latent factors underlying the items on surveys (χ^2 = 701.951; df = 237; χ^2/df = 2.962 < 3 [103]; GFI = 0.827 > 0.8 [104]; RMR = 0.028 < 0.05 [105]; RMSEA = 0.088 (90% C.I.) < 0.1 [106]; PGFI = 0.653 > 0.5 [107]; PNFI = 0.594 > 0.5 [108]). The mean (M) values ranged between 3.574 and 4.500, and the standard deviation (SD) values were between 0.496 and 0.818 (Table 7), showing moderate spread and variability of the data [109]. The skewness values fell within an absolute range of three, and kurtosis remained within an absolute range of 8, indicating an approximately normal distribution [103].

4.2. Correlation Analysis and Hypothesis Test

Table 8 presents the correlation statistics for the preliminary verification of whether there is a mutual influence relationship between the latent variables of this study. All the incentives were positively correlated with the PPP project performance in both the construction phase (control-oriented incentives: r = 0.587, p < 0.01; neutrality-oriented incentives: r = 0.347, p < 0.01; recognition-oriented incentives: r = 0.607, p < 0.01) and the operation and maintenance phase (control-oriented: r = 0.522, p < 0.01; neutral-oriented: r = 0.419, p < 0.01; recognition-oriented: r = 0.609, p < 0.01).

Table 7. Results of reliability, validity, and descriptive analysis.

Latent Variables	Observed Variables	Standardized Loading Coefficient	Means	Standard Deviations	Skewness	Kurtosis
Control-oriented incentives (α = 0.664; M = 4.079; SD = 0.432)						
	A1	0.162	4.418	0.608	−0.526	−0.616
	A2	0.733	4.020	0.556	−1.094	6.464
	A3	0.637	4.047	0.673	−0.990	3.249
	A4	0.505	3.980	0.743	−1.008	2.178
	A5	0.648	3.930	0.711	−0.824	2.024
Neutrality-oriented incentives (α = 0.735; M = 4.139; SD = 0.390)						
	B1	0.446	4.500	0.601	−0.875	0.357
	B2	0.692	4.035	0.496	−0.507	3.657
	B3	0.570	4.102	0.637	−0.272	0.161
	B4	0.638	4.074	0.606	−0.248	0.542
	B5	0.615	4.086	0.614	−0.460	1.232
	B6	0.432	4.035	0.603	−1.096	5.136
Recognition-oriented incentives (α = 0.605; M = 3.986; SD = 0.425)						
	C1	0.244	4.402	0.625	−0.548	−0.611
	C2	0.482	4.039	0.545	−0.266	1.577
	C3	0.646	3.617	0.818	0.117	−0.185
	C4	0.658	4.023	0.613	−0.836	3.904
	C5	0.612	3.848	0.775	−0.749	1.108
Rail transit PPP project performance in construction phase (α = 0.721; M = 4.012; SD = 0.462)						
	PC1	0.608	4.336	0.598	−1.176	5.909
	PC2	0.680	4.043	0.569	−1.023	5.945
	PC3	0.625	4.055	0.723	−1.150	2.960
	PC4	0.617	4.047	0.605	−1.731	8.895
Rail transit PPP project performance in the operation and maintenance phase (α = 0.668; M = 3.873; SD = 0.451)						
	PO1	0.550	4.008	0.509	−0.347	2.381
	PO2	0.589	3.574	0.710	0.298	−0.372
	PO3	0.574	3.926	0.637	−0.944	3.368
	PO4	0.624	3.984	0.674	−0.755	2.406

Table 8. Correlation coefficient among variables.

Variables	1	2	3	4	5
1. Rail transit PPP project performance in the construction phase	1				
2. Rail transit PPP project performance in the operation and maintenance phase	0.571 **	1			
3. Control-oriented incentives	0.587 **	0.522 **	1		
4. Neutrality-oriented incentives	0.347 **	0.419 **	0.433 **	1	
5. Recognition-oriented incentives	0.607 **	0.609 **	0.611 **	0.442 **	1

Note: ** $p < 0.01$, two-tailed.

Finally, SEM was conducted to test the hypothesized relations among the latent variables. Firstly, the results indicated that our hypothesized SEM model fit the data well (x^2/df = 2.972 < 3 [103]; RMSEA = 0.088 (90% C.I.) < 0.1 [106]; RMR = 0.028 < 0.05 [105]; PGFI = 0.657 > 0.5 [107]; PNFI = 0.597 > 0.5 [108]). Secondly, the hypothesis test (Figure 2) shows that hypotheses 1, 2, 5, and 6 were empirically supported while hypotheses 3, 4, and 7 were rejected. To sum up, in the construction phase, control-oriented incentives have

the strongest positive impact ($\beta = 0.527$, $p < 0.01$), ensuring accountability and measurable performance outcomes. Recognition-oriented incentives also contribute positively by motivating stakeholders ($\beta = 0.471$, $p < 0.01$), while neutrality-oriented incentives show little effect ($\beta = -0.142$, $p > 0.05$, n.s.). In the operation and maintenance phase, recognition-oriented incentives have the most significant and positive impact ($\beta = 0.618$, $p < 0.01$), fostering collaboration and long-term performance. Neutrality-oriented incentives turn out to show minor effects ($\beta = 0.227$, $p < 0.01$), providing stability and risk mitigation. Control-oriented incentives lose their effectiveness and can even have negative effects on performance ($\beta = -0.173$, $p > 0.05$, n.s.).

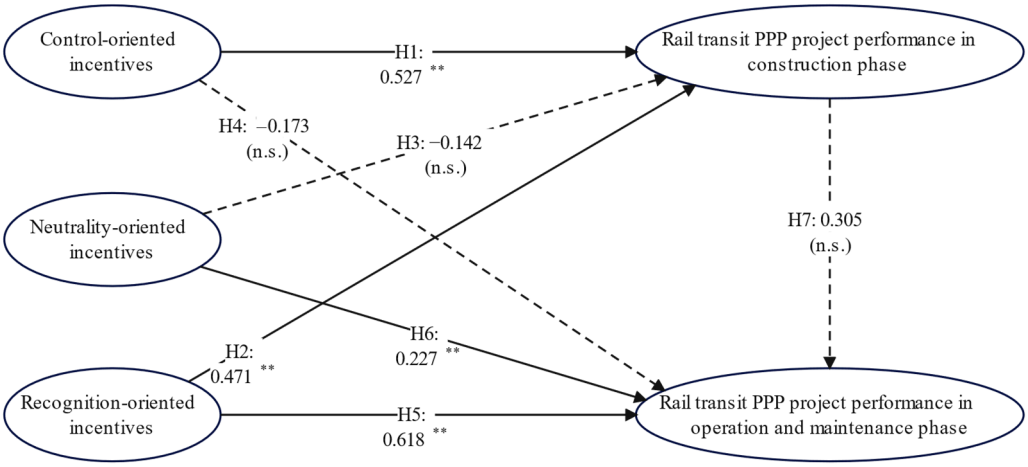

Figure 2. Results of SEM. Note: Solid lines represent significant path coefficients, while dashed lines indicate non-significant ones. All path coefficients are standardized. ** $p < 0.01$, two-tailed.

5. Discussion

5.1. The Attributes of Incentive Measures

The classification results reveal that the private sector perceives incentives differently (see Table 5). Consistent with SDT, control-oriented incentives not only refer to penalties (A4), but also tangible rewards based on performance including performance-based payment (A1), business performance bonus (A2), and other performance bonuses (A3) were all recognized by the respondents as control-oriented incentives, as they condition the receipt of rewards on meeting specific performance criteria [74]. Unexpectedly, the credit rating and reputation mechanism (A5) was also recognized as a control-oriented incentive (discussion presented later). The classification results provide an answer for the first part of research question (1)—the dual effect of "positive incentives": while these incentives are expected by government policymakers to play positive roles, they are perceived by the private sector as controlling rather than genuinely inspiring, thus possibly leading to bad sequent behaviors [59]. For example, reducing their real current performance to smooth high performance standards in the future is caused by the rachet effect (in the principal–agent relationship, an agent's strong performance or reputation leads the principal to raise future expectations and targets) [74].

Neutrality-oriented incentives (B1–B6) show a congruous balance between the interests of the public and private sectors without the pressure of overly controlling or disproportionately rewarding one party over the other. Policy support and simplified approval processes (B1, B2) reduce bureaucratic barriers, making it easier for the private sector to participate in rail transit projects [110]. Risk sharing, revenue subsidies, revenue sharing, and tax incentives (B3–B6) focus not on recognizing or rewarding superior performance but on addressing the inherent uncertainties and financial risks associated with

large-scale rail transit projects, where both parties share the risk and have their interests safeguarded [8,9,82].

Consistent with SDT, incentives (C1–C5) share a common recognition-oriented focus that fulfills individuals' intrinsic needs for competence, relatedness, and autonomy, either directly or indirectly. Assistance in financing (C1) and logistical support (C5) enable autonomy by providing the necessary resources and infrastructure to allow project companies to operate more effectively [111]. The government's positive attitude towards cooperation (C2) and logistical support (C5) contribute to a collaborative environment that nurtures positive relationships between the public and private sectors. Priority honor titles for project companies and their employees (C3), and project awards (C4) validate the efforts and achievements of the project companies and their employees [112].

The different attributes of credit rating and reputation mechanism (A5) and priority honor titles for project companies, their employees, and projects (C3, C4) provide insights into the dual nature of reputation mechanism within the context of PPP projects. A reputation mechanism refers to the use of the track record, credibility, and historical performance of both the public and private sectors to influence behavior and foster trust [14]. The private sector is often eager to strive for a good reputation, as it not only brings social acknowledgment but also enhances market competitiveness during bidding [74]. Therefore, reputation mechanisms are often assumed to be recognition-oriented (e.g., C3 and C4). However, when reputation and credit ratings are tied directly to performance evaluations (A5), they transition from being motivational tools to instruments of control [74]. In this scenario, the private sector is pressured to maintain a high reputation to avoid negative consequences, such as losing future business opportunities, and might become more cautious and conservative, reducing risk but potentially limiting creativity and innovation.

5.2. The Effects of Incentive Measures

The results of SEM provide answers to research question (2)—distinct characteristics of these three incentive categories lead to varying impacts on rail transit PPP performance at different project stages (see Figure 2).

Control-oriented incentives have a significantly positive impact on performance in the construction phase ($\beta = 0.527$, $p < 0.01$), consistent with the MIP theory. In line with research [73,79,113], the performance-based payment in rail transit PPPs is a key element of contracts, since it directly links rewards and abatements (penalties) to the achievement of performance milestones and defines risks transferred to the private sector. According to Li et al. [74], coupling reputation supervision with performance-based payment can help the government evaluate the performance of the private sector more accurately, thus reducing the incentive cost of the government. Hence, the finding can provide an answer to the second part of research question (1)—the dual effects of "negative incentives": although control incentives may impair autonomy, they act as a deterrent against delays or substandard behavior, and opportunistic behaviors for performance rewards [73,74,114], being especially effective in rail transits' construction environments, where clear, measurable goals are paramount (such as on-time delivery or budget compliance).

While control-oriented incentives were observed to lose efficiency on performance in operation and maintenance ($\beta = -0.173$, $p > 0.05$, n.s.), according to Gordon et al. [12], in some Metro contracts, most of the risk was placed on the operator, with a cap on the quality bonuses (limiting government payout), but no cap on penalties (meaning the operator could face significant financial risk if performance was poor). In addition to the naturally low passenger flows and fares of some metro lines, control-oriented incentives further discourage the private sector. Moreover, performance-based payment could lose efficiency due to the unclear evaluation methods for qualitative operational performance indicators

such as service quality [12], the incentive coefficients are fixed instead of dynamic [73,79], etc., opening the way for performance deception by self-seeking private sectors for a higher bonus, thus exerting negative effects on PPP projects [18].

Neutrality-oriented incentives were observed to have a negative but not significant impact on performance in the construction phase ($\beta = -0.142$, $p > 0.05$, n.s.), whereas they demonstrated a significantly positive impact on performance in the operational phase ($\beta = 0.227$, $p < 0.01$). The limited role of neutrality-oriented incentives during construction suggests that policy support, simplified approval processes, and tax incentives may not directly address the immediate goals of construction, such as timely completion, cost efficiency, and quality assurance. During construction, projects tend to prioritize control-oriented incentives that offer clear, measurable outcomes tied to performance milestones, such as penalties for delays or bonuses for meeting deadlines [38]. While in the operational phase, the focus shifts to sustaining long-term performance indicators such as service quality, sustainability, and financial stability [115]. Neutrality-oriented incentives become more valuable in this phase by fostering collaboration and mitigating risks over a longer timeframe [35,116].

Recognition-oriented incentives were empirically supported to have a positive impact on performance in both the construction ($\beta = 0.471$, $p < 0.01$) and operation phases ($\beta = 0.618$, $p < 0.01$), in line with SDT and MIP. Notably, recognition-oriented incentives demonstrate superior positive effects (0.618 **) compared to both the control-oriented (-0.173, n.s.) and neutrality-oriented incentives (0.227 **) in the operation phase. The operation phase often spans decades, during which the private sector is responsible for the day-to-day functioning and maintenance of the rail transit system, involving coordinating various elements such as scheduling, maintenance, customer service, safety, and regulatory compliance. The result suggests that the private sector places a higher value on incentives that provide collaboration, acknowledgment, and support in this phase to go through difficulties.

5.3. Practical Implications

Our findings empirically evidence that the ultimate effect of an incentive depends on the relative salience of whether the private sector perceives the incentive as recognition-oriented or as control-oriented, and its implementation scenario (e.g., project stage).

The same incentive can be perceived by the private sector as control-oriented or the opposite in different projects depending on factors such as project goals, stakeholder dynamics, and implementation practices. These shifting perceptions highlight the need for governments to regularly investigate how incentives are viewed by the private sector and adjust their design and implementation accordingly [61]. For example, if an incentive, such as performance-based payments, is perceived as control-oriented, governments can introduce flexibility by adjusting performance targets [73], refining evaluation methods [12], or coupling these payments with supportive policies (e.g., logistical assistance or risk-sharing mechanisms) to mitigate the feelings of excessive control. If the same incentive is perceived as recognition-oriented, it can be emphasized as a tool to promote innovation, collaboration, and long-term commitment [94]. For example, linking performance-based payments to the public acknowledgment of achievements or awards can reinforce their motivational value [21].

The perception of incentives may also change across different phases of a project (e.g., construction vs. operation). Governments should dynamically adapt their implementation strategies to suit the evolving needs of each phase [14,22]. For instance, during the construction phase, control-oriented incentives can positively influence project outcomes. However, in the operational phase, these incentives may discourage innovation and autonomy if

perceived as overly rigid. To address this, governments can adjust performance standards and evaluation methods over time. For example, in the early operational phase, setting lower performance thresholds can accommodate the private sector's initial instability while minimizing the risk of excessive profit-taking [19]. In the mid-to-late operational phase, governments should implement balanced incentive designs, such as placing caps on both bonuses and penalties, to ensure fairness and maintain long-term private sector engagement [8]. Conversely, stakeholders should prioritize the use of recognition-oriented incentives throughout the project life-cycle. For example, the public recognition of exceptional operational performance, combined with supportive policies (e.g., logistical assistance), can help private stakeholders overcome challenges and maintain service excellence [22]. In terms of neutrality-oriented incentives, they should be used as complementary measures rather than as the primary drivers of performance in the construction phase. During the operational phase, public entities can leverage these incentives to maintain strong partnerships and support the private sector in addressing ongoing operational challenges [75]. For example, risk-sharing mechanisms can help balance financial uncertainties, such as fluctuating ridership levels or revenue shortfalls, ensuring private entities remain committed to maintaining high service standards [89].

5.4. Generalizability Caveats

While this study offers valuable insights into the role of incentive measures in rail transit PPPs, it was conducted in the Chinese context. Therefore, we clarify the generalizability caveats of the findings in relation to (1) the effects of debates on the scope of the government [117], (2) the effects of performance volatility [118], and (3) the effects of limited government resources [119].

Firstly, the results may be different under other circumstances of market conditions as survey evidence is typically gathered in a short period of time [95]. For example, the increasing complexity and heightened uncertainty due to recent geopolitical events (e.g., the Ukraine war) triggered the discussion on the degree of their governments' intervention in private sector activities [117], which might alter the way neutrality-oriented incentives (such as risk-sharing mechanisms or government subsidies) are perceived. Private companies may perceive these incentives as more reliable and valuable safeguards from governments due to the instability of the market. Consequently, such incentives may be seen as more positively impactful on the performance of rail transit PPPs compared to the results in Figure 2.

Secondly, another important factor to consider is the volatility of performance metrics chosen to award incentives or penalties, which significantly impacts the effect of incentives [12,120]. According to [18], governments should design incentives that engage private investors based on their profitability outlook. Predictable performance metrics help private investors better evaluate their profitability outlook. Based on the evaluation, private investors might view PPPs as more valuable, leading to a greater willingness to invest in such projects [118]. Conversely, in projects with higher performance volatility, the effectiveness of incentive measures might be diminished, as stakeholders may perceive the risks associated with these projects to be higher or conduct opportunistic behaviors [18].

Thirdly, the role of government resources in supporting PPP projects may affect the effectiveness of incentives. In jurisdictions where governments face fiscal challenges or constraints, such as those experiencing debt-ceiling standoffs [119], even well-designed incentives may not be effective if the government lacks the resources to implement or sustain them. Private companies may perceive these incentives as less valuable or riskier due to the potential for reduced government credit [84]. This could lead to the negative effects of control-oriented incentives, which may manifest differently than the results

shown in Figure 2, as public entities may struggle to meet their contractual obligations. Consequently, the perceived reliability and effectiveness of these incentives could diminish, influencing both the private sector's behavior and the overall success of the project.

Therefore, we suggest that future research should explore how these factors influence the implementation and effectiveness of incentives in rail transit PPPs under varying conditions.

6. Conclusions

Public–private partnerships (PPP) projects have become increasingly relevant, especially given the emerging market economies. Despite the widespread implementation of incentives within rail transit PPPs, their impact on project performance sometimes remains ambiguous and ineffective. This study combines the SDT and the MIP from the discipline of psychology to examine the private sector's real perceptions regarding three dimensions of incentives—control-oriented, neutrality-oriented, and recognition-oriented, thus analyzing how different incentives influence PPP project performance from a life-cycle perspective.

The re-classification results of 16 incentives challenge the "positive" nature of some financial incentives by demonstrating that performance-based payment/bonuses were perceived as control-oriented incentives by the private sector. We also examine the dual attributes of reputation incentives, with credit rating and reputation mechanism recognized as control-oriented incentives while priority honor titles as recognition-oriented incentives. Furthermore, our SEM results empirically evidence that the ultimate effect of an incentive depends on the relative salience of whether the private sector perceives the incentive as recognition-oriented or as control-oriented, and its implementation scenario (e.g., project stage). Although control-oriented incentives restrain autonomy, they positively influence project performance during the construction phase, where clear, measurable goals are paramount. In addition, recognition-oriented incentives significantly enhance project performance in both construction and operational phases (especially the latter), fostering long-term sustainability. Finally, neutrality-oriented incentives focus on risk allocation and collaboration between the public and private sectors, showing a modestly positive effect in the operation phase.

These findings unearth the nature of incentives in rail transit PPP projects, enrich the extant literature on incentive mechanisms, and provide practical recommendations for policymakers. Nevertheless, there remain limitations and areas for further research, as survey evidence is typically gathered in a short period of time and in the Chinese context. Moreover, as SDT and MIP limit the impact of incentives on the extrinsic and intrinsic motivation of individuals and groups, future lines of inquiry can examine the potential mediating roles of the private sector's motivations and subsequent behaviors to assess whether they partially or fully mediate the relationship between incentives and project performance in rail transit PPPs.

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Enhancing the Sustainable Performance of Public–Private Partnership Projects: The Buffering Effect of Environmental Uncertainty

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Abstract: The purpose of this study was to investigate the buffering (moderating) effect of environmental uncertainty (EU) on the relationship between the critical success factors (CSFs) of public–private partnership projects (PPPPs) and sustainable performance. A survey approach was adopted to collect primary data from construction industries that have signed an agreement with the public sector. The public sector includes federal and provincial government departments such as the National Highway Authority (NHA) and the Frontier Works Organization (FWO) for the construction of roads, and the private sector includes engineering companies registered with the Pakistan engineering council. The non-probability convenience sampling technique was used to select the sample, and the Krejcie and Morgan table was used to calculate the sample size. A total of 500 questionnaires were distributed but 394 completed questionnaires were used in the analysis of the data, yielding a response rate of 78.8%. Confirmatory factor analysis was conducted to check the reliability and validity of the scales; the findings revealed that the scales met the threshold, and all the factor loadings, average variance extracted, composite reliability, Cronbach alpha, and discriminant validities met the cut-off level. Hence, the questionnaires were found to be reliable and valid. The results revealed that environmental uncertainty significantly moderates the CSFs (technical, procurement, and economic factors) of PPPs and the sustainable performance of PPPPs. Furthermore, the interaction terms of all moderating effects revealed negative beta values; this implies that a low level of uncertainty results in better economic performance, better technical and procurement factors, and highly sustainable performance. It is concluded from the findings that if EU is high, then the sustainability of PPPPs is low; moreover, fewer economic resources and no technical support and procurement also have a weak impact on enhancing sustainable performance. On the contrary, if EU is low, there is a high level of sustainability in PPPPs.

Keywords: critical success factors; economic factor; procurement factor; technical factor; environmental uncertainty; public–private partnership; sustainability

1. Introduction

A public–private partnership (PPP) is a mutual arrangement normally used to improve economic development, infrastructure delivery, and development and governance, as well as achieve the delivery of quality services around the globe in developed and developing countries. According to the World Bank Private Participation in Infrastructure (PPI) [1] database, Pakistan achieved a financial close of 108 infrastructure projects from 1990 to 2019 and made investments of approximately USD 28.4 billion (PKR 4.40 trillion). Out of the 108 PPP projects that have achieved financial closure, public and private entities from the United Kingdom and the People's Republic of China (PRC) sponsored the most projects. The gamut of PPPs is so vast that it appears difficult to formulate a complete and precise definition of PPPs [2]. However, the increased popularity of PPPs in recent decades has enhanced their importance, with researchers aiming to understand their mechanics to unveil common practices, rules, and procedures to comprehend the overall picture; from here, we can deduce a clear description of the concept [3]. A PPP (public–private partnership) is a mutual arrangement for the cooperation and coordination of the public and private sector around the world [4]. PPP projects have been used to provide a series of infrastructure projects worldwide [5]. PPPs have enhanced the economic value of infrastructure outputs [6] and contributed to the growth of overall infrastructure projects like the formation of transportation facilities, water conservancy facilities, sports facilities, and energy plants [7]. PPPs are a suitable and affordable alternative delivery system that enables infrastructure projects to be successful [8]. The main idea of the PPP scheme is collaboration between the public and private sector [9], with different tiers of responsibilities and involvement, as well as a more proficient provision of public and infrastructure services [10]. Some researchers see PPPs as a governance tool which brings competitive tendering and successfully replaces the traditional method of contracting for public services. Others see PPPs as a form of public management that expresses the old established procedures via the involvement of private organizations to deliver public services. Some researchers view PPPs as an arrangement to deal with infrastructure projects, including tunnel building or the renewal of harbors [11]. Apart from the above-mentioned groups, there are a number of people who interchangeably use the terms "public–private partnership" and "contracting". A sustainable infrastructure with modern and reliable characteristics is a critical factor and is considered the objective of people in the world. Infrastructure investments help to increase economic growth rates, facilitate investment in human capital, and offer new economic opportunities. Infrastructure development is also considered the only emerging market able to reduce poverty, obtain prosperity, achieve sustainable development goals, and tackle climate change [12].

PPPs can be considered a definite type of governance network and can be defined as a stable pattern of social relationships between two or more mutually dependent actors who work together on a policy program that is formed, changed, and maintained by a series of factors [13]. A crucial aspect of this arrangement and of the existence of the network lies in the dependency between the actors forming the partnership. The concept of PPP specifically focuses on the inter-relationship between private and public partners. Moreover, this arrangement also stems from the concept of the mutual sharing of risk, cost, and profit [14]. Undoubtedly, PPP markets in developed countries like Britain, Australia, the USA, and Canada have obtained great success and have thus attracted great private investment. Another reason for the success of PPPs in developed countries is that the PPP market is much more mature, and therefore, private investors have full confidence in their markets [15]. However, this concept is not applicable to developing countries, where very few private markets have successfully attracted private investments in recent decades [16]. PPPs are being used extensively around the globe to deliver public assets when public budgets are unable to meet the requirements [17]. While adopting PPPs, the main concern of any government is to deliver innovative services and public services more efficiently, effectively, and at a lower cost [18]. The public sector creates infrastructure development plans according to the national economic development plan of a country [19].

The prime concern of the public sector is to formulate a framework that must be feasible, attractive, and viable for the private sector. A long list of critical success factors has been discussed in several studies over many years. These factors are considered mandatory to obtain success in PPP implementation and to achieve constructive/attractive aspects of PPP implementation [20].

Critical success factors (CSFs) are considered important enablers of success in any project. Owing to the increase in PPP projects worldwide, the drivers of PPP project success have appeared as an investigation subject. Numerous studies have used an abundance of methods, including lists of questions in the shape of questionnaires, interviews with experts, and different case studies, to examine the success factors required for PPP projects in different projects and countries. However, there are very few specific studies that identify the leading factors in the success of PPPs in countries which have only recently embraced this approach [21]. Critical success factors (CSFs) have a significant impact on the performance of PPP projects and there are a plethora of studies that deal with the influence of critical success factors (CSFs) on the performance of PPP projects. Most of the existing studies have their focus on the success of projects rather than the factor of stakeholder involvement [22]. The number of identified CSFs is huge, and their behavior also varies as per the country's dynamic. According to studies, numerous factors contribute to satisfactory or unsatisfactory PPP project performance [23]. There remains a huge debate as to which partner is to blame for the unsatisfactory performance of PPP projects [24]. Performance measurement is important to measure the success of any business [25]. In fact, in PPP project management, the central activity is the measurement of project performance specific to that project. Performance measurement is the only process to quantify and report the efficiency, success, and efficacy of the action performed toward the attainment of the objectives set by the organization [21]. Past studies have highlighted the importance of PPP projects in obtaining sustainability in any country. Modern views about sustainability encompass three interconnected dimensions of sustainability: economic, social, and ecological [26]. The mentioned three forms can produce social parity, economic prosperity, a clean natural environment, and social justice. In short, we can achieve economic, ecological, and social sustainability through PPP projects and can use it as a capable tool in this regard. Whitfield [26] used a model to visualize the impact of the economic, political, and legal environment on the success of projects in different countries like Russia, China, India, Australia, Brazil, etc. He also examined the rising secondary market in PPP investments, like buying and selling schools and hospitals like commodities in a global supermarket. He also highlighted the reasons for PPPs' failure, which were mostly due to investor miscalculations about the projects. This uncertainty about implementing PPP projects is a point of great concern as it leads to the failure of a project at the end [27]. Uncertainty associated with the different risks in any environment impacts project performance; thus, projects experience a failure end state [28]. Perceived uncertainty can be defined as the degree of uncertainty associated with a specific source of organizational uncertainty [29]. Uncertainty is theorized based on elements present inside or outside the organization. Therefore, we can term the former organization-specific uncertainty and the latter environmental (external) uncertainty [30]. Christensen [31] has argued that most companies or organizations need to follow different approaches to face highly unpredictable markets.

Uncertainty is the central understanding of risk, which leads to the possibility of an undesired event happening. At the same time, uncertainty appears relevant only when it leads to a result which is unwanted and which potentially takes the project to an undesired future, which requires a response as well [32]. Once we talk about this response, we can deal with the uncertainty that comes from the partnership intensity or the partners' coordination in different forms, like their trust in each other. We can also develop some mechanism to face the uncertainty, i.e., a management system for risk. Sustained economic growth is mainly dependent on the macroeconomic stability of a country. In the case of Pakistan, we know that Pakistan's economy has seen boom-and-bust cycles in its history. Usually, this boom-and-bust cycle comprises a 3–4-year span of higher economic growth and is then followed

by a macroeconomic crisis. This macroeconomic crisis needs stabilization programs. Most of the time, there remained an inability to achieve the desired stabilization, which was due to structural issues present in our system. These structural issues require effective monetary and fiscal measures to obtain macroeconomic stability [33]. In developing countries, PPPs are considered one of the best-suited measures for financing, and they are a procurement modality to address the existing infrastructure gap. PPPs can also be used to bring down cost and time efficiencies in infrastructure projects, as well as to utilize the private sector to deliver public goods by managing it efficiently [33]. Public–private partnerships also carry fiscal risk, which needs to be managed and mitigated. To tackle these challenges, there remains a need to bring into account institutional and legal reforms in PPP arrangement. In this way, a technically sophisticated PPP ecosystem can be formulated, and it can look after the overall PPP system to pursue PPP proposals and to maximize the value for money (VfM) of the taxpayers. The formulation of this ecosystem needs to be aligned with the procedures used to carry transactions, from the identification stage to the execution stage, and it needs to be ensured that the development of the PPP transaction system is relevant to development and fiscally responsible [34]. This ecosystem is very crucial for the development outcome because the development outcome must be aligned with the system's technical capacity [35]. Pakistan, like many other developing countries, has also adopted public–private partnerships (PPPs) in different sectors since the 1990s, and this adoption has improved the delivery of public services. Owing to fiscal constraints, PPPs have been chosen as an innovative and supplementary approach to provide infrastructure: instead of the traditional approach, in which the government is the sole service provider, it has taken the finance and expertise from the private sector. A significant share of the infrastructure sector required in Pakistan can be obtained through public–private partnerships (PPPs), and this policy approach framework will lay a solid foundation for the new approach, i.e., PPPs in Pakistan. The government of Pakistan has very rightly identified the need to motivate and encourage the private sector to participate in the infrastructure development of the country. Therefore, they are using a combination of policy reforms and steps to bolster the support of institutions, incentives, and financing modalities to strengthen the participation of the private sector in the fields of finance, development, and management of future infrastructure development projects. PPPs (public–private partnerships) have resolved the problem of resource deficits for many developing countries; likewise, they are equally applicable to the Pakistani scenario, but somehow they have not been a prolific practice in Pakistan due to various reasons/risk factors. Therefore, the suitability of PPPs in the Pakistani context needs to be explored. Furthermore, different challenges that have been the cause of the ineffectiveness of PPPs in Pakistan need to be identified for a better PPP approach in the country [32]. Sustainability is an important aspect of any project, and it cannot be obtained without a comprehensive research framework. This framework must be designed in a way that can secure the interest of all stakeholders and societies along with economic benefits to business. It is quite challenging for projects to maintain sustainability constantly, and for this purpose, businesses needs a sustainability framework to maintain sustainability management. PPP projects last longer, so they need sustainable performance measurement for a long time, and uncertainties and risk factors need to be considered as well. The maintenance of sustainable performance is challenging; therefore, different attributes of comprehensive dimensions should be considered, including meeting design goals, benefits to end users, benefits to the private sector, benefits to the public sector, and preparing for the future [36]. According to Business Recorder-2019 [37], Pakistan just received about USD 25 billion of investment in PPP projects, which is the third lowest amount in the region. Keeping this investment in mind, we can formulate an idea about why there are fewer PPP projects in Pakistan. According to Pakistan's economic survey [32], the growth momentum of Pakistan's economy has remained unstable in the last couple of decades due to macroeconomic imbalances. Due to these macroeconomic imbalances, coupled with the growing population in developing countries like Pakistan, the country has been unable to meet the infrastructure requirements due to limited financial resources [38].

The lack of studies conducted about PPPs is the main source of motivation for undertaking this study, as no significant work about PPPs has been conducted in Pakistan. Also, in the future, most projects will be dependent on PPPs because developing countries must rely on PPPs to fill the gaps in their financial needs [39]. Currently, there are approximately 22 ongoing infrastructure projects in Pakistan, but ironically, there is no reliable estimation method or consideration for the incorporation of localized critical success factors for PPP projects. Owing to the non-consideration of proper localized CSFs, most PPP projects do not meet a successful end state. Therefore, there is a great need to ascertain the localized CSFs of PPP projects in Pakistan [40].

Research Gaps

Cui, Liu, Hope, and Wang [7] reviewed almost 754 studies which appeared in 56 different countries and regions from all six continents. In the study, articles from all around the globe, along with the viewpoints of co-authors, were considered. The study mentioned that the highest share of articles was produced in China, from where 165 articles on the application of PPPs originate; therefore, it can be concluded that China is rapidly developing many aspects of PPPs. The UK is considered another primary source of studies of the concept of PPPs, and the country has produced 108 articles on PPP development. The remaining countries and regions have also produced studies on this matter. Worth mentioning is the USA, with 84 articles; Australia, which has produced 80 articles; and India, which has produced 40 articles on the subject. Taken together, these countries have produced almost 50 percent of the share of articles on PPPs. The same findings were reached by Ke et al. [36]. The proportion of investment in public–private partnerships is also the same as that of published articles in this particular field.

There has been a lot of variation in the implementation of PPP practices in developing and developed countries. There are more hurdles to overcome for developing countries as compared to developed countries. This is because developing countries have more obstacles in the shape of government financial resources, inefficiencies in the public sector, uncertain contractual environment, weak political will, deficiencies in capacity, and bottlenecks present in administration [41]. The mentioned obstacles/hurdles pose great challenges to a smooth contractual agreement involving all the related contingencies to achieve value for money in PPP projects [42]. However, it has been observed that PPP projects are more beneficial for developing countries as they can receive more advantages from technical expertise and new capital brought in by the arrangement of PPPs [43]. The lack of work conducted about PPPs is the main source of motivation for undertaking this study, as there is no significant work conducted in Pakistan about PPPs. In the future, most projects will be dependent on PPPs because developing countries must rely on PPPs to fill the gaps in their financial needs. Therefore, in order to achieve sustainable PPP performance, there is a need to have a comprehensive framework on sustainable PPP performance that can encompass the relationship between CSFs and sustainable PPP performance, along with the reasons why PPPs fail, i.e., environmental uncertainty and factors such as trust and joint risk management.

It has been concluded that in terms of research on public–private partnership projects' success, failure, and sustainable performance, Pakistan is far behind the rest of the world due to reported technical, economic, and procurement issues. Furthermore, the government's weak financial capacity, uncertain contractual environment, and lack of technical support, economic stability, and political will are the factors that hinder the sustainable performance of projects. So, to boost the sustainability of PPP projects, this research highlights the gap that exists in the PPP literature and tries to fill this gap to enhance sustainable performance by reducing environmental uncertainty in developing countries through the lens of agency theory [44].

2. Theoretical Background

Agency theory, developed by Eisenhardt (ref. [45]), has been extensively used in multiple disciplines since its beginning about four decades ago. Now, this theory has captured much focus in the literature on project management, operation management, and corporate governance. Agency theory has also been applied in public–private partnership projects since the last decade due to the conflicting self-interests of partners [46]. Agency theory talks about the relationship between the principal and the agent, where the latter acts on behalf of the former [47]. In PPPs, the public context refers to the citizens as the ultimate principal, i.e., public authority, and the agent commonly refers to private companies. The relationship between the agent and the principal is labeled as a relationship or contract. In either the relationship or contract, it is likely that there appear some problems, which are called agency problems [48].

Agency theory deals with a few assumptions regarding agency problems; those are the conflicting interests of partners, the idea of rationality to undertake some steps, asymmetric information, uncertainty, and risk aversion or risk management. Mutuality between the partners is mostly difficult to achieve because of the role and understanding of different collaborators due to different orientations [49]. A limited number of studies have explored the aspects of agency problems in PPP relationships. The available literature is mainly focused on risks or on the cost associated with the cooperation [50]. When we narrow our focus, there is a lack of knowledge regarding conflicting interests, self-interest, asymmetric information, uncertainty, and risk behavior. We also need to look at trust, communication, and project risks and their management in PPPs through the lens of the principal–agent model [51]. This research has used agency theory as a basis to investigate the relationship between critical success factors and sustainable PPP performance, with the moderating impact of environmental uncertainty (i.e., an agency problem), and to achieve sustainable PPP performance as a result.

2.1. Public–Private Partnership (PPP)

A public–private partnership (PPP) is a cooperative arrangement between the public and private sectors that is formulated to undertake a project that traditionally falls under the realm of the public sector [52]. Governments around the globe are using PPP arrangements according to their requirements for the delivery of different services and products. The phenomenon of PPPs has gained enormous popularity in the last two decades [53]. The performance of PPPs can be considered to be the actual outcome of the PPP project relative to the proposed achievement, e.g., the attainment of the government's goal and objectives established at the time of the partnership. The efficacy of any PPP project can be ascertained by comparing the predetermined goals and objectives with the outcome [54].

2.2. Critical Success Factors in PPP Performance

The identification of critical success factors (CSFs) in PPPs has grown into a major area and has received significant attention from researchers. A large number of articles have defined and discussed CSFs for PPPs based on case studies and research surveys [54]. CSFs vary by project type, industry, lifecycle phase, nationality, individual, and organization. The influence of multi-dimensional factors is very complex, and the interaction of factors can vary with the project and phase; therefore, it is necessary to specify the research scope to improve their pertinence. However, based on the distinctiveness of PPP projects, it is likely that CSFs for PPPs will be different from those applicable to traditionally procured projects [55] (Table 1).

Table 1. Operationalization of CSFs of PPPPs.

Construct	Component
Technical factors	• Effectiveness of arbitration process • Existence of well-organized economic regulatory authority • Availability of labor • Availability and efficiency of supporting infrastructure • Level of transparency and corruption • Availability of indigenous technology
Legal factors	• Extent of compliance with and enforcement status of international conventions • Domestication and implementation of international laws/codes • Predictability of legal regime and enforcement
Political factors	• Consistency in government policies • Political stability and support • Provisions for reversion of policies • Clearly stated contract responsibilities and liabilities
Finance factors	• Availability of risk-sharing framework • Availability and stability of the financial market • Availability and stability of the consumer market • Access to foreign finance
Market maturity	• Stability of exchange inflation rate • PPP human capacity index • Tariff control policy and availability of tariff framework
Economic factor	• Stability of exchange rate • Stability of interest rate
Procurement factor	• Level of understanding of public–private alliance transaction • Competitiveness of the bidding process • Performance guarantee • Political will by the public sector • Availability of guarantee and stand-by financing
Regulation factor	• Existence of clear investment laws • Delay in land acquisition • Existence and adequacy of the legal framework for concession.

2.3. Sustainability Measurement System and PPP Projects

Sustainability has been defined as an ability to exist constantly/continuously, and its management is quite challenging. Sustainability management requires a thorough management framework [56]. Sustainable performance measurements for public–private partnership projects (PPP) must be effective for a longer duration of time considering the complexity and longevity of PPP project features. Therefore, it is the requirement of projects to evaluate sustainable performance while keeping in view their long duration because such projects will develop uncertainties and risks in the overall mutual agreement of the partners [57]. Public–private partnerships are excellent arrangements which are used to develop infrastructure, social (social housing, hospitals, and prisons), and economic (bridges, highways, and motorways) projects around the globe [58]. The demand for public infrastructure is increasing with every passing day due to the rapid growth of the economy and urbanization of countries [59].

Infrastructure projects are important for the socio-economic development of any nation because of their assistance in the social setup and welfare of developed and developing countries [60]. Usually, it is the responsibility of governments to undertake infrastructure projects, but due to shortage of public capital and lack of management expertise, governments take an alternative approach, i.e., they incorporate the private sector in infrastructure projects via public–private partnerships (PPPs). The mechanism of PPPs promotes the engagement of the private sector in the process of infrastructure project development, including project proposals, financing, maintenance, construction, and operation. Currently, PPPs in infrastructure projects are increasing in developing countries [61]. Public–private partnerships gain success when the public and private sectors both cooperate with each other and develop mutual trust and interest instead of a hierarchical relationship [62].

In the last few decades, the growing numbers of PPP projects have attracted the attention of scholars in the field [63]. The PPP approach in infrastructure projects has been investigated differently by different scholars in different periods; studies on this subject include concessionaire determinants [64], risk allocation [65], relation governance [66], critical success factors [67], contract governance [63], and sustainability performance [68]. In all the approaches to PPPs discussed, a growing number of scholars have attributed the successful sustainability performance of PPPs to a trade-off among social, economic, and environmental performance criteria, which can be used to examine any PPP project [69].

The maintenance of sustainable performance is a very serious challenge for our future generations [70]. Infrastructure projects executed by the government through PPPs can be benefited from by all segments of society and are considered public projects, thus enhancing the value of sustainable development [71]. We also know that sustainable development principles are divided into a triple bottom line, namely, social, environmental, and economic frameworks, which address individual, corporation, and regional activities [72]. Studies on sustainability development have devised an appraisal system related to the sustainability of infrastructure projects. They have explored the barriers to a sustainable development system, as well as improvement factors for a sustainable development system. However, their focus has been on macro-level policies, and very little attention has been given to micro-level concerns [73]. Several scholars have discussed different facets of PPPs with regard to private sectors, but the sustainable behavior of PPP projects and influence of sustainability performance on infrastructure projects has received very limited attention in the literature [74]. This aspect also motivated us to study the sustainable performance of PPP projects, specifically concerning infrastructure projects.

2.4. Environmental Uncertainty as a Moderator

Problem-solving in PPP arrangement appears as a complex and multifaceted game in which stakeholders behave strategically and are guided by diversified rules and perceptions. Thus, decision-making and problem-solving in such volatile situations are dominated by environmental uncertainties. Scientific research, command and control mechanisms, and project management provide suitable responses to emerging environmental uncertainties, yet they require very sophisticated network analysis and network management to produce comprehensive recommendations. Conclusively, the environment is becoming more and more important for PPP projects [12]. Public–private partnership projects work in an unpredictable environment and deal with many issues emerging in their environment. They are part of a network in which they are dependent on other actors, they are unable to control their behavior, and they do not understand their complexity and therefore cannot predict the situation. Such an uncertain situation affects the project's performance. Therefore, a favorable regulatory mechanism is very important to deal with environmental uncertainty. A robust institutional framework, along with a framework to deal with environmental uncertainty, can provide sustainable and efficient PPP infrastructure projects [75]. Scholars of management sciences have emphasized variability and unpredictability in the outcome of projects, market demand, and development as the main factors underlying environmental uncertainty [76]. Therefore, environmental uncertainty is a complicated aspect that can emerge from different sources and can impact the relationship of input and output in different ways [77]. This includes the effect of environmental uncertainty on process activities, project team characteristics, and new product success. Researchers have found that environmental uncertainty has a moderating effect on innovative performance [78]. They have found that an unpredictable and uncertain environment is the reason for a lack of understanding of the logical linkages between inputs and outputs and cause-and-effect relationships linked with technical know-how [79]. In a highly uncertain environment, information and knowledge may not be transferred to partners properly and thus may lead to negative performance. In sum, the value of a cooperative network for innovation will decrease in a highly uncertain environment [80,81]. Similarly, Chin et al. [82] have determined an adverse moderating effect of environmental uncertainty on the relationship

between performance and external integration. Chin et al. [82] have also proposed and established a moderating effect of environmental uncertainty on business performance. According to Saeed et al. [83], uncertainty has a moderating effect on the relationship between project performance and an organization's innovation capability [83]. On the basis of the above discussion, the framework used in this study has been developed (see Figure 1).

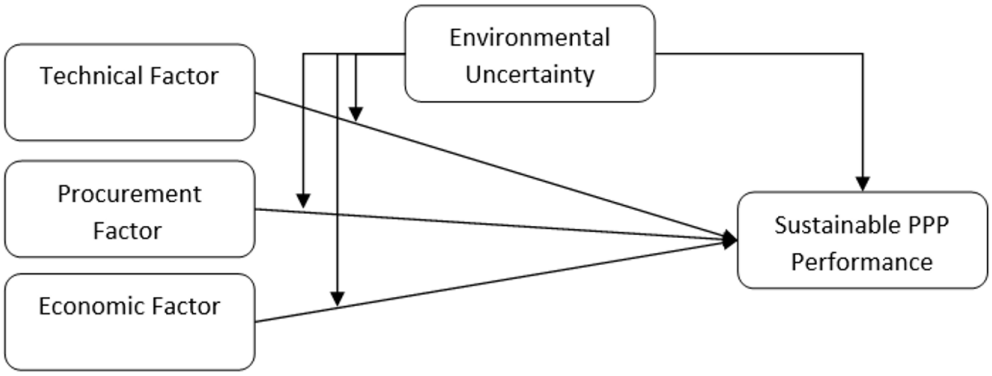

Figure 1. Theoretical framework.

2.5. Hypothesis Development

H1a. *There is a significant relationship between technical factors and sustainable PPPP performance.*

H1b. *There is a significant relationship between economic factors and sustainable PPPP performance.*

H1c. *There is a significant relationship between procurement factors and sustainable PPPP performance.*

H2a. *There is a significant moderating impact of environmental uncertainty on the relationship between technical factors and sustainable PPP performance.*

H2b. *There is a significant moderating impact of environmental uncertainty on the relationship between economic factors and sustainable PPP performance.*

H2c. *There is a significant moderating impact of environmental uncertainty on the relationship between procurement factors and sustainable PPP performance.*

3. Research Methods

3.1. Research Design

Research design is the overall plot developed by the researcher that describes the details of the research. Research design connects the theories and arguments that are the outcomes of research, as well as the collected empirical data [84]. Churchill believed that the direction of the collection and analysis of data in a specific study is ascertained from the research design [85]. The 'Research onion' approach explained by Saunders et al. [86] has been adopted in this study to enlighten the research design. The research onion is composed of six layers, encompassing all the tiers of research design: the research philosophy and approach are denoted by the outer layer, and the core layer includes the choice of methodology, time frame, techniques, and procedures. Positivist philosophy assumes that knowledge is independent of the subject being studied. A hypothetic deductive approach was used for hypothesis development. The strategy of this study was a survey. The choice of the method was single [86]. Surveys are considered the most effective and the most time- and cost-saving method for collecting primary data from a big population. Primary data, also called firsthand data, are collected for the first time at one point of time (i.e., cross-sectional data). The quantitative method was used in this research to investigate the relationship between critical success factors (CSFs) for public–private partnerships

and the sustainable performance of public–private partnership projects. Then, the moderating impact of environmental uncertainty was evaluated towards the attainment of sustainable public–private partnership performance. Moreover, this research investigates the relationship between variables. According to Creswell and Creswell [87], the most suitable design to study the relationship among variables is predictive and correlational quantitative research [87]. In this study, a cross-sectional study design was used to collect data concerning one point in time. This design can measure variations between individuals, subjects, or phenomena rather than the change process. A cross-sectional study design can use a survey method for data collection to find out the most interesting outcome because the sample is mostly collected from the complete population at one point in time. The nature of the data in this study was cross-sectional and primary data. Moreover, a deductive approach and positivist philosophy were used in this study [79]. Although the instrument used in this study was previously validated and used in developing countries, in our research, it was adapted, localized, and contextualized specifically for Pakistan. Adaptation is a process of considering the differences between the source and the target culture while maintaining an equivalence of meaning so that the instrument is completely understood. There are different methods to fulfill this requirement, including conceptual items, operational, measurement, and functional aspects [88]. In this study, an endeavor was made to take care of aspects including the items, concepts, and operational aspects of the instrument. The instrument was sent to thirteen (13) experts, including five (5) from companies undertaking PPP projects, three (3) consultants of PPP projects, and five (5) academics dealing with the discipline of project management. A few amendments (like syntax errors, rephrasing of two questions, etc.) were recommended by them and were incorporated into the instrument.

3.2. Study Setting, Population, and Sampling Technique

The population for this study includes people from the public and private sectors involved in public–private partnership projects. The public sector comprises the federal government and provincial government organizations dealing with public–private partnership projects. This includes the representation of the Pakistan Public–Private Partnership Authority (PPPA) at the federal and provincial levels, as well as registered companies with the Pakistan Engineering Council (PEC) that have undertaken public–private partnership construction projects and consultants for PPP projects working in Pakistan. In Pakistan, no exclusive website which can provide data for the population of PPP projects is available. The PPPA regulates PPP projects in Pakistan as the regulatory government authority; however, there are many firms/companies which act on behalf of private parties. The construction projects included in this study mostly involved infrastructure projects, and they fall under the jurisdiction of the National Highway Authority (NHA), so the NHA was also the regulatory body. Initially, most of the projects were undertaken by the Frontier Works Organization (FWO) as the private partner; these include projects like the Islamabad–Lahore Motorway, Hakla to Dera Ismail Khan Motorway, Lahore–Sialkot Motorway, etc. The FWO also sublets contracts to other contractors to undertake PPP projects in the country. Apart from this, the National Logistic Cell (NLC) construction company, Highway construction company, Habib construction company, China stat construction company, SKB Engineer and construction company, and Metric on (etc.) are a few examples of private partners in Pakistan. They are backed and supported by the Asian Development Bank, World Bank, or any local bank for specific PPP projects with specified terms and conditions. Apart from this, National Engineering Services Pakistan (NESPAK), Pakistan Engineering Services (PES), and many other firms and individuals work as consultants for PPP projects in Pakistan. Although all sample size calculation methods are very important and have their importance in research, researchers must choose one method to be applied in their research. Due to the objectives of this study, both generally and specifically to the analysis methodology, the non-probability convenience sampling technique was used. It allows researchers to collect data from respondents who are accessible and available and show

willingness to participate in the survey. The researchers used Krejcie and Morgan's [89] table to calculate the sample size. Based on the responses of the respondents, the sample size for this study is 394, which is sufficient and in line with all the sample calculation methods above.

3.3. Data Collection Instrument

The questionnaire comprised two sections: one was a demographic part and the other included items such as technical factors, economic factors, procurement factors, environmental uncertainty, and the sustainable performance of PPP projects with their attributes. Technical factors and procurement factors were measured with five items and economic factors with two items. Environmental uncertainty was measured with eight items and sustainable performance with five attributes; meeting design goals with four items; benefits to end user with five items; benefits to the private sector with eight items; benefits to the public sector with four items; and preparing for future with four items [55]. All items were measured on a Likert scale.

3.4. Data Collection Methods

Data were collected using an adapted questionnaire. Most data were collected personally and sometimes with the help of peers and researchers. In this regard, the officials of the PPPA were personally approached with references. Some information regarding organizations undertaking PPP projects was taken from the PPPA and these were further approached via the network method. Information was obtained from organizations undertaking PPP projects. Some information regarding experts was obtained from the PPPA and they were then approached to collect the data. In the same way, a questionnaire was sent online to the individuals in the PPPA, organizations undertaking PPP projects, and experts/consultants. Incomplete questionnaires were discarded. The data collection process was completed over a three-month span, from April to August 2021. The data collected was decoded in SPSS v25 and further underwent data cleaning.

3.5. Statistical Data Analysis: Tools and Techniques

For statistical analysis of the data, SPSS was used. For demographic information, descriptive statistics such as frequencies and percentages were used. To investigate the reliability and validity of the questionnaire, factor analysis was used, and to test the hypotheses, bivariate correlation and hierarchical multiple regressions were used. In the factor analysis, threshold values for factor loadings > 0.70, average variance extracted (AVE) > 0.50, and composite reliability (CR) > 0.70 were taken as cut-off levels, as given by Hair et al. [90]. For discriminant validity, the Fornell–Larcker criteria were used. Regarding the moderating effects and moderation graph, the Hayes process file was used. Hierarchical multiple regressions were used to test the moderation hypotheses. Variables were entered as per theoretical significance and importance. For moderation graphs, Aiken and West's [91] method of mean centering was used.

4. Results

4.1. Demographic Information

In this study, around 500 individuals were approached as part of the sampling strategy, i.e., snowball non-probability sampling. A total of 437× responses were obtained, of which 41× responses were incomplete. So, the remaining complete responses, i.e., 394, were used for the study purposes. Thus, in this study, the sample size was 394 (n = 394) and the sample comprised both the public and private sectors. There were 112 respondents from the public sector, which amounts to 28.4% of the sample size. Out of the 112 public sector respondents, 30 were from the central government, which amounts to 7.6% of the total sample and 26.8% of the public sector sample. There were 26 local government respondents, which is 6.6% of the total sample and 23.2% of the public sector sample. There were 56 respondents from public enterprise organizations, amounting to 14.2% of the total

sample and 50% of the public sector sample. There were 282 respondents from the private sector, i.e., 71.6% of the sample size. A total of 108 contractors, 56 consultants/advisors, and 118 operators/managers responded to this study, accounting for 27.4%, 14.2%, and 29.9% of the total sample and 38.3%, 19.9%, and 41.8% of the private sector sample, respectively of the total sample. The distribution of the industry experience of the respondents was as follows: there were 50 respondents with less than 5 years of experience, accounting for 12.7% of the total; 80 respondents, i.e., 20.3%, had between 6 and 10 years of industrial experience; 112 respondents, i.e., 28.4% of the total, had 11–15 years of experience; 91 respondents, i.e., 23.1%, had 15–20 years of experience; and 61 respondents, i.e., 15.5%, had more than 20 years of experience. We also visualized the data according to PPP experience. In this regard, the collected data explain that 46 respondents, i.e., 11.7% of the total sample, have undertaken only one PPP project; 130 respondents, i.e., 33%, have undertaken two PPP projects; 137 respondents, i.e., 34.8%, have undertaken three projects; 64 respondents, i.e., 16.2%, have completed four PPP projects; and 17 respondents, i.e., 4.3%, have completed five or more than five PPP projects (Table 2). From these findings, it is concluded that the majority of the respondents belong to the private sector and most of them are operators or managers, followed by contractors; on the other hand, from the public sector, the majority of respondents were from public enterprises, followed by central government respondents. Secondly, it is obvious that majority of the respondents have 11–15 years of industry experience, followed by those with 15–20 years of experience. Further analysis of results also reveals that the majority of the respondents have completed three projects, followed by those who have completed two projects, and 64 respondents have completed four projects. These findings bring the researchers to the conclusion that the respondents have vast experience in terms of their knowledge of PPP projects, either from the public or private sector.

Table 2. Demographic information.

Variable	Category	n	%
Public Sector	Central Govt	30	7.6
	Local Govt	26	6.6
	Public Enterprise	56	14.2
Private Sector	Contractors Only	108	27.4
	Consultant/Advisor	56	14.2
	Operator/Manager	118	29.9
Industrial Experience	5 Years and Below	50	12.7
	6–10 years	80	20.3
	11–15 Years	112	28.4
	15–20 Years	91	23.1
	20 Years and Above	61	15.5
PPP Project Experience	1 Project	46	11.7
	2 Projects	130	33
	3 Projects	137	34.8
	4 Projects	64	16.2
	5 Projects and Above	17	4.3
	Total	394	100

To investigate the reliability, convergent validity, and discriminant validity of the questionnaire, a measurement model was developed (See Tables 3 and 4). For this purpose, factor analysis was run. To achieve this objective, factor loadings, convergent validity (composite reliability and average variance extracted), and the Fornell–Larcker [92] criteria were assessed. For factor loadings, the acceptable value is 0.50, and for AVE, the recommended value is 0.50, but researchers such as Rasool [93] also accept 0.45 and above. For composite reliability, 0.70 and above is acceptable. Table 3 presents the findings of the CFA measurement model. The threshold for factor loadings is >0.50, and the ideal loading is >0.70; for composite reliability (CR), it is >0.70; for AVE > 0.50; and for Cronbach

alpha > 0.70 [90]. From Table 3, it is evident that all items of the constructs met the threshold, so it is assumed that scale used in the analysis is validated and reliable. It was concluded that the questionnaire fulfilled the criteria and the researchers could proceed to further analysis of the data.

Table 3. Confirmatory factor analysis.

Items	Factor Loading	CR	AVE	α
TF1	0.877	0.888	0.665	
TF2	0.831			
TF3	0.791			
TF4	0.757			
TF5	0.735			
PrF4	0.843	0.894	0.627	0.702
PrF3	0.798			
PrF2	0.783			
PrF1	0.772			
PrF5	0.760			
EF1	0.811	0.664	0.497	
EF2	0.590			
BPtS3	0.871	0.939	0.659	
BPtS4	0.857			
BPtS1	0.856			
BPtS2	0.836			
BPtS6	0.824			
BPtS5	0.812			
BPtS7	0.797			
BPtS8	0.612			
BEU3	0.831	0.904	0.654	0.849
BEU4	0.815			
BEU5	0.814			
BEU2	0.801			
BEU1	0.781			
BPbS1	0.885	0.917	0.735	
BPbS3	0.853			
BPbS4	0.849			
BPbS2	0.840			
PFF3	0.870	0.903	0.701	
PFF2	0.812			
PFF4	0.785			
PFF1	0.678			
EU2	0.885	0.914	0.579	0.899
EU3	0.869			
EU8	0.826			
EU6	0.799			
EU4	0.774			
EU1	0.725			
EU5	0.671			
EU7	0.448			

Note. TF: technical factor; EF: economic factor; PrF: procurement factor; BPtS: benefit to private sector; BPbS: benefit to public sector; BEU: benefit to end user; PFF: preparing for future; EU: environmental uncertainty.

Table 4. Fornell–Larcker discriminant validity criterion: correlation matrix.

	SPPPP	TF	EF	PrF
SPPPP	1			
TF	0.52	0.8154		
EF	0.343	0.25	0.708	
PrF	0.35	0.444	0.422	0.7918

4.2. Discriminant Validity

Discriminant validity was assessed by the Formell–Larcker criterion [92], which establishes discriminant validity among constructs in which the square root of each construct's AVE (Average Extracted Value) is higher than the uppermost correlation values with other constructs [92]. Table 4 presents the values of the Fornell–Larcker [92] criterion obtained, where the square root values of each construct's AVE are diagonally arranged in bold and the values of the correlations between constructs are tabulated off-diagonally. It is evident from Table 4 that all the values highlighted in bold are discriminated from each other; hence, discriminant validity following the Fornell–Larcker [92] criterion is established. As a result, based on the estimates, discriminant validity was established for each construct.

Thus, it was concluded that the model exhibited adequate levels of reliability and validity, suggesting that the quality of the model is robust and conducive to further evaluation.

The bivariate Pearson correlation test was used to test Hypotheses H1a, H1b, and H1c. The results in Table 5 indicate that there is a weak, positive, and significant relationship between TF and EF (0.250 **, $p < 0.01$); TF and PrF (0.444 **, $p < 0.01$); and TF and EU (0.149 **, $p < 0.01$); and moderate relationship between TF and SPPPP (0.520 **, $p < 0.01$). Further analysis of results reveals that there was a relationship between EF and PrF (0.422 **, $p < 0.01$); a negative weak and significant relationship was found between EF and EU (-0.102 *, $p < 0.05$); and a positive relationship was found between EF and SPPPP (0.343 **, $p < 0.01$). The relationship between PrF and EU is insignificant (-0.045, $p > 0.05$), but that between PrF and SPPPP is positive and significant (0.350 **, $p < 0.010$); the relationship between EU and SPPP is also significant (0.190 **, $p < 0.01$). It can be concluded that there are weak to moderate relationships between all the constructs. These relationships are mostly positive, which indicates that an increase or decrease in a predictor could possibly bring about an increase and decrease in the other variables (criterion variables). The negative sign shows the direction of the relationship; this indicates that an increase in EU could decrease the economic stability and procurement factors, while a decrease in EU could enhance the economic situation and procurement factors. Thus, it is concluded that there is positive and significant relationship between TF, EF, PrF, and SPPPP; therefore, all of H1a, H1b, and H1c are substantiated and accepted.

Table 5. Correlations between hypotheses H1a, H1b, and H1c.

Variables	1	2	3	4	5
1. TF	1				
2. EF	0.250 **	1			
3. PrF	0.444 **	0.422 **	1		
4. EU	0.149 **	−0.102 *	−0.045	1	
5. SPPPP	0.520 **	0.343 **	0.350 **	0.190 **	1

Note. * means relationship is significant at $p < 0.05$ level and ** means relationship is significant at $p < 0.01$ level. TF—technical factor; EF—economic factor; PrF—procurement factor; EU—environmental uncertainty; SPPPP—sustainable public public–private partnership project performance.

4.3. Moderating Impact of Environmental Uncertainty on the Relationship Between TF and SPPPP

This part was executed to test Hypothesis H2a, i.e., whether there is a significant moderating impact of environmental uncertainty (EU) on the relationship between the technical factor (TF) and sustainable PPP performance (SPPPP). The process macro file of Hayes [94] was used to test the moderating hypothesis. Table 6 presents the results of the moderating effects of environmental uncertainty on the relationship between TF and SPPPP. $R^2 = 0.3095$, i.e., TF and EU explain 30.95% of the variance in SPPPP. The goodness of fit, i.e., F value = 58.2629, is also significant at $p < 0.05$ level. As seen in Table 4, TF has a positive and significant effect on SPPP (0.8039 ***, $p < 0.05$); in addition, EU also has a positive and significant effect on EU (0.0836 ***, $p < 0.05$). Likewise, the interaction term (TF × EU) has a negative but significant effect on SPPPP (-0.2004 **, $p < 0.05$). $\Delta R^2 = 0.0265$ is significant at $p < 0.05$ level, with a goodness of fit F = 14.9862, also significant at $p < 0.05$.

This means that one unit change in TF could bring about 80.39% change in SPPPP and one unit change in EU could bring 8.36% change in SPPPP. After adding the interaction term, there is a negative pattern, which means that one percent increase in EU could bring about 20% negative change in TF and SPPPP and vice versa. The change in R^2 also confirms that TF, EU, and the interaction term could bring about 2.65% variance in SPPPP. Thus, we find support for hypothesis H2c. According to Preacher and Hayes [95], Hayes [96], Field [97], and Hair et al. [90], a change in R^2 with *p*-value significantly validates the moderation effect of the moderating variable.

Table 6. Moderation of the relationship between TF and SPPPP by EU.

D.V	I.V		R	R^2	F	β	SE	*t*	*p*	LLCI	ULCI
SPPPP	Constant		0.5563	0.3095	58.2629	5.8408	0.0473	123.5047	0.000	5.7478	5.9337
	TF					0.8039	0.0700	11.4806	0.000	0.6662	0.9416
	EU					0.0836	0.0370	2.2605	0.0243	0.0109	0.1564
	Int (TF × EU)					−0.2004	0.0518	−3.8712	0.0001	−0.3022	−0.0986
	R2-chng	F	df1	df2	*p*						
X × W	0.0265	14.9862	1.0000	390.0000	0.0001						

Note. SPPPP: sustainable public–private partnership performance; TF: technical factor; EU: environmental uncertainty.

Aiken and West's [91] method of plots was used. Figure 2 indicates that a low EU is steeper than a high EU, which implies that a low level of EU could uplift sustainable public–private partnership project performance more as compared to a high EU. Providing technical support by reducing EU could increase the success of PPP projects and their performance. Thus, we find support for the hypothesis which states that "there is a significant moderating impact of environmental uncertainty (EU) on the relationship between the technical factor (TF) and sustainable PPP performance (SPPPP)". Two-way interactions between technical factors (TFs) and environmental uncertainty (EU) with sustainable public–private partnership performance (SPPPP) were plotted one standard deviation above and below the mean, as shown in Figure 2. The blue line represents a low EU, while the orange line represents a high EU.

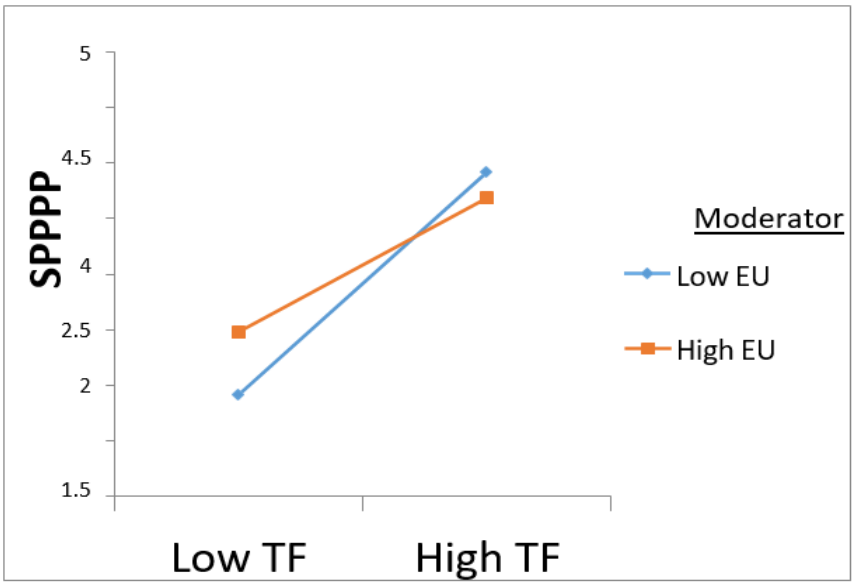

Figure 2. Moderating impact of EU on relationship between TF and SPPPP.

4.4. Moderating Impact of Environmental Uncertainty on the Relationship Between EF and SPPPP

This part was executed to test Hypothesis H2b, i.e., whether there is a significant moderating impact of environmental uncertainty (EU) on the relationship between the

economic factor (EF) and sustainable PPP performance (SPPPP). The process macro file of Hayes [86] was used to test the moderating hypothesis. Table 5 presents the results of the moderating effect of environmental uncertainty on the relationship between EF and SPPPP. R^2 = 0.2068, i.e., EF and EU explain 20.68% of the variance in SPPPP. The goodness of fit, i.e., F value = 33.8863, is also significant at $p < 0.05$ level. It is shown in Table 7 that EF has a positive and significant effect on SPPP (0.4568 ***, $p < 0.05$); in addition, EU also has a positive and significant effect on SPPPP (0.2055 ***, $p < 0.05$). Likewise, the interaction term (EF × EU) has a negative but significant effect on SPPPP (−0.1909 **, $p < 0.05$). Δ R^2 = 0.0379 is significant at the $p < 0.05$ level, with the goodness of fit F = 18.6563 also significant at $p < 0.05$. This means that a one percent change in economic factors could bring about 45.6% change in SPPPP, and one unit change in EU could bring about 20.5% change in SPPPP. When interaction was added, it explained 3.79% of the variance in SPPPP and led to a negative change in SPPPP. This means that when EU is high, SPPPP could be 19% lower, and vice versa. According to Preacher et al. [95], AHayes [96], Field [97], and Hair et al. [90], a change in R^2 with *p*-value significantly validates the moderation effect of the moderating variable. Thus, researchers find support for hypothesis H2b, which states that "there is a significant moderating impact of environmental uncertainty (EU) on the relationship between the economic factor (EF) and sustainable PPP performance (SPPPP)".

Table 7. Moderation of the relationship between EF and SPPPP by EU.

D.V	I.V	R	R^2	F	β	SE	*t*	*p*	LLCI	ULCI
SPPPP	Constant	0.4547	0.2068	33.8863	5.7912	0.0505	114.7468	0.000	5.6919	5.8904
	EF				0.4568	0.0537	8.5059	0.000	0.3512	0.5624
	EU				0.2055	0.0392	5.2388	0.000	0.1284	0.2826
	Int (EF × EU)				−0.1909	0.0442	−4.3193	0.0000	−0.2778	−0.1040
	R2-chng	F	df1	df2	*p*					
X × W	0.0379	18.6563	1.0000	390.00	0.0000					

Note. SPPPP: sustainable public–private partnership performance; EF: economic factor; EU: environmental uncertainty.

A two-way interaction graph between economic factors (EFs) and environmental uncertainty (EU) with sustainable public–private partnership performance (SPPPP) was plotted one standard deviation above and below the mean, as shown in Figure 3. A low EU possibly leads to high economic stability and more sustainable PPPP performance. The blue line is steeper than the orange line (high EU) and vice versa at 1 S.D above the mean, as moderation lines interact at 1 S.D above the mean with a high EF and high SPPPP. The blue line represents a low EU, while the orange line represents a high EU.

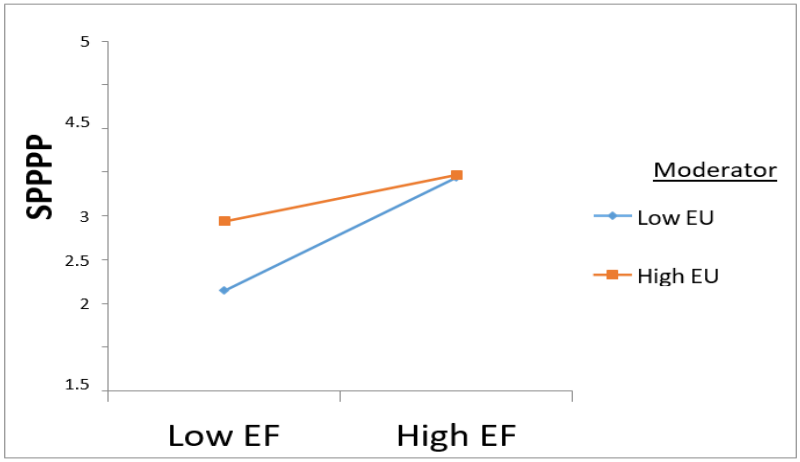

Figure 3. Moderating impact of EU on relationship between EF and SPPPP.

4.5. Moderating Impact of Environmental Uncertainty on the Relationship Between PrF and SPPPP

This part was executed to test Hypothesis H2c, i.e., whether there is a significant moderating impact of environmental uncertainty (EU) on the relationship between the procurement factor (PrF) and sustainable PPP performance (SPPPP). The process macro file of Hayes was used to test the moderating hypothesis. Table 6 presents the results of the moderating effect of environmental uncertainty on the relationship between PrF and SPPPP. R^2 = 0.1858, i.e., PrF and EU explain 18.58% of the variance in SPPPP. The goodness of fit, i.e., F value = 29.6696, is also significant at $p < 0.05$ level. As seen in Table 8, PrF has a positive and significant effect on SPPP (0.4901 ***, $p < 0.05$); in addition, EU also has a positive and significant effect on SPPPP (0.1807 ***, $p < 0.05$). Likewise, the interaction term (PrF × EU) has a negative but significant effect on SPPPP (−0.1481 **, $p < 0.05$). Δ R^2 = 0.0205, is found significant at $p < 0.05$ level, with the goodness of fit F = 9.8131 also significant at $p < 0.05$. A change in procurement and EU could change 49% and 18% of SPPPP, respectively. Moreover, one percent increase in EU could negatively affect SPPPP up to 14.81%. PrF and EU explain 2.05% of the change in SPPPP. Thus, we find support for hypothesis H2c.

Table 8. Moderation of relationship between PrF and SPPPP by EU.

D.V	I.V			R	R^2	F	β	SE	*t*	*p*	LLCI	ULCI
SPPPP	Constant			0.431	0.1858	29.669	5.8079	0.0509	114.1534	0.0000	5.7079	5.9079
	PrF						0.4901	0.0645	7.5969	0.0000	0.3632	0.6169
	EU						0.1807	0.0395	4.5719	0.0001	0.1030	0.2584
	Int (PrF × EU)						−0.1481	0.0473	−3.1326	0.0019	−0.2410	−0.0551
	ΔR^2	F	df1	df2				*p*				
X × W	0.0205	9.8131	1.0000	390.0000				0.0019				

Note. SPPPP: sustainable public–private partnership performance; PrF: procurement factor; EU: environmental uncertainty.

Two-way interactions between procurement factors (PrFs) and environmental uncertainty (EU) with sustainable public–private partnership performance (SPPPP) were plotted one standard deviation above and below the mean, as shown in Figure 4. The blueline represents a low EU, while the orange line represents a high EU. It is evident from the graph that the blue line, i.e., a low level of EU, results in high procurement and sustainable pppp performance at 1 S.D above the mean. When EU is high, SPPPP is low.

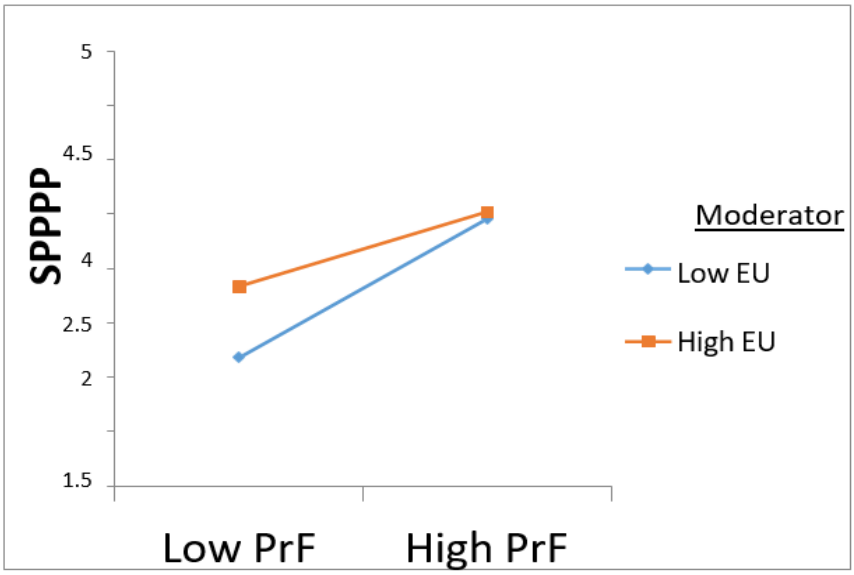

Figure 4. Moderating impact of EU on relationship between PrF and SPPPP.

5. General Conclusions from the Analysis of the Research Results

It is concluded from the findings that both respondents from public enterprises and private sector operators/managers participated in the survey. Further analysis of the results reveals that the majority of the respondents have 11–15 years of experience in PPPP and the majority have completed three projects. Factor analysis findings confirm the reliability and validity of the questionnaire. Furthermore, a weak to moderate relationship is found among the predictors and criteria. Environmental uncertainty significantly moderates the relationship between technical factors, economic factors, procurement factors, and sustainable public–private partnership project performance. Thus, this study significantly contributes to agency theory and offers valuable insights and contributions. All hypotheses are substantiated.

6. Discussion

The findings of this study have shown that critical success factors (CSFs) are significantly related to sustainable public–private partnership performance (SPPPP). The total variance explained by CSFs is 70.7%, which shows a good contribution towards the achievement of SPPPP. These results are in line with the results of [16,98]. Many other researchers, e.g., [94,99], have also discussed the contribution of CSFs to the achievement of project success by ranking these factors.

This study, along with others, has very successfully investigated the impact of CSFs on PPP projects, but the uniqueness of this study is that it has linked CSFs with sustainable public–private partnership project performance. As mentioned and explained in detail, the literature has plenty of critical success factors for project success. It is also very possible that CSFs in one country may not be considered CSFs in another country; therefore, researchers have tried to rank them so their contribution towards the success of projects may be accounted for. This study has identified a few CSFs and considers them important and relevant. They are attributable to the country dynamics, as these factors are most cited and mostly used in developing countries. Critical success factors are enablers of the successful conduct of projects; therefore, the more of these factors we make, the better performance we are likely to achieve. Therefore, we suggest that our policymakers and decision-makers investigate the betterment of the identified CSFs for sustainable public–private partnership projects in the country. In this study, the findings have proved that there is a significant relationship between technical factors and sustainable PPP performance. These findings align with the findings of [100], the authors of which worked on a project's success, proving that technical factors are very much required for project success. Technical factors are important factors that address the technical aspects of a PPP project. The aspects considered under technical factors, like indigenous technology, which is the native technology used by people, play a very important role in project success. The availability of labor is another aspect that plays a role in PPP project success, because labor, coupled with indigenous technology, can lead to project success. Technical factors have also been seen through the lens of well-organized regulatory authority and the availability of supporting infrastructure for transparency. All of these aspects undoubtedly lay the foundation for successful project performance. These factors comprehensively mark the technical factor as a critical success factor used in this study, and the outcome is a significant correlation with sustainable PPP project performance, which indicates that it is an important aspect that must be incorporated in planning and execution to obtain sustainable PPP projects.

This study has investigated the relationship between economic factors and sustainable public–private partnership project performance and found that they were significantly correlated. These findings are in line with the findings of [101], the authors of which also investigated this and concluded that economic factors play a very important role in project success. In this study, economic factors encompass the stability of the exchange rate and the stability of the interest rate [102]. The stability of exchange rates and interest rates plays an important role in the contractual arrangement of public–private partnership projects

agreements, thus impacting project success. Macroeconomic indicators are very crucial for project success [103]. We must keep in mind that stability in the interest rates and the exchange rate is a very important factor for any country. Policymakers must keep this aspect in mind, as good economic factors will lead to more sustainable public–private partnership project performance.

The relationship between procurement factors and sustainable PPP project performance was also found to be significantly correlated. These findings align with the investigation in [104], the authors of which investigated the relationship between procurement factors and project success, as well as PPP success. In this study, the procurement factor encompasses the level of understanding of public–private alliance transactions, the competitiveness of the bidding process, performance guarantee, political will in the public sector, and the availability of guarantee and stand-by financing. All these aspects mark the procurement factor for PPP projects. The procurement factor is a factor by which a project is adjudicated to the contractor and many facets concerning this factor can arise from the client side or the contractor side, or both. We can also view these issues from the lens of the public sector or private sector. Policy regarding procurement procedures plays a significant role in project success, as this analysis has found. Therefore, the procurement factor must be viewed as significant, as it has a significant role in sustainable public–private partnership project performance.

In this study, the moderating impact of EU on the significant relationship between economic factors and sustainable PPP project performance has been explored. This result also appeared significant. This significant result has proved that EU moderates the relationship, whereas the −ve beta value proves that the relationship direction has changed. Thus, the moderating effect of EU has been confirmed. The result of this study is in line with the findings of other studies, like [105,106], which have established that EU has a moderating impact on project success/performance.

In this study, the moderating impact of EU on the significant relationship between procurement factors and sustainable PPP project performance has been explored, and the this result appeared significant. This significant result has proved that EU moderates the relationship, whereas the −ve beta value proves that the relationship direction has changed. Thus, the moderating effect of EU is confirmed. The results of this study are in line with the findings of other studies, like [107] and [108], which have established that EU has a moderating impact on project success/performance.

This scope of the study was limited to formulating a framework for sustainable PPP performance by dealing with environmental uncertainty and incorporating this aspect into the research model. Although there are numerous impediments to the successful completion of any project, this study could only explore the impact of one factor, i.e., environmental uncertainty. These factors can be termed partnership pillars, as partnerships hinge on these pillars and use them to tackle the failures caused by, e.g., environmental uncertainty. The incorporation of partnership pillars is another limitation of this study, as there can be more partnership pillars. The research focused on an important national issue, i.e., PPP project practices in Pakistan. PPP practices remain country-specific practices, and therefore the framework produced in this research is Pakistan-specific, meaning that it is specific to the PPP units working in Pakistan. To be implemented in other countries, the presented framework may need some refinement, but it can be assumed that the framework would remain helpful in other developing countries. As the research is highly context-specific and the generalizability of the findings is not an aim, countries with similar contexts may implement whatever seems best to them. This study was conducted to formulate a framework for sustainable public–private partnership project performance. Critical success factors have been evaluated, and environmental uncertainty, which is a challenge to any project's success, has been incorporated to obtain sustainable PPP performance. This is a basic framework and can be utilized for sustainable PPP performance and can play its role in the PPP regime of any country.

6.1. Contribution to Body of Knowledge

This study provides a great insight into agency theory by tackling the agency problems of environmental uncertainty between the partners/agents. This study provides a deeper perspective on PPP project management by taking on board all the partners to deal with envisaged challenges for the successful application of PPP projects. This study provides a comprehensive framework for sustainable PPP projects in developing countries and thus sets a stage for policymakers to formulate policy recommendations relevant to PPPs. This study investigates the relationship between CSFs and sustainable PPP performance in developing countries and subsequently discusses the moderating effect of EU on this relationship to shed light on the factors involved in PPP failure. Then, this study explains the moderating impact of EU on the relationship between CSFs and sustainable PPP performance. This study highlights the importance of PPP projects to bring sustainability to any country.

Though the existing literature has provided a beginning point in the development of this study, the emphasis of this study is not only different from that of current studies but also supplements the present knowledge base on PPPs. This study provides substantial contributions to the current literature, which are as follows: Firstly, this study finds out the relationship between CSFs and sustainable PPP performance in the context of Pakistan. Secondly, the moderating impact of EU on this relationship is studied as a new contribution. This moderation or two-way interaction leads us to zoom in on the PPP agency problem as a means to tackle sustainable PPP performance. Lastly, this research also presents the partnership pillars for sustainable PPP projects. This study discusses the relationship of CSFs (technical factors, economic factors, and procurement factors) with sustainable PPP performance. This relationship can guide policymakers to maintain a favorable environment for successful PPP projects in the country. We can formulate a policy and framework to take measures to have more investment in projects of this kind that meet the highlighted requirements. This study also tests agency theory by discussing and empirically testing the agency problems of uncertainty, to bring sustainability to principal and agent relationships for better and sustainable performance.

6.2. Implications for Practitioners

This study is not only significant for academicians but also gives valuable insights for PPP project practitioners. The theoretical model can help practitioners to formulate strategies for sustainable PPP performance under the realm of environmental uncertainty, which persists in most developing countries. Thus, the theoretical model envisages achieving sustainable PPP performance by incorporating partnership pillars to neutralize the impact of EU. The outcomes of this study can be valuable regarding the formulation of policies and strategies to manage PPP projects to have better and sustainable PPP performance. Subsequently, the outcomes can be used by the Public–Private Partnership Authority (PPPA) as policy/strategy points in PPP projects for sustainable PPP performance.

6.3. Recommendations for Researchers/Areas of Future Research

This study's findings can be adopted by future researchers in the development of further areas of interest. They can provide a basis for upcoming studies on PPP performance and an empirical basis for sustainable PPP performance. The idea of trust and joint risk management to moderate the impact of environmental uncertainty can help researchers explore more factors involved in sustainable PPP performance. In this way, more partnership pillars may be added for more sustainable PPP performance. Researchers can also benefit from the contribution of an extensive body of knowledge to PPP studies by the mentioned relationship of CSFs and sustainable PPP performance as partnership pillars, along with the moderating impact of environmental uncertainty on that outcome. The findings of this study can lead a way forward to creating a favorable environment for PPP projects, as well as to maximizing the outcomes of these projects to bring sustainability to our homeland, as future projects will be dependent on successful PPPs.

7. Conclusions

In the realm of sustainable road construction projects in Pakistan, this study carves a niche by pinpointing and valuing the pivotal factors that catalyze and contribute to the successful positioning of PPP projects' sustainable performance. This study has served as an imperative resource for public and private sector stakeholders, equipping these parties with knowledge of enhancing sustainable performance through CSFs and by reducing EU and solving agency problems. Theoretically, this study has contributed by adding EU as a moderating intervening variable, but methodologically, the current study has implemented a robust quantitative framework to test agency theory, enhance sustainability, and identify CSFs. Public–private partnership projects play a key role in society's development, as well as in sustainable business performance. In recent years, uncertain events have influenced the sustainable performance of public–private partnership projects. What success factors enable sustainable PPP projects' performance, and which uncertain events need to be considered in implementing PPP projects? Studies have investigated the relationship between CSFs and sustainable performance [109], but limited studies exploring the moderating effect of uncertainty on CSFs and sustainable performance from Pakistan's perspective have been conducted. Six hypotheses were developed to investigate which factor has a more dominant role in the framework of uplifting sustainable performance by reducing uncertainty. The findings revealed that technical factors were the most dominating in the whole framework, followed by economic and then procurement factors. It was found that appropriate technical factors and technology would contribute the most towards obtaining economic benefits for public and private partners. Moreover, this study also helps in obtaining sustainable performance benefits for users, meeting design goals, and obtaining benefits for the public and private sectors as well. Businesses operating in certain environments want to obtain economic benefits, such as cost reduction, reduction in expenses, reducing pollution using advanced technology, and taking into consideration the procurement factor. Buying eco-friendly raw materials to produce user-friendly and eco-friendly products also helps enhance the sustainable performance of PPP projects. The findings also revealed a negative but significant moderation of EU. The negative sign shows the direction of the moderating effect; this implies that an increase in environmental uncertainty could reduce the relationship between CSFs and sustainability and vice versa by up to 20%, 19%, and 14%. On the contrary, if environmental uncertainty is reduced, it could impact that relationship in a positive way. Most studies, like [110–113], have worked to prioritize the impact of CSFs on PPP projects. The current study has validated the claim of [114], which has termed it an agency problem and declared it a factor that interferes with PPP project success, as well as with the PPP relationship.

The principal–agent theory is highly relevant to several problems that may arise in relationships between project participants. This finding addresses the concern of [115–118], which highlight that economic development and the sustainability of public–private partnership challenges may be used to tackle the agency problem for project success. This study has proved that once environmental uncertainty has deteriorated, the project performance between partners can tackle this challenge and the project may yield the required objectives. We can deduce that the EU behavior of firms in the framework is the most important factor keeping sustainable PPP performance intact. Thus, we can term it a "partnership pillar" in PPP projects. We have seen in research that these factors are pillars on which a partnership hinges and these pillars keep PPP projects intact and successful even in the presence of impediments, i.e., environmental uncertainty; thus, these pillars are very important to mitigating any negative impact on PPP project performance.

8. Implications of Study

PPPs are not a new concept, and their roots are very old, but the terminology was coined in the 1990s. In Pakistan, PPPs have grown in the last few years, and their authority, i.e., the Pakistan Public–Private Partnership Authority (PPPA), came into existence in 2019. Many PPP projects are in progress, but no basic framework exists in the country. This

framework can provide the basics to formulate PPP arrangements in industries like defense, infrastructure, health, etc. This study has highlighted different CSFs as enablers for PPPs and as mechanisms that mitigate the negative impact of challenges such as environmental uncertainty. This simple framework can provide a basis to establish a PPP relationship to undertake any project.

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Review

Critical Success Factors of Water and Power Public–Private Partnerships in Developing Countries: A Systematic Review

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Abstract: Public–private partnerships (PPP) have evolved as a choice of infrastructure procurement for numerous developing countries, particularly in the water and power sectors, thereby capturing the interest of researchers. A rich body of literature exists in the field of PPPs, as well as their critical success factors (CSF). Despite the valuable insights garnered from individual studies, a research gap exists in conducting a meta-synthesis of the findings from multiple developing countries and investigating the broader elements and themes of power and water PPP CSF research. This systematic review employed the PRISMA protocol and identified 30 records. We explored the regions, sectors, yearly output, adopted research methods, key authors, and themes of the corpus reviewed. The review recognised four emerging trends in the records, which are identifying, ranking, exploring the interrelationship, or utilising CSFs. The review identified the top 30 frequent CSFs in the corpus, as well as their ranking by importance across multiple settings. The review concludes by addressing geographic and methodological limitations and proposing directions for future research.

Keywords: public–private partnership; PPP; systematic review; literature review; critical success factor; infrastructure; power; water; developing countries

1. Introduction

Governments, especially in developing countries, lack the financial resources necessary to maintain existing and build new infrastructure facilities [1]. Additionally, there are issues of lack of transparency and low efficiency in the management of infrastructure projects by governments [2]. These factors give rise to poor or limited infrastructure development and warrant a need for alternative solutions other than traditional public spending based on taxation or natural resources. Hence, developing countries are increasingly shifting towards utilising private capital to fund infrastructure projects, with yearly private sector commitment reaching USD 91.7 billion across 263 projects in 2022 [3].

Public–private partnerships (PPP) are defined as

> "Sustained collaborative effort between the public sector and the private sector to achieve a common objective while both players pursue their own individual interests". [4]

> "Long-term contracts between the public and the private sectors in which all or a substantial part of the design, construction, operation, and financing are by the private sector" [5] (p. 3).

> "A mechanism for government to procure and implement public infrastructure and/or services using the resources and expertise of the private sector. Where governments are facing ageing or lack of infrastructure and require more efficient services, a partnership with the private sector can help foster new solutions and bring finance". [6]

> "A process whereby private management assumes an operational role in a public project via a long-term "concession" or lease-type contract with a public authority". [7]

Overall, the definitions emphasise the long-term, sustained contractual nature of PPPs, highlighting that a significant portion or entirety of a project's lifecycle—from design and construction to operation and financing—is undertaken by the private sector. The World Bank's definition focuses on PPPs as a solution primarily for countries grappling with infrastructure deficits that might inadvertently overshadow the broader utility and versatility of PPP models. While PPPs are indeed valuable for addressing infrastructure gaps, they are not exclusively confined to countries with ageing or lacking infrastructure. Many developed nations with robust infrastructure and ample capacity also engage in PPPs to enhance efficiency, innovate service delivery, leverage private sector expertise, and manage fiscal constraints effectively. The definition provided by Levy, while accurately capturing the operational aspect of PPPs through long-term contracts, falls short in encapsulating the comprehensive involvement of the private sector, which extends beyond mere management to encompass critical roles in financing, designing, constructing, and potential ownership stakes in the project. Yescombe and Farquharson's definition stands out as one of the best due to its comprehensive depiction of PPPs, effectively delineating the key parties involved, the extended contractual duration, and the broad spectrum of responsibilities entrusted to the private sector. By emphasising long-term contracts and the extensive involvement of the private sector across design, construction, operation, and financing aspects, this definition adeptly encapsulates the essence of PPPs concisely and inclusively. Recognising the merits of Yescombe and Farquharson's definition, this research article adopts it as the foundation for its analysis.

Different PPP sectors, such as power, water, health, transportation, social infrastructure, and security, reflect unique patterns and are better investigated individually; hence, this review adopted a sector-specific approach. The power–water nexus (P&W) is imperative to the development of a nation. Statistics reflect that P&W projects accumulated 65% of PPPs from 1995 to 2015 [8]. This nexus is fit to be analysed collectively as (a) multiple PPP projects are integrated or interdependent P&W plants; (b) P&W PPP projects have close execution mechanisms; and (c) P&W projects are both capacity-based PPPs; one can argue that transportation PPPs can be capacity based but power and water projects are far more similar in terms of the generation and distribution of the commodity and service.

Review Roadmap

This systematic review begins by establishing the concept of critical success factor, tracing its evolution and dispersion into PPP literature. Moving forward, the review details the methodology employed, including the research questions addressed and the PRISMA protocol utilised for filtering records. The exploration then extends to an in-depth examination of various dimensions within the corpus of literature, including geographical regions, industry sectors, annual publication output, research methodologies adopted, influential authors, and thematic trends. Notably, the review identifies and analyses four emerging trends within the literature: the identification, ranking, exploration of interrelationships, and the utilisation of CSFs. A pivotal aspect of the review is the identification and ranking of the top 30 most frequent CSFs, as well as their ranking by importance across multiple settings. This analytical depth enhances our understanding of the critical factors driving success in PPPs. The review concludes by revisiting the core contributions of the article and critically assessing the limitations inherent in the reviewed literature. Furthermore, the review provides a roadmap for future research, outlining potential avenues for addressing existing gaps and advancing the discourse on PPP CSFs in the power and water sectors.

2. Evolution of Critical Success Factors

The earliest notion of quantifying and deriving factors from success was in the field of management information systems by McKinsey and Co.'s consultants in 1961 as "suc-

cess factors" [9]. The concept later resurfaced as "critical success factors" in a paper by Rockart [10], who defined it as "things that must be done if a company is to be successful". Freund [11] then introduced characteristics to segregate it from other similar concepts in the field by stating that CSFs must be (a) crucial to achieving an objective(s), (b) assessable, (c) limited in number, and (d) applicable to peer entities. CSFs then dispersed to many fields such as IT [12–14] and project management [15–17]. In project management, CSF is defined as "elements in a project that are critical to the project achieving its mission or goal" [18]. The concept of CSF was adopted by leading project management bodies such as PMI and PRINCE2, which incorporated the concept into their curriculums [18,19].

Critical Success Factors in Public–Private Partnerships

With regards to PPP, the concept first sparked the attention of PPP researchers in 2005 [20,21]. The topic then gained traction and became a viable tool for investigating PPPs [22–25], becoming the backbone to multiple PPP assessment papers [26–29]. Researchers have published valuable reviews in the field of PPP, among which multiple reviews discussed PPP CSF including concession period CSFs [30] and transportation PPP CSFs [31,32], but there was no documented attempt to conduct a review on critical success factors of water and power PPPs in developing countries.

3. Review Methods

This paper aims to present a review of critical success factors in developing countries with a focus on infrastructure projects in the water and power sectors by addressing the following research questions:

MRQ: What are the most prevalent critical success factors of the implementation of power and water (P&W) PPPs in developing countries?

SRQ1: What research methods dominate P&W PPP CSF literature in developing countries? What are their geographic domains and who are the principal contributors?

SRQ2: What are the main themes and topics in P&W PPP CSF literature in developing countries?

SRQ3: What are the gaps and limitations of P&W PPP CSF literature in developing countries? And what are the recommendations for future research?

This literature review adopted a systematic literature review (SLR) approach to present a holistic review of the topic. Systematic literature reviews (a) employ a clear and transparent approach to retrieving and reviewing the literature; (b) adhere to a well-defined sequence of stages; and (c) are written in an updatable, replicable structure [33]. Although SLR can be rigorous and gradual, it excels in producing a holistic review of the body of literature as well as analysing primary research, methodologies, geography, themes, and multiple characteristics of the papers, aiding in articulating gaps in the literature, mythologies used, and geographic saturation [34–36].

3.1. Retrieving and Selecting Papers

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is a search protocol for conducting systematic reviews [37]. In Figure 1, PRISMA was utilised to retrieve literature. By following PRISMA, the reviewers can minimise selection bias when retrieving papers by following explicit identification, screening, and eligibility guidelines [38]. SCOPUS was utilised to search and retrieve articles due to being trusted and considered the standard search engine by PPP and PM researchers [39–41]. SCOPUS was also utilised in multiple PPP systematic reviews [34,42,43]. This Boolean phrase was used to conduct the search: (TITLE-ABS-KEY ("Public Private Partnership*" OR "Public-Private Partnership*" OR PPP) AND TITLE-ABS-KEY (CSF OR "Critical Success Factors").

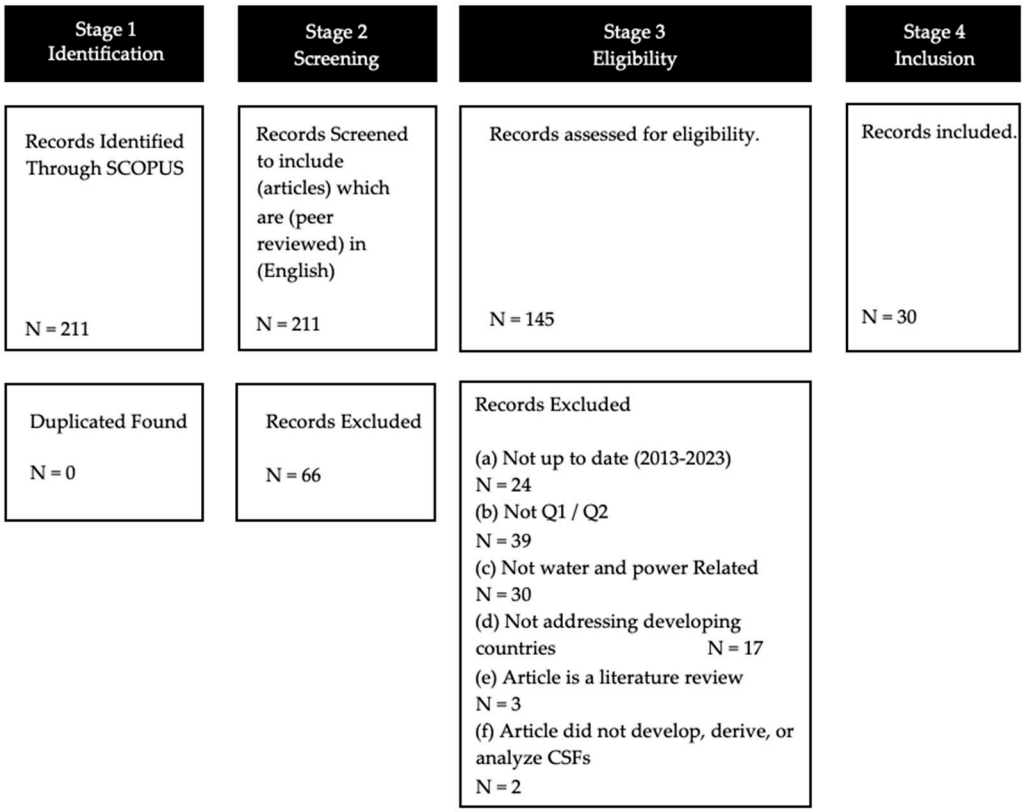

Figure 1. PRISMA review method.

Paper Filtering Stages

Stage 1: SCOPUS search (1) identified 207 papers; no duplicates were found.
Stage 2: SCOPUS toggle switches were used to (2) screen and filter "articles" that were "peer-reviewed" in "English" which reduced the papers to 144.
Stage 3: The papers were assessed for (3) eligibility by the reviewers with the aid of Rayyan AI, an AI tool deemed helpful by multiple researchers [44,45]. Exclusion criteria were developed through studying multiple PPP reviews and are as follows:

- The article is not up to date "2013–2022" [34,42,43];
- Article is not Q1 or Q2 [42];
- The article did not address the sectors of interest "Power and Water" [32,46];
- The article did not address developing countries;
- The article is a literature review;
- The article did not develop critical success factors or contribute to CSF PPP research [42].

Stage 4: A total of 30 articles were (4) included in the systematic review. The number of articles deemed adequate as multiple PPP systematic reviews investigated a close number of articles [34,46–48].

4. Literature Analysis

In this section, the reviewers analyse and discuss the literature through the lens of geography, sectors, research methods, and author contributions. Descriptive analysis aids in unveiling gaps beyond the ones existing in the body of literature (methodological, geographic, et cetera) through precise quantitative profiling, which helps define notable contributors in the field of interest.

4.1. Geography, Sectors, and Yearly Outputs

Countries were sorted by the World Bank countries and economies report [49]. Table 1. presents geographic, sectorial, and chronological profiles of reviewed articles. Ghana leads PPP CSF research, with 27% of the papers investigated. Researchers investigating Ghana tackle a wide array of topics, including public sector perception, country readiness, and PPP policy, as well as produced success prediction models, policy implementation strategies, and best practice frameworks. China comes second (20%), with a significant output in quantitative research, particularly in statistical tools to identify, rank, and measure the interrelationship of PPP CSFs using fuzzy logic, structural equations modelling, and indexation of success criteria. Third comes India, with three papers (10%) covering CSF identification, unsolicited CSF projects, and a case study on grid privatisation. A total of 90% of papers were country-specific, while 10% were not, out of which, two papers were directed towards developing countries in general while one paper focused on Latin America and the Caribbean. The review included power-and-water-specific literature along with general PPP CSF literature discussing power and water PPPs. As presented in Table 1, the majority of papers were non-sector specific. The review showed scarcity in power-focused PPP CSF research, with one power-focused paper.

Table 1. Geography, sector, and yearly output of the papers reviewed.

Country	Papers	Percentage	Sector	Papers
Ghana [1]	8	27%	General	21
China	6	20%	Water focused	7
India	3	10%	Power focused [2]	1
South Africa	2	7%		
Nigeria	2	7%	Year	Papers
Indonesia	2	7%	2013	1
Bosnia	1	3%	2014	1
Albania	1	3%	2015	3
Malaysia	1	3%	2016	5
Vietnam	1	3%	2017	3
			2018	4
Regional Papers			2019	4
Developing Countries	2	7%	2020	1
L. America and the Caribbean	1	3%	2021	5
			2022	1
Total	30	100%	2023	2

[1] Ghana and China dominated the reviewed CSF PPP papers. [2] The review reflected scarcity in power-focused PPP CSF research [50].

4.2. Adopted Research Methods of Reviewed Literature

In analysing the methodologies used in the literature, several key observations emerge from Table 2. Firstly, a predominant trend is the utilisation of quantitative research methodologies, aligning with the broader landscape of PPP literature reviews [34,42,43]. This emphasis on quantitative analysis underscores the growing significance of empirical data and statistical analysis in understanding CSFs within PPPs. Notably, China's pioneering role in employing quantitative research methods was observed, signifying regional leadership in adopting empirical approaches to investigate CSFs in PPPs.

Table 2. Descriptive statistics of research methods.

Research Method		Collection Method		Analysis Method	
Quantitative [1]	67%	Questionnaire survey	67%	Factor analysis/principal component analysis	31%
				Fuzzy logic	11%
				Structural equation modelling	17%
				Mean score analysis	19%
Mixed methods	17%	Interview	14%	Semi-structured	8%
				Delphi method	6%
Qualitative	17%	Case study	14%	SWOT/PESTLE analysis	3%
				Content analysis	11%
		Literature review	6%	Document analysis	6%

[1] Quantitative research dominated PPP CSF research.

4.3. Key Authors

To identify the key contributors in the field of critical success factors of public–private partnerships within developing countries, this systematic review utilised an Equation (1) formulated by Howard et al. [51] to calculate the contribution scores of various authors. The equation assumes a weighted distribution of contributions, where the first author is deemed to contribute the most, followed by subsequent authors with decreasing levels of contribution.

$$\frac{1.5^{n\ 1}}{\sum_{i\ 1}^{n} 1.5^{n\ 1}} \quad (1)$$

Howard's contribution score was deemed helpful by one PPP review [43]. However, it is crucial to acknowledge the limitations of the formula. First, the equation assumes a non-linear decrease in contribution with authorship order, which may not accurately reflect the actual distribution of contributions in all cases. Some authors might contribute equally or more substantially, regardless of their position in the author list. Secondly, the equation's parameters, such as the base value (1.5), might not be universally applicable and could introduce biases depending on the specific context or field of study.

Table 3 presents the authors who have made significant contributions based on their total number of papers, their calculated contribution scores, and their respective countries of affiliation. It is imperative to note that only authors with multiple contributions were included in this analysis. Robert Osei-Kyei emerges as the most prolific contributor with a total of six papers in this domain, reflecting a significant and consistent engagement with the topic, primarily focusing on policy, experts' opinions, and best practices. His contribution score of 6 underscores the depth and breadth of his influence in the papers produced, representing Australia. Albert P.C. Chan follows with a total of nine papers; however, his contribution score is calculated at 3.26. Albert played specific roles in the papers, contributing to distinct aspects or assuming specialised responsibilities; however, he was not the primary author or lead contributor in these works. Consequently, while his involvement in various capacities adds value to the papers, his contribution score is comparatively lower due to the weighted nature of authorship in which the lead author's contribution holds greater weight in the calculation. Authors such as Ernest Ameyaw (Hong Kong), Khotso Dithebe (South Africa), Lihong Liu and Chuan Chen (China), Clinton Aigbavboa, and Wellington Thwala (South Africa) have also made contributions to the field, albeit with a smaller number of papers and subsequently lower contribution scores. This analysis provides insight into the landscape of contributors within the P&W critical success factors of PPPs in developing countries, highlighting the varied levels of influence and engagement among the key authors identified, along with their diverse geographic

affiliations. This analysis provides insight into the landscape of contributors within the critical success factors of PPPs in developing countries, highlighting the varied levels of influence and engagement among the key authors identified, along with their diverse geographic affiliations.

Table 3. Contribution score of key authors.

Author	Total Output	Country	Institution	Total Citations	Contribution Score
Robert Osei-Kyei	6	Australia [1]	Western Sydney University	249	6
Albert P.C. Chan	9	Hong Kong [2]	Hong Kong Polytechnic University	326	3.26
Ernest Ameyaw	3	Hong Kong	Hong Kong Polytechnic University	171	1.19
Khotso Dithebe	2	South Africa	University of Johannesburg	13	0.8
Lihong Liu	2	China	Sichuan University	37	0.6
Chuan Chen	2	China	Sichuan University	3	0.58
Clinton Aigbavboa	2	South Africa	University of Johannesburg	13	0.54
Igor Martek	2	Australia	Deakin University	3	0.38
Wellington Thwala	2	South Africa	University of Johannesburg	13	0.35

[1] Authors affiliated with Australia stand out with the highest cumulative contribution score. [2] Authors from Hong Kong account for the highest paper count.

5. Discussion of Research Themes

In this review of PPP CSF literature, a corpus of 30 seminal papers was reviewed to distil insights into the critical success factors that underpin the efficacy of these collaborations. Our synthesis reveals a spectrum of approaches employed by scholars in unravelling PPP success. While a significant subset focuses on the identification of CSFs, others venture into ranking their importance through surveys, providing practitioners with strategic insights. Moreover, a subset of the literature explores the interrelationships between CSFs using advanced statistical techniques like factor analysis and structural equation modelling, unravelling the complex web of interactions within PPP ecosystems. Additionally, some scholars translate CSFs into frameworks and best practice models, not only enriching theoretical discourse but also offering actionable guidance for stakeholders involved in the planning, implementation, and evaluation of public–private partnerships.

5.1. Unveiling Success: Evaluating CSF Identification and Ranking Methods in PPP Literature

5.1.1. Identification of CSFs

A subset of the reviewed papers primarily focused on the identification of CSFs, seeking to delineate the key determinants that significantly influence the outcomes of PPPs. These studies lay the groundwork for understanding the fundamental components crucial to the success of collaborative endeavours between the public and private sectors.

A study by Osei-Kyei and Chan [25] explored the CSFs for the construction stage of PPPs in Ghana by analysing two successful projects. Five CSFs were identified, with implications for policy and practice. The research provided helpful data for policymakers and practitioners, but limited focus on two cases may affect broader applicability. Comparative analysis contributed valuable strategies for international private developers, aiding PPP practices. Another research with a cross-country perspective examined the CSFs in PPP projects in the context of Ghana as a developing country and Hong Kong as a developed country. The study highlighted the shared priorities, such as legal frameworks, while uncovering divergent phases of socio-political and organisational aspects to enrich the global PPP implementation framework [52]. A third study by Osei-Kyei et al. [53] compared a public sector view on PPP practices in Ghana and Hong Kong through semi-structured interviews. The study offered strategies useful for international private developers interested in PPP practices in Ghana and Hong Kong. Multiple CSFs were extracted from the interviews including capacity building and training, project viability, proper planning and good feasibility studies, international study tours, and organising courses and seminars.

Also, interviewees mentioned sensitisation programs as a factor for managing external stakeholders. The studies were limited in terms of interviewing experts from one developed country, Hong Kong, from which only 27 were surveyed and two experts were interviewed. The number and profile of experts may not fairly represent international experts, potentially impacting generalisability.

The articles [25,52–54] primarily focused on the identification of CSFs within the context of PPPs. However, it is noteworthy that these papers are characterised by an absence of ranking and in-depth analysis of the relative importance and impact of these identified CSFs. While these studies effectively enumerate the factors that are deemed critical in PPP projects, they fall short of providing a comprehensive assessment of their hierarchical significance, thus limiting the depth of insight into the relative weightage and interplay of these factors in the success of PPP initiatives.

Table 4 showcases the top 30 frequent CSFs identified in the papers reviewed. Papers were physically examined, and CSFs were extracted from each paper; table marking indicates that the CSFs were developed or used for analysis in the labelled article.

Numbered lists can be added as follows:

1. *Favourable legal framework* is the most frequent CSF in the papers reviewed. The frequency is evidenced by multiple sources. Findings highlight that effective implementation of PPP projects depends on having strong legal and regulatory structures in place [54,55]. Additionally, the European Bank for Reconstruction and Development Assessment supports this notion by indicating that PPP projects' success is reliant on a strong legal framework [56].
2. *Appropriate risk allocation* comes second in terms of frequency in the corpus; the criticality of this factor was demonstrated in Osei-Kyei and Chan's project success index, which weighed it at 0.353, emphasising its significant impact on project outcome [40]. Research suggests that challenges encountered in PPP projects stem from the diverse array of risks and uncertainties inherent in long-term PPP contracts [57]. Hence, the consortium should divest the exposure to the stakeholder best fit to manage each risk [58]. Moreover, knowledge management, PPP experience, and addressing project complexity may aid in mitigating uncertainty [59].
3. *Private sector capacity* comes third in this table. Sources indicate that financial [41,60], technical [61], and workforce capacity [62] are all crucial for successful PPPs. In developing nations, there is a significant dependence on foreign companies to overtake PPP projects. This reliance stems from the substantial capital and technical capability needed for PPP. Furthermore, local investors often lack the capacity to effectively compete with their foreign counterparts [52].

5.1.2. Ranking and Grouping of CSFs

Beyond identification, some researchers investigated the relative importance of identified CSFs. Through comprehensive surveys and expert opinions, these studies sought to elucidate the hierarchical significance of each factor, providing practitioners and policymakers with nuanced insights into where strategic emphasis may be most warranted.

Via international PPP experts' perceptions, one study identified success criteria such as risk management, time adherence, and long-term partnerships [63]. This research helped in advancing the understanding of the dimensions of PPP success by providing practitioners with essential benchmarks for evaluation. The findings emphasised seven very critical success criteria, offering insights for practitioners. The research employed surveys, but its response rate of 14% introduced the possibility of non-response bias, potentially affecting the representation of stakeholders' perceptions.

Table 4. Identified critical success factors of power and water public–private partnerships.

Criritcal Success Factors	Frequency	[23]	[24]	[25]	[39]	[40]	[41]	[50]	[52]	[53]	[54]	[55]	[57]	[58]	[59]	[60]	[61]	[63]	[64]	[65]	[66]	[67]	[68]	[69]	[70]	[71]	[72]	[73]	[74]	[75]
Favourable legal framework	21	x			x	x	x		x		x	x	x	x	x	x	x		x	x		x	x	x		x	x	x		x
Appropriate risk allocation	18	x			x	x			x		x		x	x	x	x		x		x		x	x	x		x	x		x	x
Private sector's Capability	16	x		x		x		x	x		x		x	x	x	x				x	x	x	x	x			x			
Public opinion	14	x		x		x	x		x			x			x	x		x				x	x			x		x		x
Stable macro-economic environment	14		x			x			x		x		x	x	x	x		x				x	x	x				x		x
Political support	14	x	x		x	x	x		x		x		x		x					x		x		x				x		x
Competitive bidding	14	x				x			x		x	x	x			x			x	x		x		x				x	x	x
Government administrative capabilities	13	x			x	x	x		x		x		x		x			x		x			x	x				x		
Profitability	13	x		x					x		x		x	x	x			x					x	x		x	x	x		
Government commitment	13		x			x			x		x	x		x	x	x				x		x		x			x	x		
Feasibility study and implementation plan	13					x	x		x	x	x		x	x		x				x		x		x			x		x	
Transparency	13				x	x			x		x	x	x			x	x			x		x		x			x			x
Clear cooperated departments	12	x			x		x					x	x	x	x	x			x	x		x	x							
Cost, time and quality management	12							x					x	x	x	x		x	x				x			x		x	x	x
Sound economic policy	11					x			x		x		x	x	x	x						x	x	x			x			
Standardization PPP procedure	10					x			x		x		x	x	x	x	x			x									x	
Clear project scope and documentation	10					x			x			x	x	x	x	x					x	x				x				
Available financial and capital market	9	x				x			x		x			x	x	x								x			x			
good governance	9				x			x				x	x	x										x	x	x			x	x
capacity building and training	9	x				x	x	x		x										x			x					x	x	
Technological innovation	9					x		x	x		x		x					x							x	x				x
The level of public recognition	8					x			x	x		x		x	x	x										x				
Open communication	8					x			x	x		x		x									x		x	x				
Public satisfaction	7						x							x	x			x		x							x		x		
Renegotiation and arbitration	7						x					x				x		x		x									x	x
Cost-benefit assessment	7				x						x			x		x						x		x					x	
The feasibility of operation mode	6					x										x		x					x				x		x	
Multi-benefit objectives	6								x				x	x								x		x						x
enviromental impact	6					x	x	x	x									x								x				
Government's financial support	6					x			x											x				x			x	x		

"x" indicates the occurance of the critical success factor and the relevant paper.

A study on Albania [41] extracted CSFs from the literature and utilised questionnaire surveys to rank factors that drive successful PPP implementation. Among these, project selection, financial capacity, trust and accountability, negotiation, and predictable revenue stream had the most weight. One interesting study [61] worked on transition economies; this study explored critical success factors for establishing sustainable PPPs. Like the previous studies, this research also used factor analysis. The study identified four CSFs, namely, a central PPP unit, a compatible legal/regulatory framework, national PPP policies, and standardisation/transparency. The paper contributed to PPP knowledge, but its applicability might be limited to transition economies. Another paper examined the unresolved issues in PPP by providing an in-depth analysis of motivations and success factors for such projects [64]. It is noteworthy to mention that the researcher used avoidable negative-worded questions in the survey; such questions may induce negativity bias which can compromise reliability scores and validation measures [76]. Another research by Wibowo and Alfen [65] explored government-led CSFs in PPP infrastructure development within the Indonesian context. They identified 30 CSFs through literature and assessed their importance, highlighting the underperformance of these factors in Indonesia. The authors employed weight gap analysis and the Holland and Copenhaver procedure to assess the importance and performance of these factors. The top five factors were "sound legal basis, irrevocable contract except through due process, sensible and manageable risk-sharing arrangement, clearly defined mechanisms of PPP needs, and strong political support". The paper provided valuable insights into Indonesia's PPP activities, which are relatively underrepresented in the literature. The research offered a practical and replicable approach for governments to assess and improve PPP-specific determinant factors, enhancing their practical relevance.

A study by Dithebe et al. [39] explored the critical success factors (CSFs) in water infrastructure projects delivered under PPPs in South Africa. In line with this research, another paper by Bao et al. [66] explored water PPPs in China. Both studies combined mean value analysis and confirmatory factor analysis to analyse CSFs, identifying the top factors influencing success and grouping the CFS into Component axes. Dithebe could benefit from Bao's approach of tackling a specific phase (transfer phase) and categorising CSFs into appropriate groups to generate more fruitful findings. The most important factors mentioned by Dithebe et al. [39] were "(1) Establish models for realistic projections on guaranteed revenue; (2) Thorough planning for project viability; (3) Show high level of transparency; (4) Legal framework stipulating policy continuity; (5) Use of new, improved, transparent, cost-effective and competitive procurement processes". Bao et al.'s [66] findings were "(1) contract system, (2) infrastructure, (3) transferred assets, (4) transfer acceptance criteria, and (5) overhaul information".

Multiple studies explored PPP projects through the lens of stakeholder engagement and perception. Babatunde et al. [24] and Sanni [58] both took Nigeria as a case in pursuit of unravelling CSFs through analysing the stakeholder viewpoints and CSFs of PPP projects in Nigeria using a multifaceted approach, including literature reviews, questionnaire surveys, and statistical analyses to shed light on the pivotal role of stakeholders' perceptions and factors determining success. Babatunde et al. used factor analysis to consolidate the factors derived from the literature into six main factors which are "reliable concession arrangement with due diligence; serious commitment with adequate technical strength; favourable economic environment; government support with enabling legislation; a bankable project with adequate stakeholders' involvement; and strong political will with committed private partners". Babatunde and other researchers aimed to identify CSF through multiple mediums such as literature review and case studies. However, most have neglected the attempt to validate the CSFs derived before testing for importance. Sanni attempted to fill the gap by validating the CSFs extracted from the literature through expert interviews. The researcher investigated the implementation of PPP projects in Nigeria, identifying critical factors influencing their success and developing a public and private sectors' success factors model for PPP projects using a rotated factor matrix. While both papers address

public sector and private sector stakeholders, the survey profiles of Babatunde et al. and Sanni are composed of 17.9% public sector and 82.1% private sector participants, and 73.9% public sector and 26.1% private sector participants, respectively. The parity in weight may question the validity of the results in terms of fair representation of stakeholders [24,58]. The papers are centred around the examination of PPP projects in specific countries, specifically focusing on success criteria, implementation practices, challenges, and their interactions with governmental roles. However, the narrow focus of the studies on specific countries and regions may restrict the broader relevance of its findings to PPP projects in other countries. Chou and Pramudawardhani [67] addressed this issue by highlighting the cross-country comparisons of key drivers, CSFs, and risk allocation preferences in PPP projects. This study differs from the above studies because it explores PPPs in multiple countries including Taiwan, Singapore, China, the United Kingdom, and Indonesia. This research contributed to the PPP literature by highlighting similarities and differences among these countries.

Overall, the existing literature showed a common thread of identifying and ranking CSFs in their exploration of critical success factors and challenges in PPP projects within developing countries. The strengths of these papers include their contributions to the understanding of PPPs and their potential to inform policy and practice. However, limitations such as sampling, geographical focus, and selection of experts should be considered when interpreting and applying their findings.

Table 5 showcases the top 5 CSFs of the 10 articles focusing on ranking PPP CSFs by importance. *Favourable legal framework* emerges as the paramount element with four appearances in Table 5. The observation supports the finding in Table 4, where this CSF was the most frequent in the literature. This consensus underscores the pivotal role of a conducive legal framework in the success of PPP initiatives. *Available financial market* comes second, appearing three times as various interpretations such as "*Favourable investment environment*" and "*Involvement of development banks and financial institutions*". PPPs can be funded via multiple channels. PPPs can seek bilateral or multilateral funding through a single institute or consortium of financiers, respectively. PPPs can also seek capital from debt markets through securitisation [29]. Hence, the presence and capacity of financiers within a country is key to successful PPPs, primarily due to the fundamental reliance of PPPs on private funding [41,68]. *Good governance* comes third, including synonyms such as "*effective leadership*" and "*effective management*". Research indicates governance is a principal element of PPP success and failure [69,70,77]. Wange et al. [71] further elaborated that good governance can mitigate societal and environmental stigma towards PPP.

Table 5. Ranking of critical success factors of public–private partnerships.

Papers	**[69]**	**[55]**	**[66]**	**[39]**	**[52]**
Themes/Ranking	**General PPPs**	**PPP Disputes**	**Transfer Phase**	**Water PPPs**	**Cross Country Comparison**
1	Good governance	Ensuring adequate project planning and control	Contract system	Establish models for realistic revenue projections	Favourable legal and regulatory framework
2	Commitment and responsibility of public and private sectors	Providing effective leadership	Transfer acceptance criteria	Thorough planning for project viability	Transparent PPP process
3	Favourable legal framework	Formulating appropriate strategies for the management of stakeholders	Acceptable assets	Show high level of transparency	Clarity of roles and responsibilities among parties
4	Sound economic policy	Confirming clear goals and objectives of the project	Transfer arrangement	Legal framework stipulating policy continuity	Political stability

Table 5. *Cont.*

Papers	**[69]**	**[55]**	**[66]**	**[39]**	**[52]**
Themes/Ranking	**General PPPs**	**PPP Disputes**	**Transfer Phase**	**Water PPPs**	**Cross Country Comparison**
5	Available financial market	Ensuring effective communication	Transferred assets	Transparent, cost-effective, and competitive procurement	Appropriate risk allocation and sharing
Papers	[61]	[24]	[64]	[70]	[63]
Themes/Ranking	**Transfer Phase**	**General PPPs**	**Unsolicited Projects**	**Relationship Management**	**International Experts Opinion**
1	Clear procedures for initiating PPPs	Transparency in the procurement process	Adequacy of legislation encourages private sector	Commitment and participation of senior executives	Effective risk management
2	Political/parliamentary support	Effective management control	The cost incurred by competing proposal	Defining the objectives of the RM strategy	Meeting output specifications
3	Establishing regional PPP offices	Good governance	Time for competing proposals	Integration of the different divisions of the organisation to meet RM objectives	Reliable and quality service operations
4	Involvement of development banks and financial institutions	Project economic viability	Fees to evaluate unsolicited proposals	Multidisciplinary team for implementation of the RM	Adherence to time
5	Central PPP unit has a knowledge centre	Favourable investment environment	Time to review USP proposals	Effective communication approaches among PPP parties	Satisfying the need for public facility/service

5.2. Beyond Isolation: Understanding the Interdependencies among Critical Success Factors in Public–Private Partnerships

A subset of the literature delved deeper into the interplay between identified CSFs. Employing sophisticated statistical techniques such as factor analysis and structural equation modelling, these studies endeavoured to unravel the intricate web of relationships among various success factors. This approach not only identifies individual elements but also sheds light on how these factors interact and influence one another within the complex PPP ecosystem.

One study explores the interrelationships among CSFs in PPP projects, focusing on the dynamics between public and private partners. Research revealed the subtle nature of their relationship and highlighted the inequalities in their responsibilities and resources [59]. Another study conducted in China investigated the CSFs of PPP project refinancing and uncovered pivotal factors such as asset quality and security design that drive the success of PPP asset-backed securitisation (PPP-ABS). The study resulted in a structural equation modelling web of inter-relationships of multiple factors reflecting a positive influence on PPP-ABS success. Findings provided valuable insight for investors and financial stakeholders [72]. Ameyaw et al. [73] investigated CSFs for attracting private sector participation in water supply projects in developing countries. They conducted a structured questionnaire survey of international PPP expert opinions, identifying key factors required to attract the private sector to water PPPs. The analysis revealed strong agreement among experts regarding the significance and rankings of CSFs, adding credibility to the findings. The study was confined to the water sector, limiting its applicability to other infrastructure areas. Moreover, the research primarily reflects the opinions of PPP experts, potentially overlooking the viewpoints of other stakeholders. Hai et al. [57] took a more comprehensive approach by identifying and assessing six primary clusters of CSFs, enhancing their applicability to various types of PPP infrastructure projects in developing countries. They formulated a theoretical structural equation model based on a review of prior studies and

an investigation involving 216 PPP infrastructure professionals and practitioners. While the study covers a wide range of CSFs, it does not delve deeply into sector-specific nuances.

Overall, the reviewed papers contributed valuable insights into CSFs and their interplay with PPP infrastructure projects, but they differ in their scopes, approaches, and contexts. Shi [59] tackled financial aspects, primarily PPP securitisation, whereas Ameyaw et al. [73] and Hai et al. [57] provided sector-specific insights.

5.3. Shaping Success: Examining the Utilisation of CSFs in PPPs

Taking an interventive turn, some scholars utilised the identified CSFs to construct comprehensive frameworks, best practice schemes, and success predictive models. These endeavours aim not only to enhance theoretical understanding but also to provide actionable insights for stakeholders engaged in planning, implementing, and evaluating public–private partnerships.

One of the existing studies gave a best practice framework for PPP implementation in Ghana's construction projects. By using a multi-stage analysis of critical success factors and some expert opinions, this framework addresses local context and standardises PPP practices [78]. Liu et al. [74] took a different approach to utilising CSFs of infrastructure PPPs. They proposed a life-cycle CSF framework with a project success and project management success perspective and a learning mechanism embedded within it. The primary objective of that research was to provide a comprehensive understanding of the factors critical to successfully implementing PPP projects and to enhance stakeholders' understanding of PPP contract strategy. Moreover, the paper primarily focuses on CSFs but provides insights into risk management embedded within the framework, which is a critical aspect of PPP project success. While the framework is valuable, it is not tailored to the unique challenges and contexts of developing countries, which may limit its applicability in such settings. Another paper by Munoz-Jofre et al. [75] introduced a selectivity index to evaluate PPP project feasibility in the urban water and sanitation sector in Latin America and the Caribbean. While the index offers a practical tool, the paper does not thoroughly explore potential challenges or limitations in applying the index. Additionally, the lack of explicit connections between the index and broader sustainability aspects of PPP projects raises questions about the tool's comprehensive utility. A study by Osei-Kyei and Chan [40] contributed significantly by developing a practical predictive model for PPP project success in a developing country, using Ghana as a case study. This model has practical implications for PPP practitioners in Ghana and similar regions. They emphasise the importance of government commitment, sound economic policy, and appropriate risk allocation as key predictors of success in Ghanaian PPP projects. The authors used a questionnaire survey with experienced PPP experts and employed regression analysis, ANOVA, and other statistical tests. The use of these rigorous statistical methods, including regression analysis and various tests, enhanced the validity and reliability of their model. Another study by Ameyaw and Chan [23] addressed the success factors for PPPs in the specific context of water supply projects in developing countries, making it highly relevant to the specific challenges in this sector. They derived 14 perceived CSFs from project cases and literature, establishing five critical success factor groups (CSFGs) through factor analysis. These five key CSFGs are the commitment of partners, strength of consortium, asset quality and social support, political environment, and national PPP unit. Their research aimed to provide a predictive tool for evaluating project success adds practical value and can aid decision-makers in assessing PPP viability. Collectively, this existing literature extends the discourse on PPP effectiveness to practitioners, researchers, and stakeholders by providing tools and frameworks aiding in achieving success in diverse PPP contexts.

6. Conclusions

This systematic review has provided insights into critical success factors within the realm of public–private partnerships, with a focus on literature published between 2013 and 2023 addressing water and power PPP projects. By adhering to the PRISMA protocol,

we systematically identified and analysed 30 pertinent articles, illuminating key trends and patterns in PPP research. Notably, our findings reveal scarcity in papers focused specifically on power PPP projects, which highlights a potential gap in the literature warranting further investigation. Methodologically, the prevalence of quantitative research methods among the reviewed papers reflects a predominant approach in examining CSFs within PPPs.

Numerous research papers exist which shed light on the critical success factors of public–private partnership projects. Within the realm of public–private partnerships, scholarly investigations exhibit a diverse array of approaches. Some researchers undertake the meticulous task of identifying critical success factors specific to PPP contexts, while others engage in quantitative analyses to rank these factors according to their perceived importance. Additionally, certain scholars delve into the realm of multivariate analysis to explore the complex interrelationships among CSFs. Concurrently, a subset of researchers applies CSFs as foundational elements to construct comprehensive frameworks, develop best practice models, and create predictive tools. These endeavours collectively contribute to a deeper understanding of PPP dynamics and offer practical insights for stakeholders involved in PPP planning, implementation, and evaluation. The findings collectively emphasise the multifaceted nature of PPP CSF research and underscore the need for continued scholarly inquiry and collaboration to advance our understanding of CSFs and enhance the efficacy of PPP implementation worldwide.

6.1. Research Gaps

It is noteworthy to mention that there is a common research limitation across these papers, notably,

- limited consideration of qualitative data and contextual nuances in developing countries, relying on quantitative and empirical methods may miss the deeper contextual understanding required for effective PPP implementation. In contrast, qualitative research methodologies can help in exploring the attitudes, perceptions, and behaviours of stakeholders that significantly influence decision-making processes. This is due to the nature of qualitative research, which tends to "discover (e.g., grounded theory), seek to understand (e.g., ethnography), explore a process (e.g., case study), describe the experiences (e.g., phenomenology), or report the stories (e.g., narrative research)" [79]. By employing qualitative approaches such as interviews, focus groups, and case studies, researchers can gain deeper insights into the contextual nuances within PPPs in developing countries, thus providing a more comprehensive understanding of the dynamics of PPP implementation.
- Research revealed that energy projects account for 52% of PPPs in developing countries [8]. The absence of power-focused studies in the corpus hampers the ability to fully explore the unique challenges and success factors inherent in power PPPs. Due to the paucity of research in this area, the generalisability of non-sector-specific PPP research findings may be nullified, particularly when attempting to apply insights to power-related PPPs. Each sector within the PPP domain presents its own set of complexities, ranging from regulatory frameworks to stakeholder dynamics and project delivery. Consequently, insights derived from non-sector-specific PPP research may overlook or inadequately address the requirements and considerations specific to power projects. For instance, while certain CSFs identified in generic PPP studies, such as "effective risk allocation" or "capacity building", may hold relevance across sectors, their implementation and effectiveness in the power sector could be vastly different due to the sector's unique characteristics and challenges.
- While there are valuable insights from the World Bank and development banks such as ISDB and CAF, there is a relatively low output of peer-reviewed journal articles on PPP CSFs in South America and the Middle East/North Africa regions, where the ten-year combined PPP commitments total to USD 300 billion. This poses challenges in achieving a comprehensive understanding of PPP dynamics globally. While PPPs are seeing uptake globally in developing countries, the patterns are not uniform; countries

endure different challenges in achieving PPP success. To illustrate, distressed countries may have issues with capacity building and securing funding, while resource-rich countries mainly struggle with policy failure and public rejection [80]. Regional disparities in research output may result in an imbalance in the representation of PPP experiences and challenges, potentially overlooking valuable insights and lessons learned from underrepresented regions.

Papers exhibit other limitations that may affect their applicability, robustness, and coherence. More representative sampling, clearer research gap justifications, deeper exploration of connections, and thorough discussions on limitations would strengthen the overall quality and impact of the research.

6.2. Path Forward

Future research can benefit from conducting ad hoc analyses on project implementations to test their adherence to critical success factors. By systematically examining the alignment between project outcomes and identified CSFs, researchers can offer valuable insights into the efficacy of these factors in predicting project success. Also, there exists a significant opportunity for scholars to leverage CSFs in the designing of training and development frameworks tailored for PPP practitioners. These frameworks could serve as structured guides for enhancing the capacity and competence of PPP stakeholders.

6.3. Limitations

It is crucial to acknowledge inherent limitations that may shape the review's scope and insights:

- The search parameters used following the PRISMA protocol may have inadvertently excluded valuable articles that could contribute to a comprehensive understanding of PPPs in developing countries.
- Merely addressing developing countries may have overlooked valuable insights and successful PPP experiences from developed countries, which could provide important comparative perspectives and lessons learned.
- The sole focus on critical success factors in the review may be considered a limitation, as future research could benefit from examining risk factors and failure factors as well. This broader perspective would offer a more complete understanding of PPP projects' dynamics and outcomes.

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Driving Factors of Concession Period in Healthcare Public Private Partnerships

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Abstract: Public Private Partnerships (PPPs) play a vital role in infrastructure development and public service delivery, with government entities collaborating with private sector organizations to achieve shared goals in the long term. An essential aspect of PPP contracts is the concession period, during which Special Purpose Vehicles (SPVs) are responsible for financing, building, operating, and maintaining public assets. The concession period has significant implications, associated with project risk, revenue, operations expenses, profitability, and bankability. While numerous studies focus on determining "optimal" concession periods, fewer explore the factors driving concession periods in national PPP programs, especially for social infrastructure projects relying primarily on availability payments. To fill this gap, this research aims to identify and analyze the effect of various potential factors on the length of the concession period, using linear regression analysis on a data set of healthcare PPP projects in Italy. This research theoretically contributes to understanding the driving factors of concession periods in PPP projects and provides insights for a balanced approach to PPP project planning and regulation and related strategies. On the practical side, decision makers can negotiate optimized concession periods, ensuring successful and sustainable public infrastructure projects.

Keywords: construction; risks; project delivery; capacity; public share; investment; decision making

1. Introduction

Public Private Partnerships (PPPs) are cooperative ventures between government entities and private sector organizations [1]. They involve a collaborative arrangement where both parties contribute resources, expertise, and capital to achieve public infrastructure projects and deliver public services [2]. In these projects, the private sector provides its expertise in handling the risks related to the construction and operations of these projects, while the public sector provides legal frameworks and, frequently, funding to carry out public projects [3]. PPPs are largely used for infrastructure development and service delivery in developed and developing countries [2].

An essential aspect of a PPP contract is the concession period, which refers to the time during which a business entity, namely, Special Purpose Vehicle (SPV), is responsible for financing, building, operating, and maintaining a public asset before transferring it back to the granting authority [4]. The duration of the concession period may span from 10 to 99 years, but usually lasts from 20 to 30 years. A typical concession duration is set as a fixed 30-year long period, such as in bridges, pay toll roads, and other transport infrastructures [5]. However, a reasonable length of the concession period must be determined and negotiated in order to compensate the SPV with an appropriate return on investment and risk taking [6]. A vast literature reports cases of PPP projects where the duration has

implications on the risk profile and financial viability, such as municipal buildings, urban infrastructures, and social facilities [7–9].

In fact, the concession period has several significant implications. Firstly, longer concession periods increase project-related uncertainties and risks, as economic, political, and social conditions can change over time, affecting the project's viability and regulatory environment [10]. Moreover, longer periods lead to higher Operational Expenses (OPEX) for the private partner due to maintenance, upgrades, and labor costs [11]. Additionally, longer concession periods prolong the payback period for private companies, impacting cash flow and financial viability [12]. Furthermore, longer durations may result in higher Capital Expenditures (CAPEX) during the construction phase to ensure long-term performance [2]. Longer concessions also may trigger detrimental impacts on public funding in the long term due to the longer payback periods for the SPVs [13]. Understanding the driving factors behind concession periods is then crucial for effectively regulating PPP contracts [14].

Although there are countless papers on models to determine "optimal" concession periods of PPP projects [4,11,13,15–17], far less attention has been devoted to understanding the determinants of the concession period based on evidence from projects conducted within national PPP programs. Moreover, the definition of an adequate concession period becomes more complex for social infrastructure PPPs, particularly under an availability payment mechanism. To contribute to addressing these gaps, this study conducts a statistical analysis of PPP projects to build or renovate Italian healthcare facilities in order to analyze the main factors that may influence the concession period of PPPs. This is expected to contribute to a better definition of the concession period, especially for social infrastructure that does not rely on user payments.

The paper is structured as follows. In Section 2, an overview of the current relevant literature on the concession period of PPP projects is presented. Moving on to the research methodology in Section 3, the main factors related to the concession period are identified and a model is proposed to establish their relationship. Section 4 includes the project data set and the results of the linear regression analysis. Empirical findings are discussed in Section 5, offering interpretations of the research results. Finally, the research conclusions are drawn, providing recommendations and outlining future research directions.

2. Conceptualization of PPP Concession Period

The concession period denotes the timeframe during which the concessionaires are entrusted with the responsibilities of financing, constructing, operating, and maintaining a public capital asset before its eventual transfer back to public authorities [13]. This temporal dimension assumes profound significance as it encapsulates several pivotal facets of the project.

Primarily, the concession period functions as an indicator of the protracted uncertainties inherent in the project. A protracted concession period augments the spectrum of uncertainties and risks associated with the undertaking [18]. Prolonging the partnership's duration extends the window within which various risks and uncertainties may manifest [17]. Economic, political, technological, and societal conditions can undergo substantial transformations over extended periods [15], thereby impacting the project's fiscal feasibility, demand forecasts, regulatory frameworks, and operational milieu. Effectively managing these uncertainties becomes increasingly challenging with the elongation of the concession period, potentially resulting in unforeseen expenditures, performance gaps, or disputes between the public and private stakeholders.

Moreover, protracted concession periods entail a lengthier provision of operational services, consequently yielding higher overall OPEX. As the partnership endures over an extended timeframe, the private partner assumes responsibility for the sustained maintenance and operation of the infrastructure or the continuous provision of services. Over time, operational outlays, including maintenance, repairs, upgrades, and labor costs, are prone to escalation due to factors such as inflation, evolving market dynamics, and aging

infrastructure [19]. Additionally, as the project evolves and technological advancements materialize, the private partner may necessitate investments in modernization or the adoption of emerging technologies, further amplifying operational expenditures [15].

Moreover, the concession period significantly affects the determination of the payback period of the SPV's investment. Longer concession periods result in a delayed payback period for the private companies involved and the private equity invested in the public project [11,12]. Extending the time frame for revenue generation may trigger multiple underperformances such as gradual project ramp-ups and lower accuracy in long-term demand [20–22]. Moreover, prolonging the payback period for the SPV impacts project cash flow and long-term public payments. From a public sector's perspective, longer concession periods mean a prolonged duration of public payments and an increase in long-term subsidies paid by the government because the project IRR is significantly higher than the public debt interest rate [2]. Additionally, during the concession period, the long-term public payments necessarily imply diverting funds from the public budget and potentially impacting other public expenses [23].

Furthermore, a longer concession period can further be detrimental as it can lead to a larger Capital Expenditure (CAPEX) in the construction phase. As the SPV takes the operation responsibility for a longer period, it may need to invest more upfront capital during the construction phase to ensure the infrastructure meets the expected standards and requirements for a larger concession period. This may involve additional spending on higher quality materials, enhanced design features, technological advancements, or future proofing measures [24]. While this approach aims to minimize the need for major upgrades or costly modifications in the later stages of the project, it also requires more upfront financial resources.

As a consequence, it is crucial to determine the driving factors for the concession periods of healthcare PPP projects. The first step towards this endeavor is analyzing the potential driving factors that influence the length of the concession period. Conducting a comprehensive analysis of these factors can help improve decision making, and enhance the performance and sustainability of PPP projects [25,26].

The interplay between project risk and concession period is intricate, dynamic, and profoundly influenced by the nature and magnitude of the associated risks [27]. These risks yield substantial influence over the economic feasibility of projects, alongside their capacity to allure investments and secure financing [4]. The rationale behind this lies in the potential for risks to precipitate substantial financial losses and obligations, consequently undermining the financial robustness of these projects and diminishing their attractiveness to investors and financiers [28].

The risk profile characterizing PPPs typically delineates the probability and potential consequences of events that could impact the project's cost, schedule, or performance during the concession period [29]. A multitude of factors can exert influence on the risk profile, encompassing technical intricacy, legal and regulatory prerequisites, market conditions, financial exigencies, and environmental hazards [17]. PPPs inherently bear a higher risk profile compared to conventional procurement methodologies due to their protracted engagement between the involved parties across multiple lifecycle phases, ranging from planning and design to construction and operations [30].

The concession period underpinning a project delineates its framework, incorporating the roles and obligations of the public and private counterparts with respect to elements such as financing, revenue, and risk [31]. The PPP business model necessitates meticulous design to ensure the project's fiscal viability and judicious allocation of risks [32].

The correlation between a PPP project's risk profile and its concession period is intricate. A heightened risk profile typically mandates a more substantial financial commitment from the private partner, consequently influencing the concession period. In essence, the private partner may demand a greater return on investment to offset the heightened risk, potentially resulting in longer concession periods [33]. Consequently, the business model must be artfully devised to strike an equilibrium between risk and return for both parties.

To mitigate the impact of risks on the PPP concession period, it is imperative to adopt suitable risk management strategies tailored to the precise nature and magnitude of these risks. This necessitates an exhaustive comprehension of the risks associated with specific infrastructure types, along with the technical, financial, and regulatory challenges they may pose. One approach to risk management in PPP projects involves the adoption of a risk-sharing business model, entailing the apportionment of risks and rewards between the public and private sector partners [34]. This approach ensures that both parties have a vested interest in the project's success and are incentivized to embrace optimal risk management practices. Another approach involves optimizing project design and development to enhance the economic viability of PPP projects without requiring an increase in the concession period, thereby diminishing financial risks and other prospective liabilities. The mitigation of these risks further augments the social and environmental sustainability of PPPs [35].

3. Research Methodology

This paper presents an analysis of the various factors influencing the concession period in PPP projects. To achieve this, the first step is to identify a set of potential variables that could serve as influencing factors in the model. Subsequently, a statistical analysis method is employed to measure the effect of the chosen factors and their relationship with the concession period.

The analytical process unfolds in several distinct steps. The initial phase involves the meticulous identification of a set of potential variables that could serve as influential factors within the model. These variables are carefully chosen to encompass a broad spectrum of potential influencers on the concession period, taking into account past research and practical considerations. Once the potential variables were identified, data from real cases were gathered. To collect data on healthcare PPP cases, a triangulation approach was employed, drawing information from diverse sources including scientific literature, public databases, Italian newsletters, and direct access to the contracts of some PPP projects. A total of 28 healthcare PPPs initiated in 2004, with a total value of EUR 3.2 billion, were considered for analysis. Finally, a statistical regression analysis was conducted to identify significant drivers of PPP outcomes. This statistical technique enables the testing of the influence of independent variables on the chosen dependent variable, the concession period. It is worth noting that the correlation among the independent variables is closely examined to ensure that there are no collinearities among them.

3.1. Driving Factors for the Risk Model

This section presents the potential driving factors that may significantly influence the concession period of PPP contracts. The chosen variables include project investment size, project construction scale, project capacity, project normalized cost, public share, public experience, SPV size, and catchment population. Table 1 provides an overview of these factors.

Table 1. Potential factors influencing the concession period.

Independent Variables	Quantifiable Parameter	Acronym
Investment Size	(Total Investment in EUR m)	InS
Project Construction Scale	(Construction period in years)	CoP
Project Capacity	(Hospital capacity as in No. of beds)	HoC
Normalized Cost	(Cost per bed)	CPB
Public Share	(percentage of Investment)	PSh
Public Experience	(year of contract award)	YCA
SPV Size	(No. of equity holders)	NoEH
Catchment Population	(No. of people in the served province)	CPop

The first variable considered is the overall investment size of PPP projects, which represents the total initial investment required to build or renovate the healthcare facility. It encompasses the sum of Public Financing, Private Debt, and Equity contributed by the SPV undertaking the project. Current practice and extant literature require considering the size of the project investment when estimating the concession period [36]. Similarly, construction costs have been considered in previous research as a potential factor affecting the concession period [13,16].

The project construction scale, represented by the duration of the construction period, is another potential factor indicating the complexity and scale of the overall project [37]. Multiple studies have previously used the construction period as an indicator of project complexity and its impact on the concession period [13,17,38]. On the one hand, larger projects with longer duration of construction may be expected to be positively related to the concession period. Conversely, extant research also supports larger public projects can benefit from greater economies of scale, and, consequently, higher potential revenues that may result in shorter concession periods [39].

The capacity of the healthcare PPP projects is also considered for the analysis, reflecting the number of patients the hospital can treat at a given time. Higher capacity could potentially generate higher revenue for the SPV over time. Literature highlights the importance of revenues and related uncertainties as determinants of concession periods [16]. Previous studies have also considered hospital capacity as a potential factor, though primarily focusing on public finance and project performance parameters [39–41].

The normalized cost per bed is another factor considered to incorporate the investment made for each patient that can be simultaneously treated in the hospital. This factor could indicate the intensity of the investment and identify specialized facilities with particular complexities or risks. This parameter has been utilized in studies of toll road PPP projects to account for the project's normalized cost [42,43].

Moreover, the public share, representing the proportion of the initial project investment paid directly through public subsidies, is another significant factor. Several studies have attempted to use public financing and government subsidies as a determinant of the concession period [4,36,44]. A balance between the level of government subsidies provided and risks borne by the private sector is crucial to the concession period [4].

The year of contract award, serving as a proxy for the experience of the public authorities in regulating and carrying out PPP projects, is another factor considered. Moreover, as time passes, the PPP-enabling legislation is enhanced, in particular for Italy. The last legislation in this regard is the Italian Legislative for Public-Private Partnerships, which came into effect in 2016. The effect of increased public experience in PPP projects has been pointed out in previous studies [45]. Previous research has pointed out how public authorities focused primarily on utilizing private financing sources rather than adopting a value-for-money approach in PPPs procured decades ago, which resulted in imbalanced profit gains by the private sector in those projects [14]. Public and private sector experience in PPP undertakings has also been pointed out as an important factor [39]. It is expected that the more recent the contract award, the better the experience and capacities of the public sector in managing PPPs.

Furthermore, the size of the SPV participating in the PPP project is considered another potential factor that could affect the concession period. A higher number of companies and stakeholders in the SPV may indicate a stronger capacity to deal with project tasks. Previous studies have considered the SPV size as a potential contributor to the project risk [46]. However, a large number of partners in the SPV could be the result of higher perception of risk and complexity of the project. A large number of partners in the SPV might also increase the occurrence of contractual and management issues [47].

Finally, the Catchment Population is added to the analysis. It represents the number of people the hospital or facility must serve in a given area or province. The catchment population has been used as an influencing variable for project outcomes in previous stud-

ies [40]. Additionally, a higher Catchment Population may impact the project's profitability, and thus can be considered to assess its potential influence on the PPP Concession Period.

Before proceeding with the statistical analysis, it is crucial to convert the identified independent variables into quantifiable parameters. A summary of these parameters is provided in Table 1.

Regarding the investment size, the total initial investment of the project is considered, as recommended by previous studies [17,36]. The project construction scale is measured by the construction period, defined as the number of years between the financial closure and the beginning of operations [40]. For the hospital capacity, the number of beds in the facility is considered, following the recommendations of previous research [39,41]. The independent variable of project normalized cost is quantified by dividing the capital investment by the number of beds. To determine the public share, the overall percentage of project investment covered by the public sector is considered [12,39]. The size of the SPV is quantified by the number of equity holders participating in the SPV, as recommended by past research [48]. For the catchment population, the number of inhabitants in the province where the facility is located is used as a parameter, as previously considered in extant literature [40].

Public experience is represented by the year of contract award, indicating when the PPP project was awarded to the SPV. The rationale behind using the "year of contract award" as a metric for public experience is rooted in the assumption that public authorities' knowledge and proficiency in handling PPPs have likely evolved and improved over time. Over the years, governments and public entities have gained valuable experience in structuring, negotiating, and managing these complex partnerships. This experience has been accumulated through trial and error, learning from past projects, and adapting to changing economic and legal environments. When governments first began engaging in PPPs, they often faced challenges related to project design, risk allocation, and contract negotiation. These early experiences highlighted the need for continuous improvement and learning, which grows as time passes. As a result, public authorities have become more adept at addressing the intricacies of PPP agreements. PPP legal and regulatory frameworks are enhanced over time as a result of a deeper understanding of best practices and lessons learned from earlier projects. Regulatory improvements often translate into more effective governance and oversight of PPPs, contributing to better outcomes and a more mature PPP market. As governments increasingly turn to private sector partners to deliver public infrastructure, the industry responds with innovative solutions and standardized practices that improve as time passes. This evolution has encouraged both public and private parties to adopt more sophisticated approaches to project development. Experience has also sharpened the decision-making abilities of public authorities who are now better equipped to assess the suitability of a project for the PPP model, determine risk-sharing arrangements, and evaluate potential private sector partners. This enhanced decision-making process can lead to more successful project outcomes.

3.2. Data Collection

To gather data regarding healthcare PPP cases, multiple sources were triangulated. The information regarding the business case of PPP hospital projects was complemented and refined through the analysis and comparison of multiple sources. These sources included scientific literature, public databases, Italian newsletters, and direct access to the contract of some PPP projects, facilitated by the involvement of the authors in those projects.

One of the authors acted as a consultant to the Regional Government Evaluation Board of PPPs and could collect first-hand data from the main contract documents of 13 PPPs. Complementary, 15 additional projects were gathered through a comprehensive content analysis of public databases and scientific literature related to PPPs and concession periods. The literature search included the following keywords: *PPP, Public Private Partnership, Build Operate Transfer, BOT, private finance initiative, health care project, hospital project, PFI,* and *concession period.* The search was focused on papers related to Italian cases spanning

from the year 2003 to 2023. From the resulting papers, the authors screened and analyzed PPP projects specifically related to healthcare to gather data on the business cases of these projects.

For the purposes of this paper, the selected healthcare cases are a set of 28 PPPs initiated in the year 2004, with a total value of EUR 3.2 billion. Most of these projects are already in the operation phase, while a few are scheduled to begin construction in the year following the time of writing this paper.

Having established the model and with access to the data set of the PPP healthcare projects, Table 2 provides a summary of the Italian healthcare PPP projects and the statistical distribution of the corresponding independent parameters, which are hypothesized to influence the concession period. The table includes the lower, median, and upper quartiles of the data, along with the corresponding standard deviation.

Table 2. Healthcare projects database summary table.

Variables	Acronym	Lower Quartile	Median	Upper Quartile	Standard Deviation
Investment Size (EUR m)	InS	74.48	113.95	137.43	84.85
Project Construction (years)	CoP	2.15	2.90	5.00	2.15
Project Capacity	HoC	403	545	670	369
Cost/No. of beds	CPB	0.16	0.21	0.28	0.15
Public Share	PSh	0.30	0.58	0.63	0.21
Public Experience	YCA	2005	2007	2012	7
No. of equity holders	NoEH	1.0	1.0	2.3	2.3
Catchment Population	Cpop	539,849	768,112	972,223	979,950
Concession Period (Dependent Variable)	CcP	23.45	25.00	27.53	4.73

3.3. Data Analysis

In the model, the Concession Period (CcP) is the response variable, representing the number of years during which the SPV is responsible for operating the project.

To identify the significant parameters among those considered, a linear regression test was conducted, which is a widely-used method in literature for identifying significant drivers of PPP outcomes [39,40,46,48]. Linear regression analysis makes it possible to statistically test the influence of independent variables on the chosen dependent variable and reveals positive or negative relationships between them [46]. SPSS was used as the analytical tool to conduct the regression test.

In this type of analysis, a positive correlation implies that variations in the independent variable result in corresponding changes in the dependent variable in the same direction. Conversely, a negative correlation indicates that changes in the independent variable lead to opposite changes in the dependent variable.

It must be noted that the correlation among the independent variables must be checked to check that there are no collinearities among them. This can be achieved by calculating a Variance Inflation Factor (VIF) for each of the independent variables. The absence of multicollinearity can be guaranteed if the VIF value is low. Variables with high VIF values, indicating unacceptable levels of collinearity, must be excluded from the regression analysis.

4. Results

An exploratory analysis is first carried out in order to verify the reliability of the independent variables and to check for any multicollinearities between them. Table 3 shows the analysis results based on the mentioned database by considering all the independent variables.

Table 3. Results of linear regression analysis.

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	1483.407	379.5283251		3.908554125	0.001029602		
InS	0.037052089	0.013344793	0.65331123	2.776520343	***0.012446879*** *	0.435328977	2.297113341
CoP	−0.475024682	0.434383267	−0.215499708	−1.09356119	0.288566863	0.620653074	1.611206071
HoC	−0.003344215	0.003213619	−0.263530698	−1.04063819	0.311820377	0.375831516	2.660766744
PSh	−11.23263105	4.044398631	−0.493593652	−2.77733035	***0.012425336*** *	0.76308348	1.31047261
YCA	−0.725099131	0.188557994	−0.923808985	−3.84549664	***0.001184946*** *	0.417634735	2.394436851
NoEH	1.015433233	0.44582713	0.518731326	2.27763894	***0.035182352*** *	0.464666015	2.152083363
CPop	1.67244×10^{-6}	7.9337×10^{-7}	0.359741649	2.108020978	***0.049308904*** *	0.827607691	1.208301967

Note: * Italic bold shows significant *p*-factors less than 0.05, pointing to the reliability of the variables.

In order for the results to be valid, the significant *p*-factor must be of a certain value, which would, in turn, show the reliability of the independent variable in question. A mean value of 0.05 was chosen as the benchmark for the significant factors. In addition, a multicollinearity analysis is carried out in parallel to make sure that the dependent variables are not overly affecting each other. This is carried out by calculating a Variance Inflation Factor (VIF). Ideally, this value would be between 1 and 5 so that we are able to reject multicollinearity.

A first analysis was conducted, indicating that the variable of CPB has a VIF value of more than 5, indicating the existence of multicollinearity between CPB and other variables, resulting in its removal.

The results of the analysis are given in Table 3. In essence, the regression assesses the relationships between the Concession Period (CcP) and multiple independent variables. It can indeed be observed that the removal of CPB has had a positive impact on the reliability of the other independent variables. Moreover, variables of InS, PSh, YCA, NoEH, and CPop have shown significant *p*-factors that render their influence on the dependent variable a reliable one, while CoP and HoC do not show to have a noteworthy influence on the PPP Concession Period. Also, there are no longer any multicollinearities among the remaining variables, and all VIF values are under 4 as recommended by previous sources [46], indicating that the dependent variables are not overly affecting each other. Consequently, the result of the regression analysis performed can be expressed as:

$$\mathrm{CcP} = 1483.41 + 0.04\mathrm{InS} - 11.23\mathrm{PSh} - 0.73\mathrm{YCA} + 1.02\mathrm{NoEH} + 1.67 \times 10^{-7}\mathrm{CPop} \quad (1)$$

In order to validate the results of the analysis, some tests on the regression residuals were conducted. The histogram of the residuals resembles a normal curve, thus demonstrating the normality of the data set (Figure 1). The normal probability plot shows that the residuals are normally distributed, and they generally follow a straight line with few significant outliers (Figure 2). In addition, the residuals versus fits test (Figure 3) does not show evidence of systematic error in the residuals of the regression. Finally, the residuals versus orders test (Figure 4) shows no indication of the presence of trends, time series, or periodicity.

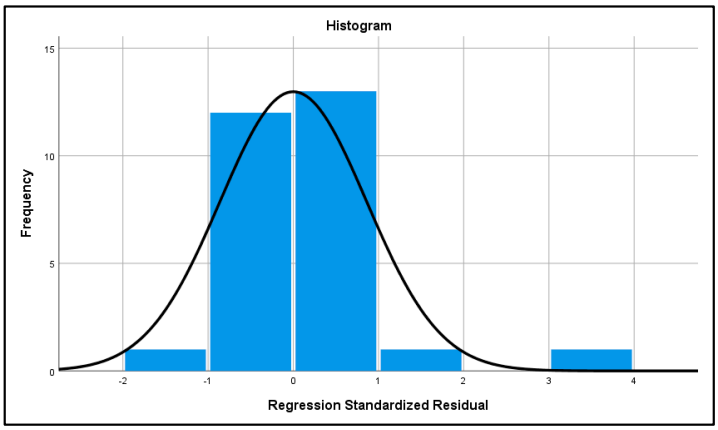

Figure 1. Histogram of residuals.

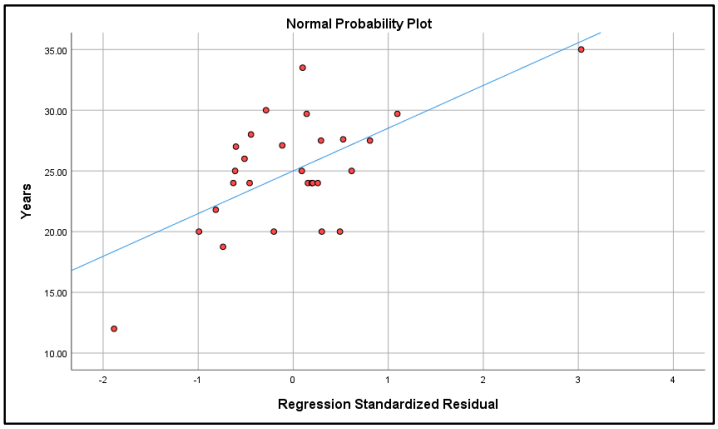

Figure 2. Normal probability plot of residuals.

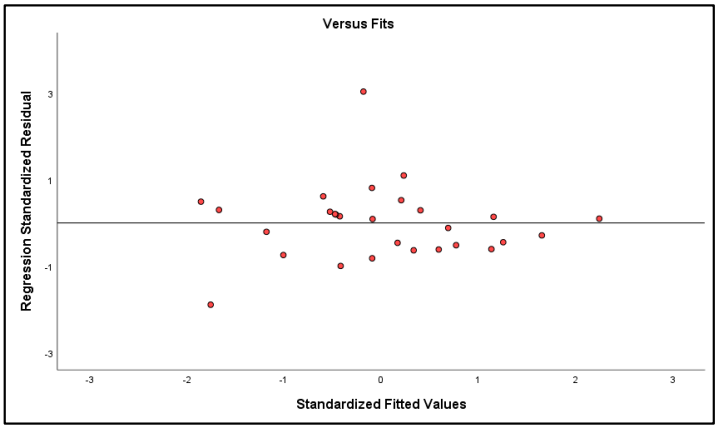

Figure 3. Residuals versus fits.

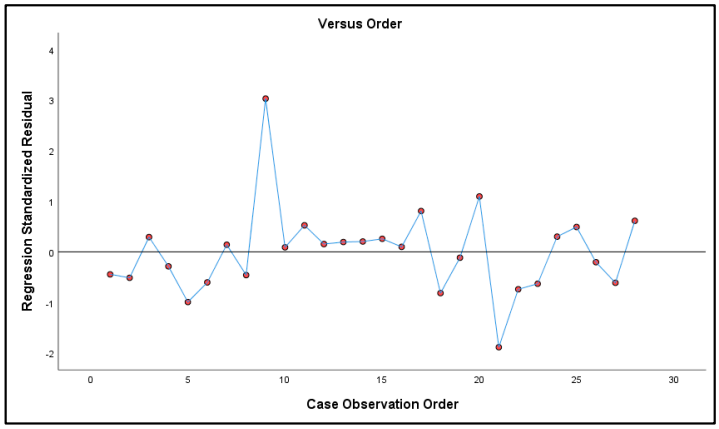

Figure 4. Residuals versus order plot.

5. Discussion

Results indicate that certain factors, namely, Investment Size (InS), Public Share (PSh), Year of Contract Award (YCA), Number of Equity Holders (NoEH), and Catchment Population (CPop), significantly influence the Concession Period granted to the SPVs by the public sector. Conversely, the Construction Period (CoP) and Hospital Capacity (HoC) were found to have no significant impact on the Concession Period.

Two parameters were found to have no significant relationship with the concession period. Interestingly, both factors were recognized as significant parameters for the concession period in the extant literature as follows.

Firstly, the Construction Period (CoP) is not a significant parameter for the concession period of healthcare projects. Interestingly, the construction period has been extensively incorporated to determine optimal concession periods in general PPPs [17], and has been specifically applied to estimate this period in toll road PPPs [38]. There are suitable reasons that may explain why our findings contrast with previous literature. Firstly, healthcare PPP projects may possess distinct characteristics compared to other types of PPPs, such as toll roads or general PPP projects, such as complex services and specialized equipment that may not be related to the construction period, which could differ significantly from the construction of other buildings or infrastructure. Additionally, the financial viability and risk allocation in healthcare PPPs may rely on long-term revenue streams from government payments or insurance reimbursements, which might not be directly influenced by the duration of the construction period. Moreover, a higher proportion of private financing generates strong incentives to complete the construction quickly regardless of the project size, resulting in relatively homogeneous construction periods.

Secondly, the lack of significant impact of Hospital Capacity (HoC) on the project concession period also contrasts with previous studies. In previous research, hospital capacity was found to be influential in determining the public share of PPPs [39]. However, this study presents contrasting results in this regard, indicating that hospital capacity does not exert a similar influence on the concession period. These findings suggest that the link between hospital capacity and the concession period might be more context dependent. For example, PPPs with higher hospital capacity may result in higher public subsidies and a lower proportion of private capital provision, which could shorten the concession period. Alternatively, even in higher hospital capacity PPPs with a higher proportion of private capital, there may be mechanisms in place to ensure increasing yearly revenues, thus preventing the need for an extended concession period.

Complementary, the analysis also uncovered a positive relation between the Number of Equity Holders (NoEH) in the SPV and the concession period. This suggests that when the market notices a bidding process with a relatively long concession period, the private companies interested in the project tend to form SPVs shared by more equity holders to enhance their capabilities and risk sharing. Having increasing equity holders may indicate a

more robust and capable SPV, better equipped to deal with project risks and ensure lenders' timely debt repayments. Extant literature explored the effect of the number of partners in the SPV in reducing project risk, however, they only considered its effect on public finance [46,49,50]. This paper complements this perspective by extending the analysis to consider the influence of shareholders in the concession period.

Surprisingly, the Catchment Population (CPop) was found to have a counterintuitive effect, positively influencing the concession period. This contradicts the initial hypothesis, which assumed that a higher population of end users would result in increased revenues or higher availability payment, thereby shortening the concession period. Moreover, the complexity of facilities and services offered by healthcare PPPs catering to large populations along with the fiscal constraints faced by the public sector concerning yearly payments contribute to the decision to opt for longer concession periods. This finding contrasts with previous studies that disregarded catchment population as a significant influencing factor in PPP projects [40] and Build-Operate-Transfer toll road projects [12]. This analysis demonstrates that this factor indeed plays a significant relationship with the concession period. In summary, this implies that as the number of potential users increases, there is a corresponding need for more extensive maintenance and operational interventions. This heightened demand for OPEX may, in turn, extend the concession period. While the connection between OPEX and concession period has been examined in prior studies [51,52], it is worth noting that the specific role of catchment population as a mediator in this relationship has not been thoroughly explored in previous research.

Findings indicate a significant and positive relation between Investment Size (InS) and the concession period. This relationship can be attributed to the high risk and complexity associated with larger projects, prompting the public sector to offer a longer concession in order to incentivize private sector participation in those projects. This finding complements the previous hypotheses that larger project initial investments lead to extended concession periods, mainly due to the higher expected returns sought by the investors [16]. This aligns with claims that larger projects bear greater risk for private investors, necessitating longer concession periods to mitigate the perceived risks [13].

Furthermore, results show a significant negative relationship between the Public Share of capital expenditure (PSh) and the concession period, indicating that, as the share of public funding in the initial investment decreases, the concession period increases. Consequently, when the SPV receives fewer subsidies from the public sector, it may require a longer concession period in order to generate sufficient revenues over time to ensure the desired profitability and project internal rate of return. PPP literature considered the effect of public financing and concession periods on the project NPV [44]. This paper's findings emphasize the relevance of understanding the negative relationship between public share and concession period to strike a balance between public and private sector interests. These results are consistent with other studies, which also found that government subsidies shorten the concession period [39] and help governments secure earlier operational revenues [4].

Furthermore, the analysis reveals a negative relationship between the Year of Contract Award (YCA) and the concession period. This suggests that PPPs awarded more recently, tend to have reduced concession periods. One suitable explanation for this trend is that over the years, the public sector has gained more experience and expertise in contract management of PPP projects, particularly in the context of healthcare facilities. As a result, they have become more prone to procure shorter concession periods in order to avoid burdening public budgets with excessive long-term costs. The adjustments made in 2016 to the PPP Italian legislation also serve as an indicator of the public sector's commitment to regulating and improving the efficiency of PPP contracts, while ensuring the preservation of the benefits for the public.

6. Conclusions, Implications, and Limitations

This study helps in understanding the factors that influence the length of the concession period in PPP projects, particularly in the context of healthcare facilities in developed countries. The findings shed light on the importance of understanding the driving factors behind concession periods to effectively regulate PPP contracts. The results show that investment size, public share, year of contract award, number of equity holders in the SPV, and catchment population significantly influence the concession period, while the construction duration and the hospital capacity do not show a significant impact.

The findings of this study have practical implications for both the public and private sectors involved in PPP projects. Decision makers in the public sector can leverage the understanding of the negative relationship between the public share and concession period to strategically plan concession periods according to short-term fiscal constraints. Prioritizing higher short-term public shares can help reduce the need for private capital investment, leading to shorter concession periods and avoiding long-term financial burdens.

For the private sector, the positive relationship between the number of equity holders in the SPV and the concession period offers valuable insights for structuring SPVs during the procurement phase. Recognizing the correlation between concession period and uncertainty, private sector stakeholders can consciously shape SPV compositions to optimize risk management strategies. A higher number of partners in the SPV can better manage project risks by leveraging diverse technical knowledge, experiences, and strengths.

The findings of this study offer valuable insights that can be strategically utilized by decision makers to purposely plan the concession period and related strategies.

Firstly, the understanding of the significant negative relationship between the public share and concession period can be leveraged by public sector decision makers to purposefully determine the concession period based on their short-term fiscal constraints. In cases where the public budget is not excessively constrained due to fiscal pressures (as seen in multiple developed countries), decision makers can prioritize increasing the short-term public share. As a result, they can reduce the need for private capital investment, leading to a shorter concession period and ultimately preventing excessive public payments and additional financial costs in the long term. Overall, this approach allows decision makers to strike a balance between meeting immediate PPP financial requirements and optimizing the long-term benefits of the project.

Furthermore, the positive relationship found between the number of equity holders in the SPV and the concession period holds practical implications for the private sector in structuring the SPV during the procurement phase and tendering process. Understanding this correlation can help private sector stakeholders in consciously shaping the SPV composition in alignment with the established concession period and optimizing risk management strategies. When the concession period is longer, it implies a higher level of uncertainty, which can be better managed by a greater number of partners in the SPV to specifically manage specific risks. This is achieved by leveraging the diverse technical knowledge, experiences, and strengths of each partner. Conversely, when there is less uncertainty associated with a shorter concession period, a lower number of partners may suffice to manage the risks effectively.

The positive impact of the catchment population on the concession period holds significant implications for the public sector. When procuring healthcare PPPs in areas with smaller catchment populations, such as local or regional public sector entities, a strategic approach should prioritize shorter concession periods. This approach is advantageous as it helps to prevent the burden of excessive long-term expenses and financial costs, particularly when the level of services required may not be as high. Conversely, for public institutions procuring PPPs in larger cities with substantial catchment populations, there is an opportunity to focus on enhancing the capacity and service levels through financially leveraging higher short-term capital investments.

Despite its contributions, this study has certain limitations that should be acknowledged. Firstly, the analysis relies on a linear regression model, which assumes a linear

relationship between independent and dependent variables. This simplification may not capture more complex, non-linear interactions that could exist in the data. Secondly, while the analysis identifies relationships between factors and the concession period, it cannot definitively establish causative links, given that linear regression establishes correlations between variables but does not prove causation. Thirdly, given the data available from the 28 projects studied, the analysis focuses on the selected independent variables and does not consider other potentially influential factors that may affect the concession period.

To further enhance the understanding of concession periods in PPP projects, future research could also explore additional factors that might influence the concession period such as political and institutional factors. By delving into these factors, policymakers and stakeholders can gain a more comprehensive view of the determinants of concession periods, enabling better decision making and project planning.

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Public–Private Partnerships in Urban Regeneration Projects: The Italian Context and the Case of "*Porta a Mare*" in Livorno

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Abstract: Urban regeneration projects have been used in urban planning in different cities to recover strategic areas and combat new land consumption. Often, Public–Private Partnership (PPP) agreements are signed to meet the demands of these projects. In the Italian case, PPP arrangements can be one of three types, namely, contractual, institutionalized, and negotiable. Urban regeneration, in the Italian context, aims to increase the value of the existing infrastructure. Despite this, there are several obstacles to how these practices are developed, which demand more attention to be paid to the enabling environment and the Critical Success Factors (CSFs) that can improve the performance of these practices. Based on this, this study aims to analyze the Italian context of PPP arrangements in urban regeneration projects and the specific case of the Livorno "*Porta a Mare*". To this end, the study adopts a previously established CSFs framework. The data analyzed are derived from secondary sources obtained through documentary collection and primary sources obtained through interviews. Regarding the PPP process, the results indicate the commitment of the public and private sectors, despite limitations in the selection process and the lack of public participation. Concerning urban regeneration, although not yet completed, the project allocates a significant area of waterfront to urban use.

Keywords: Public–Private Partnerships (PPPs); urban regeneration; Critical Success Factors (CSFs); Italy; *Livorno Porta a Mare*; framework analysis; case study analysis

1. Introduction

Urban regeneration has been included in the urban planning of different cities, either as a response to observed urban degradation and decline or as part of an attempt to give new functions to obsolete areas and control urban growth [1].

Notwithstanding its enormous importance in today's urban contexts, urban regeneration is not a simple task, and, in many cases, urban regeneration projects are complex, involving different types of risks and high investments. Furthermore, it is known that the public sector, as the provider of several types of infrastructure and public services, does not have the resources to meet all of today's urban demands. In this sense, the actions of the private sector through Public–Private Partnership (PPP) agreements can be strategic in the context of urban regeneration and the development of urban regeneration projects.

In Italy, urban regeneration is often associated with the enhancement of existing infrastructure [2]. In the Italian context, PPP arrangements can be one of three types: contractual PPPs, institutional PPPs, and negotiable PPPs [3].

However, implementing PPP arrangements in urban regeneration projects is controversial, and the initial objectives are not always achieved. Despite sounding good in theory, in many cases, these projects do not meet their initial objectives, do not achieve the public service objectives proposed, and have negative consequences, both in financial and social terms. In addition, the literature on PPP agreements in urban regeneration focuses mainly on topics related to public policy, projects and governance issues. Issues related to contracts and management constitute a gap in the literature [1].

Based on this, the present study focuses on PPP arrangements in urban regeneration projects from a perspective not restricted to urban planning but including important contract and management aspects of these practices. The study starts with the assumption that it is important to understand the best practices for these partnerships to work effectively, which would contribute to the achievement of better results from an urban planning perspective as well.

Best practices can be observed if the Critical Success Factors (CSFs) are followed [4]. CSFs are elements, conditions, events and activities that must be considered so that an organization or a project can achieve its goals, ensuring its success [5,6].

Despite this, studies on CSFs in PPPs in urban regeneration projects are limited. Studies that analyze specific contexts or cases, which could benefit the understanding of these practices, are also limited.

In this sense, this study aims to analyze the Italian context concerning PPP agreements in urban regeneration projects and a specific case of an urban regeneration project carried out through a PPP agreement—the Livorno Port project, called "*Porta a Mare*", which is responsible for regenerating a sprawling industrial area and giving it new urban functions.

The analysis aims to identify which critical success factors are observed in the Italian context and in the specific case study, and which factors can be improved. Meeting the proposed objective, the study also aims to answer the following research questions:

- How are PPP arrangements understood and applied in urban regeneration projects in the Italian context?
- Which CSFs are most relevant in the Italian context? Which factors could be better addressed?
- Which CSFs are most relevant in the "*Porta a Mare*" case study? Which factors could be better addressed?

To this end, the study uses a previously established framework, which considers clusters related to the external environment related to the PPP projects—a country's enabling environment that facilitates or does not facilitate the implementation of partnerships and exogenous factors found in that country—and the internal environment of the PPP projects—referring to the partnership itself and its different phases [7].

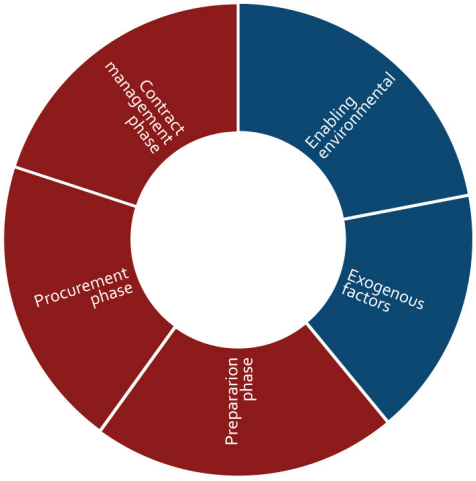
Using that framework and analyzing the country's context and a case study, this research contributes to the literature on PPP arrangements in urban regeneration projects, increasing knowledge on the subject via a critical analysis of a real context. Furthermore, from a practical point of view, the study provides an interesting example of how the framework can be used to identify points of success and critical points in a specific context. Through the identification of these points in a specific context, the study makes it possible to identify the best practices that can be incorporated into PPP agreements in urban regeneration projects. In this sense, this research can be useful for academics involved in the topic and for professionals in both the public and private sectors.

The study consists of five sections, namely, this brief introduction, Section 2 on the research methodology, Section 3 on the analysis of the Italian context and the analysis of the case study, Section 4 on the discussion of the results obtained and Section 5 on the conclusions drawn from the research.

2. Materials and Methods

The study aims to analyze the Italian context of PPP agreements in urban regeneration projects, also delving into a specific case of a PPP agreement for the urban regeneration of a waterfront area—the case of the Port of Livorno and the "*Porta a Mare*" partnership. The analysis focuses on the CSFs observed in the Italian context and the PPP analyzed, and the issues that could be improved.

To this end, the study uses a previously established framework of CSFs in PPP agreements for urban regeneration projects [7]. The framework considers five distinct clusters; two relate to the external environment, and three to the internal environment of the partnership. The external environment includes the enabling environment and exogenous factors. The internal environment includes the three phases of the partnership: the preparation phase, the procurement phase, and the contract management phase (Figure 1).



Enabling environmental	Exogenous factors
Favorable legal and regulatory framework Government support and guarantees Leadership focus Political support and stability Standardization procedure for PPP projects Well-organized and committed public agency	Available financial and capital market Community support Favorable socio-economic factors Stable macroeconomic condition and sound economic policy

Prepararion phase	Procurement phase	Contract management phase
Availability of resources and skilled and dedicated team of professionals Clear defined responsibilities and roles Clear project scope definition and documentation Comprehensive and business viability of project feasibility study Good governance	Availability of resources and skilled and dedicated team of professionals Competitive and standardized bidding process Transparent procurement process Trust and openness	Commitment and responsibility of public and private sectors Effective conflict management Effective contract management Good governance Open and constant communication among stakeholders

Figure 1. Framework of PPP CSFs for urban regeneration projects. Source: Vale de Paula et al. (2024) [7], adapted.

The enabling environment consists of the entire environment external to the PPP projects, but which can be controlled in such a way as to facilitate the development of partnerships. Concerning the enabling environment, six factors were identified, as follows:

- Favorable legal and regulatory framework. Laws and regulations that follow the country's legislation at different levels and that facilitate the development of partnerships, protecting the rights and interests of all parties;

- Government support and guarantees. Government support in the form of guarantees to ensure the financial viability and creditworthiness of the project;
- Leadership focus. The capacity of the public sector to exercise its leadership role in implementing the partnership;
- Political support and stability. Political stability at different levels beyond the period of a political mandate that can guarantee the continuity of the partnership;
- Standardization procedure for PPP projects. The standardization of the process to assure the public sector that the partnership is carried out in accordance with governmental and local objectives and to facilitate the private sector to prepare the partnership;
- Well-organized and committed public agency. An organized and committed public body, with technical capacity and experience in partnerships.

Exogenous factors include factors that cannot be controlled, but which also influence the development of PPP projects. The following factors were identified:

- Available financial and capital markets, which allow for low financing costs and offer a diversified range of financial products;
- Community support. Acceptance, understanding and participation from the community are important to ensuring the smooth running of the PPP, avoiding delays, facilitating the hiring of local labor, providing projects valued by citizens, managing expectations, and mitigating disagreements;
- Favorable socio-economic factors. A favorable socio-economic scenario in which the public sector and the population have a robust payment capacity, creating an environment that encourages partnerships;
- Stable macroeconomic condition and sound economic policy, capable of creating a stable and growing economic environment, allowing for a low cost of capital and greater certainty in the market, thus reducing risks.

For the preparation phase, the following factors were identified:

- Availability of resources and a skilled and dedicated team of professionals. Because these are long processes, it is necessary to guarantee resources for the PPP during the transition. Furthermore, it is necessary to have a dedicated and competent team of professionals to accompany the entire PPP;
- Clear definition, already in the preparation phase, of the different roles and functions of the actors involved;
- Clear project scope definition and documentation. Clear definition, already in the preparation phase, of the project documentation, including objective, scope, geographical area, technical project, functional responsibilities, and previous experience in similar projects;
- Comprehensive and business viability-orientated project feasibility study A comprehensive business feasibility study of the project, including technical feasibility studies, financial and socio-economic analyses, and realistic assessments of costs and benefits;
- Good governance. Managing the relationships between the different actors involved is important at all stages of the PPP, including the preparatory phase.

For the procurement phase, the following factors were identified:

- Availability of resources and a skilled and dedicated team of professionals. Just as in the preparatory phase, the availability of resources and a team to accompany the PPP is fundamental during the contracting phase;
- Competitive and standardized bidding process. A standardized process must define the rules a priori and present them to bidders, facilitating the preparation of bids and allowing them to be fairly compared. The competitive process, in turn, guarantees the best cost–benefit ratios;

- Transparent procurement process. A transparent procurement process that makes it possible to reduce transaction costs and shorten negotiation and contracting times;
- Trust and openness. Openness between the parties to create trust and a solid relationship, increasing their willingness to cooperate.

Finally, regarding the contract management phase, the following factors were identified:

- Commitment and responsibility of public and private sectors. The commitment of both parties to the objectives of the partnership and the project, including the allocation of their best resources;
- Effective conflict management. Effective and efficient management of the conflict, as early as possible and involving those responsible in both sectors, to avoid aggravating the conflict and compromising the partnership;
- Effective contract management. Effective and efficient contract management by controlling costs, time, security, materials, techniques, and skills so as to avoid renegotiations and compromising the partnership;
- Good governance. Managing the relationships between the different players involved is important at all stages of the PPP, including the contract management phase.
- Open and constant communication among stakeholders. Openness and communication between all the actors involved, not just the public and private sectors, ensuring that the interests and concerns of all parties are managed, increasing trust in and commitment to project management.

The external environment will be used to analyze the Italian context in general, while the PPP's internal environment will guide the analysis of the specific case study. The data collected for analysis were initially secondary data extracted from documentary analysis. The data include different types of documentation found, including laws on the subject (national, regional, and local), regulations and technical documents, scientific articles, and publicity material about the project. While most documentation is available online, official documents were requested and received directly from the Municipality of Livorno.

To complement the case study analysis, primary data were extracted from interviews conducted with stakeholders involved in the case study. Five interviews were conducted with stakeholders or experts in the Porta a Mare partnership and project in January 2025 (Table 1). The interviews were conducted online in a semi-structured format based on open-ended questions (Table 2).

Table 1. Interviews—interviewee profile.

Interviewee 1	Architect—Autorità di Sistema Portuale del Mar Tirreno Settentrionale (North Tyrrhenian Sea Port System Authority)
Interviewee 2	Architect—Former Head of the Urban Regeneration Sector-Municipality of Livorno
Interviewee 3	Engineer—Former Head of the Urban Planning Sector-Municipality of Livorno
Interviewee 4	Engineer—Engaged in the Participatory Process "il futuro è dietro la Porta! (a Mare)" (the future is behind the Door to Mare, in English), concerning the *Porta a Mare* area and its surrounding areas.
Interviewee 5	Journalist and writer—Author of a Book About the *Porta a Mare* area

Table 2. Interviews—open-ended questions.

How was the Livorno *Porta a Mare* area before the project?
What was the context of the Orlando Shipyard crisis and the creation of the *Porta a Mare* PPP?
Which external entities were involved?
How do you evaluate the urban results obtained through the regeneration of the area? What aspects do you see as positive, and what aspects could be better addressed?
How do you evaluate the partnership between the Municipality of Livorno and Azimut Benetti (Livorno, Italy)? What aspects do you see as positive, and what aspects could be better addressed?
Were there any conflicts observed during the development of the *Porta a Mare* partnership and project? How were these conflicts managed?
How did the local population respond to the partnership and the *Porta a Mare* project? Was there support or opposition?
If the process was done again, what could be done differently?

3. Results

3.1. Italian Context

To analyze the Italian context based on the clusters identified previously, the study focused first on the enabling environment and, subsequently, on the exogenous factors that influence the Italian scenario of PPP arrangements in urban regeneration projects.

3.1.1. Enabling Environment in the Italian Context

The Italian legal framework on PPP arrangements is related to the "Green Paper on Public–Private Partnerships and Community Law on Public Contracts and Concessions". Concerning the Green Paper, the European Commission defines Public–Private Partnerships as "forms of cooperation between public authorities and the world of business which aim to ensure the funding, construction, renovation, management or maintenance of an infrastructure or the provision of a service" [8]. The paper also defines two types of PPP arrangements: purely contractual PPPs and institutionalized PPPs.

Purely contractual PPPs are based on contractual relationships between public and private partners. These relationships can cover one or more tasks, such as the design, financing, building, renovation, operation, and maintenance of a work or service, but are always based on a clear division of tasks for both sectors [8].

Institutionalized PPPs involve the creation of a separate entity (joint venture) for cooperation between the two sectors, which will be responsible for delivering the infrastructure or service to be provided. An institutionalized PPP can be carried out either through the creation of an entity jointly owned by the public and private sectors, or through the transfer and private control of an existing public entity through a change of shareholders [8]. Concerning institutionalized PPPs, in 2008, the European Commission also developed the "Commission Interpretative Communication on the Application of Community Law on Public Procurement and Concessions to Institutionalized PPP (IPPP)" [9].

The Italian legal framework is aligned with the European level, considering contractual PPPs and institutionalized PPPs. In addition to the two modalities, the Italian national framework also considers negotiable PPPs [3].

Pure contractual partnerships are regulated in the Italian legal system by Legislative Decree no. 36/2023, called the "*Codice dei contratti pubblici*" (Public Contracts Code) [10]. This document replaces Legislative Decree no. 50/2016, called "*Codice degli appalti pubblici e dei contratti di concessione*" (Code of public procurement and concession contracts) [11]

and Legislative Decree no. 163/2006—"*Codice dei Concontractti Pubblici di Lavori, Servizi, Forniture*" (Code of Public Contracts for Works, Services, Supplies) [12].

The code dedicates Book IV to Public–Private Partnerships and Concessions. The document defines a PPP project as an economic operation in which the following characteristics coexist: a long-term contractual relationship is established between a contracting authority and one or more private economic operators to achieve a result in the public interest; the financial requirements related to the implementation of the project are largely covered by resources provided by the private partner, due to the operational risk assumed by it; the private partner is responsible for the implementation and management of the project, while the public partner is responsible for defining the objectives and monitoring their implementation; the operational risk associated with the deployment of works or the management of services is allocated to the private partner [10].

The document also refers to the types of PPP contracts, including concessions, financial leases, and availability payment contracts. In addition, the document refers to any other type of contract concluded between the public administration and a private operator, as long as they have the characteristics mentioned above.

Although it refers to institutional PPPs, the "*Codice dei contratti pubblici*" emphasizes that institutional PPPs are governed by the Legislative Decree no. 175/2016, known as the "*Testo unico in materia di società a partecipazione pubblica*" (Consolidated law on publicly owned companies) [13]. The "*Testo unico in materia di società a partecipazione pubblica*" replaced the "*Testo unico delle leggi sull'ordinamento degli enti locali*" (consolidated law on the organization of local authorities) (Legislative Decree no. 267/2000) [14] regarding the regulation of public companies.

The document states that "public administrations can only participate in companies, including consortiums, set up as public limited companies or limited liability companies, including cooperatives" [13]. Companies can be publicly controlled, publicly owned, in-house, or mixed Public–Private. Institutionalized PPPs are thus used to manage public services to produce goods and activities aimed at achieving social objectives and promoting the economic and civil development of local communities. In the Italian context, the most common type of institutionalized PPP in the urban context is the Urban Transformation Society, introduced in 1997 [3].

Negotiable PPPs, conversely developed mainly through the so-called Complex Programs, which were implemented from the 1990s onwards. From the 2000s onwards, regional initiatives began to carry out negotiable PPP initiatives in the urban context [3].

The topic of urban regeneration, in turn, has been gaining prominence in urban planning concerning the need to contain land and enhance existing land. At the national level, some documents refer to the issue, such as the following: Law no. 10 of 2013, called "*Norme per lo sviluppo degli spazi verdi urbani*" [15]; Decree-Law No. 133 of 2014, called "*Decreto Sblocca-Italia*" [16]; *Disegno di legge C-2039* [17]. However, it is at the regional level that the issue has been effectively dealt with. In this sense, some stand out, such as Regional Law of Veneto No. 14/2017 [18]; Regional Law of Abruzzo No. 24/2014 [19]; Regional Law of Lazio No. 7/2017 [20]; Regional Law of Toscana No. 65/2014 [21]; Regional Law of Lombardia No. 31/2014 [22]; Regional Law of Umbria No. 1/2015 [23]; Regional Law of Emilia-Romagna No. 24/2017 [24]. Finally, there are also some initiatives at the municipal level, such as regulations for collaboration between citizens and public administrations for the healing and regeneration of common goods [25] and regeneration experiments through temporary reuse [26].

The Italian context includes public agencies committed to PPP arrangements. It is interesting to note the roles, at different times, of the two agencies responsible for supporting the development and implementation of PPP arrangements in the country.

The first agency is the *Unità Tecnica Finanza di Progetto—UTFP* (Technical Unit Project Finance—UTFP), established by Law No. 144 of 17 May 1999 [27], which operated until 2015. In 2015, Law No. 208 of 28 December abolished the UTFP and transferred the relevant functions in terms of PPP arrangements to the *Dipartimento per la programmazione e il coordinamento della politica economica—DIPE* (Department for Planning and Coordination of Economic Policy—DIPE) [28].

In the field of PPP projects, DIPE's competencies include supporting contracting authorities by providing technical, legal, and financial assistance at all stages of the processes; collecting data and monitoring PPP operations; promoting and disseminating PPP models; activating collaborative relations with institutions, including at the international level, with bodies and associations operating in sectors related to the DIPE's action in the field of PPP projects [29].

Another relevant aspect when developing PPP agreements in Italy is the Standard PPP Contract Model under Legislative Decree No. 50/2016. This document deals with important points related to PPP arrangements; in addition to the general conditions, it addresses the obligations of both parties, the different phases of design, construction and management, economic and financial balance and rebalancing, guarantees, and resolutions to different conflicts. However, it is important to note that the model is aimed at contractual PPPs. For institutional PPPs, no standard model was identified—only an explanatory circular refers to Urban Transformation Societies, a specific type of institutional PPP.

Finally, it is important to note that the National Anti-Corruption Association (ANAC) has a document with guidelines for monitoring by contracting authorities on the economic operator's activity in PPP contracts. The latest edition of this was updated in 2023.

3.1.2. Exogenous Factors in the Italian Context

The exogenous factors analyzed include the availability of a financial and capital market, community support, favorable socio-economic factors, and a stable macroeconomic condition and sound economic policy.

The Italian scenario remains unsatisfactory regarding the availability of a financial and capital market. According to a report by *Cassa Depositi e Prestiti*, a company controlled by the Ministry of Economy and Finance, Italy's public and private capital markets are not favorable for the economy. On the one hand, the public market is undersized compared to those in other European countries; on the other hand, the private market is too fragmented. The credit system is still largely dependent on bank loans with limited recourse to the capital market. The limited diversity of funding sources restricts the private sector's ability to invest in riskier projects or those with long payback periods, as well as making companies more vulnerable to possible shocks [30].

Concerning community support, in Italy, as in many other countries, a series of criticisms made of different PPP arrangements have led to a deterioration and politicization of the relationship between public and private actors. Despite this, in recent years, the country has once again opened up to the possibilities of partnerships to respond to social, digital, environmental, and economic challenges [31]. However, PPP arrangements will only be successful if the public sector can use PPP projects strategically and if the private sector understands the need to generate public value [31].

In terms of socio-economic factors, since the country's unification in 1861, Italy has been characterized by socio-economic disparities and a strong division between north and south. In general, the southern regions of Italy have less favorable socio-economic conditions. Some aspects influence the less favorable conditions in the southern regions, such as deindustrialization, demographic imbalances, the inability to develop an advanced tertiary sector and resist the pressures of emerging markets, and the collapse of public

investment [32]. In general, the south of Italy has a lower level of industrial development, fewer public services, less territorial infrastructure, a reduced number of companies and lower employment [33]. Nevertheless, the division between north and south does not constitute two homogeneous parts. In fact, we can identify four different scenarios for the country—four different "Italies": two Italies (which include the north and part of the center) perform better than the national average; one Italy represents the average (and includes regions in the center and part of the south); and one Italy is below the national average (and includes mostly southern regions) [32].

The most recent trends for the country reflect the difficulties of the 2008 financial crisis, considered the worst recession in recent Italian history, and the COVID crisis. Concerning the current situation, important socio-economic factors were identified, as follows: globally renowned centers in the north and the capital region drive economic development; economic advantages come at a cost in the north and the capital region, with high levels of continuous immigration leading to rising living costs; vast but less populated areas of central Italy are characterized by average living standards and average conditions for economic development; the regions of southern Italy lag behind the national average economically, with limited employment continuing to cause emigration and demographic decline [32].

Finally, to understand the country's macroeconomic scenario, some indicators relating to annual GDP per capita growth as a percentage and inflation were analyzed, based on the data obtained from the World Bank over the last twenty years.

Concerning annual GDP per capita, the World Bank data show negative peaks in two years—2009 with −5.7% and 2020 with −8.5%. Despite strong growth in 2021 (+8.9%), growth in 2023 was only 1.2%. In terms of GDP per capita growth, the macroeconomic scenario does not indicate a robust economy, but rather an economic slowdown.

Concerning inflation, the country has had considerable inflation peaks in recent years, particularly in 2022, with 8.2% inflation. In 2023, inflation stood at 5.6%, representing a high and unfavorable inflation rate for the country's macroeconomic scenario.

3.2. "Porta a Mare" Case Study

After a general overview of the Italian context, this study focuses on the case of "*Porta a Mare*" in Livorno. To this end, the study begins with an initial contextualization of Livorno and its port. Then, it presents the proposed urban regeneration project. Finally, the study focuses on the PPP responsible for developing the project.

3.2.1. Context of Livorno and the Port

Livorno is a municipality in Tuscany, a region located in central Italy. With a population of around 160,000, it is the third largest city in the region. Its geographical position is favorable since it is in the middle of Italy and the Mediterranean (Figure 2).

Livorno, together with the municipalities of Pisa and Collesalvetti, form the so-called "industrial triangle" [34]. Furthermore, from a strategic point of view, the port of Livorno is part of the coastal logistics platform, together with Pisa Airport and the Guasticce Interport, and is also linked to the Gonfienti Interport in Prato and Florence Peretola Airport, as well as the other ports on the Tyrrhenian Sea [35]. In this sense, considering its large territorial scale, the port area of Livorno is strategic for the whole region and is easily accessible by main roads (Figure 3).

The city of Livorno was founded at the service of the port, which was the central element of the city until then [35]. From 1421, the small fishing village began to develop as a defensive port, leading to an international commercial port of call that reached its peak

in the mid-18th century. *Buontalenti's* project in 1577 marked the city's founding, which encompassed the preexisting village and reinforced its character as a port city [35].

Figure 2. The context of Livorno. Source: Prepared by the authors.

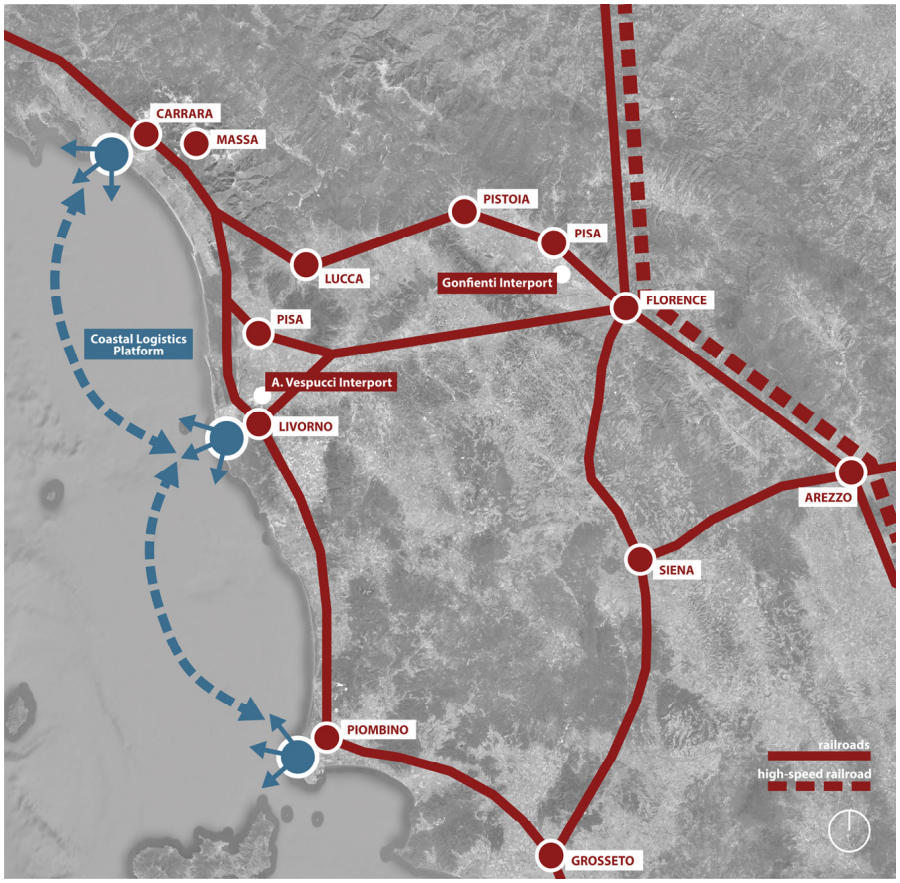


Figure 3. The context of Livorno and the port. Source: Prepared by the authors based on [35].

On an urban scale, the port is placed in an interesting pedestrian context, close to the historic center, important monuments, streets, squares, areas of commercial and public activities, and educational facilities [34]. In this sense, the Livorno port area and the waterfront have been receiving greater attention from the municipality, including major urban intervention projects.

The area currently subject to urban regeneration on Livorno's waterfront is part of the original port, located in the central area of the city. The area was subsequently called *Porta a Mare.* The area was previously occupied by the *Fratelli Orlando* shipyard, which began its activities in 1866, producing merchant ships and warships, acting as a strong element in Livorno's economy and history. However, due to foreign competition, the shipyard fell into crisis. In 1984, the *Orlando* shipyard was passed to the *Fincantieri* Group, a company with state participation. Finally, in 1993, the company was announced as for sale [36].

To avoid a complete shutdown, the shipyard was managed through a cooperative during 1996–2002. However, due mainly to mismanagement and economic and financial issues, the cooperative's activities were also closed down [36].

During the crisis, in 1995, the Municipality of Livorno started thinking about alternatives for the area at a project level, including the possibility of new urban uses—services, shops, residences, and a tourist port. In this context, the 1997 Structural Plan presented the project proposal and new functionalities for the *Porta a Mare* area [36].

With the demise of the *Orlando* Shipyard and the Cooperative, the search began for a private company interested in taking over the area, mainly seeking to guarantee the employment of the workers from the old shipyard and, at the same time, releasing part of the area for urban uses.

It was then proposed that the area be divided into two different uses: one part is still for industrial use and another part is for urban use. The regenerated area destined for urban use constitutes the *Porta a Mare* project and was the objective of the PPP arrangement. The industrial area was bought by the company Azimut Benetti, which was also a private partner in the Porta a Mare PPP arrangement.

3.2.2. *Porta a Mare* Project Proposal

As mentioned, the initial area was divided between industrial and urban parts. The industrial part continued to be privately owned and managed (by the Azimut Benetti company), while the part for urban use was the subject of urban regeneration and the PPP arrangement, called *Porta a Mare.*

The urban regeneration project for the area, covering more than 10 ha, aims to transform Livorno's waterfront and port into a "waterfront of excellence" through a multifunctional hub that brings together commercial, office, residential, and service spaces linked to tourism, as well as new mooring areas [37].

The entire project is made up of five zones—*Piazza Mazzini, Officine Storiche, Molo Mediceo, Arsenale*, and area *LIps*, each with its own identity and specificity (Figure 4). *Piazza Mazzini* and the *Officine Storiche* are dedicated to developing residences, offices, retail spaces, shops, restaurants, and parking spaces, while *Molo Mediceo* and *Arsenal* are intended for tourist facilities and accommodations (*Molo Mediceo*, especially because of its relationship with what was to be the future tourist port). The *LIps* area—connected by a bridge to the *Molo Mediceo* and the *Arsenal* area—is dedicated to leisure and recreational activities, as well as residences and tourist facilities [34,37].

The development of the project was divided into two phases; the first phase focuses on *Piazza Mazzini* and the *Officine Storiche.* The second phase involves the *Molo Mediceo*, the *Arsenal* area, and the *LIps* area, with completely autonomous development of the works due to their geographical positioning and the possibility of exclusive access [34].

Thus, the project aims to restore historic buildings with industrial architecture and former shipyards, proposing new functionalities and creating a relationship of continuity between the past and present of the area. The hope is to give the waterfront and the city itself a new image, as has happened in other European cities that have regenerated their waterfronts (Figure 5). The entire project was initially scheduled for completion in 2022.

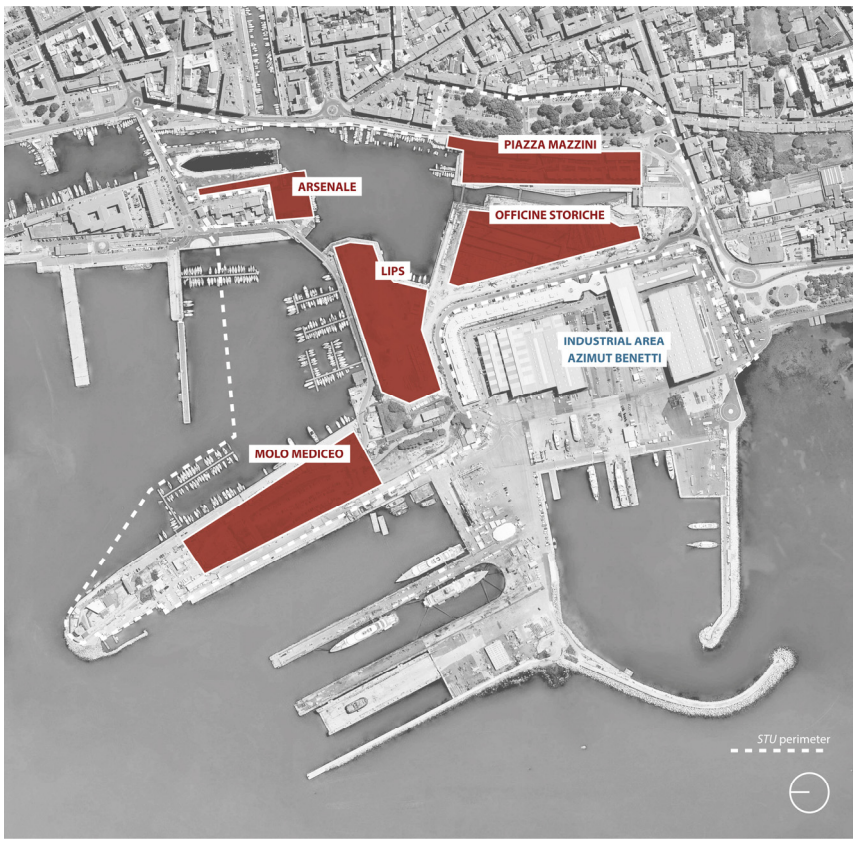


Figure 4. The five areas of the proposed project. Source: Prepared by the authors based on [38].

Figure 5. The area covered by the project (**above**) and the idealized masterplan (**below**). Source: [37].

3.2.3. STU Porta a Mare

As mentioned before, the designation of the *Porta a Mare* area and the possibility of its regeneration were presented following the 1997 Structural Plan in the context of the crisis of the *Orlando* shipyards [39].

Although it was first mentioned in 1997, the partnership responsible for regenerating Livorno's waterfront was only established in 2003 [38]. In this case, it was a "*Società di Trasformazione Urbana*" *(STU)*, i.e., an institutionalized PPP between the public and private sectors.

The former head of urban planning for the Municipality of Livorno (interviewee 03) has referred to the use of the *STU* to develop an area that had already been considered in the Structural Plan, stating that "*the STU is a tool, but the idea arises from traditional urban planning, of urban planning studied as early as 95, according to the classical canons of tools at the time, supported by considerable economic studies and studies also regarding the activities*" (translated from Italian).

The creation of the *STU* went through different stages, starting back in 2001 [39]. At the end of 2001, faced with the *Orlando* shipyards crisis and the cooperative trying to manage the area, the Municipal Administration proposed an *STU* for the area. In this context, pre-feasibility plans were put in place, under the responsibility of *Europrogetti e Finanza*, which later formed the basis of the proposed company [39].

The real process of setting up the company began during the first months of 2002. The process of setting up the *STU* has progressed through several different deliberations made by the Municipal Council [40–52].

In this context, the first relevant document was formalized in April 2002, and was responsible for setting out the general guidelines for the area's transformation and delimiting a preliminary perimeter [40]. The document formed the basis for the feasibility study, which was requested in September, and its preliminary version was delivered in the same month [53].

The document also refers to two important aspects—the municipality's renunciation of a majority participation in the company that will be formed, and the private partner's obligation to own buildings and areas within the delimited perimeter [39].

Following this document, the situation of the *Orlando* shipyard became increasingly difficult until it filed for bankruptcy. In July 2002, the shipyard went into receivership, and the search began for a buyer who, using the proceeds from the sale of the shipyard, could make an offer to creditors and restore the company's profitability. The entire complex was put up for sale at a price estimated by the judicial authorities at EUR 50 million [39].

Given this scenario, negotiations for the sale of the shipyard took place between September 2002 and June 2003. At the end of this period, a preliminary sale contract was signed with Azimut Benetti, a world leader in the production of large yachts. The effective purchase of the area took place in December 2003, when Azimut Benetti paid the full amount requested with an increase of EUR 600,000.00 [39].

During this period, a definitive feasibility study was also drawn up, and it was delivered in April 2023. Also, in April 2003, the mayor of Livorno publicly presented the *STU Porta a Mare* project, which was approved by a majority of the city council. The administration has committed itself to moving ahead quickly with setting up the *STU*, and even has a dedicated group within its staff [54].

In July 2003, the document presenting *STU's* detailed plan was released, both for the industrial area (the responsibility of the *Amizut Benetti* company exclusively) and for the real estate area, which is the object of the *STU* [42,43]. Once the feasibility study had been finalized, negotiations for the sale had taken place and the detailed plan had been

drawn up, a resolution was adopted in July approving the incorporation of the *STU* [44]. In October 2003, the previously drawn up detailed plan was approved [45,46].

Also, in October 2003, the tender document for private partners was published [48]. It is important to note that the document makes it clear that the private partner must own areas within the perimeter or be in the process of acquiring areas within the perimeter, as is the particular case of the Azimut Benetti company [53].

With the purchase of the shipyard, Azimut Benetti has become the largest owner in the area designated for the *STU*, and has been chosen as the company's private partner [49]. The company was established on 11 December 2003, with very different shareholdings between the public and private partners; while the Municipality of Livorno contributed EUR 50,000.00, Azimut Benetti contributed EUR 250,000.00 [39].

Regarding the luxury yacht company Azimut Benetti and its involvement as a private partner of *STU Porta a Mare*, the interviewees have positive opinions. Interviewee 02 stated that "*We have been very fortunate to have found a developer like Azimut Benetti, which has grown since then, and so the industrial activity on Livorno has grown together with this interlocutor, this private partner who is one of the few large Italian companies that continues to be growing, is a world leader of the luxury yachts. So, it is a reliable partner*". (translated from Italian). Interviewee 05 stated that "*as a partner, I think you couldn't have found a better one. Because a company of this level is hard to find in the market. It seems to me that actually the result that was to be achieved through them was secured*" (translated from Italian).

The private entities *SPIL* and *LIPS*, owners of land within the delimited area, decided not to participate in the partnership, and put their land up for sale. The capital needed to buy these areas (around EUR 40,000,000) was paid by the private partner, reducing the municipality's holding in the company to symbolic participation, as planned at the start of the operation [39]. The constitution of the *STU* includes the following documents (Figure 6).

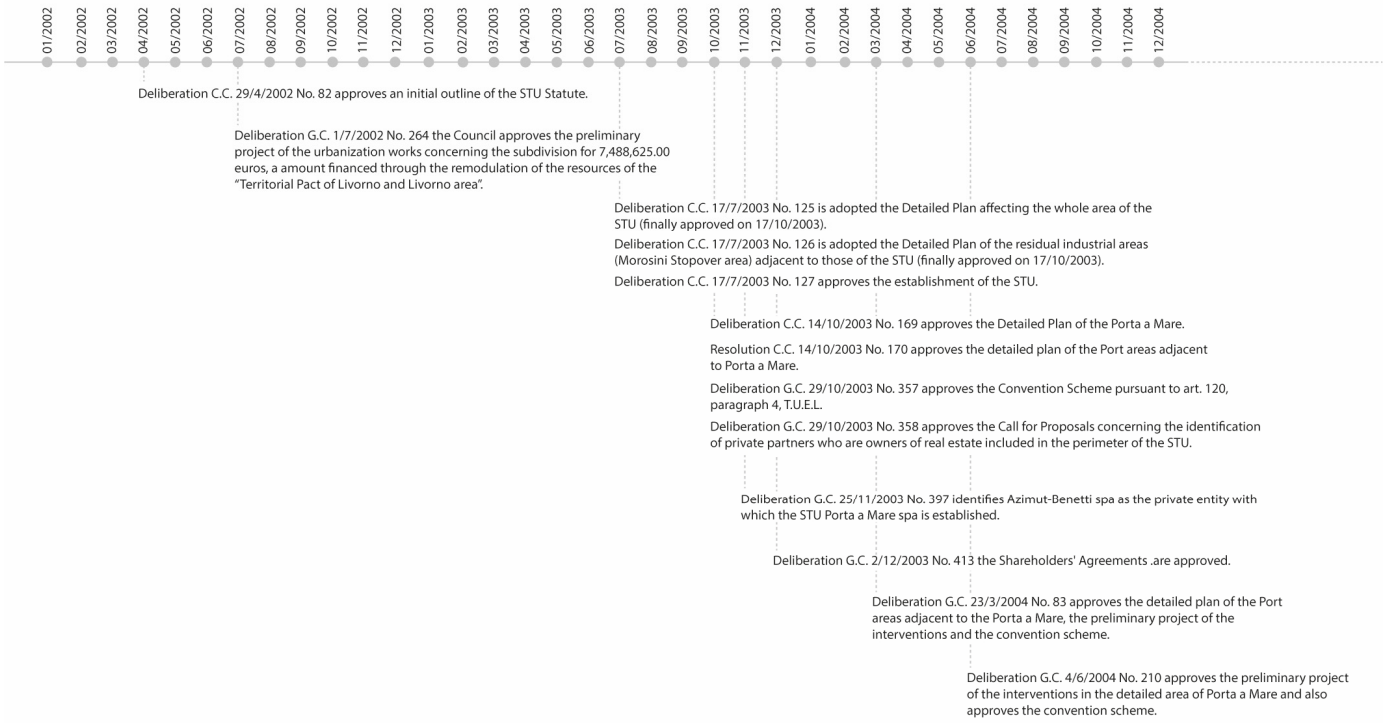


Figure 6. Timeline of the constitution of *STU Porta a Mare*. Source: Prepared by the authors based on [39,53,54].

The *STU's* obligations include purchasing the areas and buildings involved in the transformation operations; obtaining the necessary authorizations and concessions, both for the buildings and the bodies of water used for the construction of the tourist port and related infrastructures; taking care, directly or indirectly, of the preliminary, final and executive design of the necessary buildings and infrastructures; carrying out the planned operations, either directly, through its partners, individuals or associates, or by awarding construction and management contracts or works contracts. It is also possible to cede areas or parts of them to third parties, who are committed to respecting the project constraints already defined. It must also market and manage all or part, directly or indirectly, of the building and infrastructure works carried out, also through its partners, individuals, or associates. The company may take part, directly or indirectly, in any other operation related to its corporate purpose, including the study, design, execution, and construction of specific facilities [50].

As can be seen, at the time the *STU* was established, almost all the land was owned by Azimut Benetti. In 2004–2006, Azimut Benetti sold all the areas included in *STU Porta a Mare*, except those affected by the new *Benetti* shipyard. On 4 April 2007, the Municipality sold to *STU* two areas that are part of the *Molo Mediceo* subdivision and one area that is part of the *Arsenale* subdivision, as well as the building indexes of *Piazza Mazzini* [54].

In June 2007, building licenses were obtained for the subdivisions of *Piazza Mazzini*, *Officine Storiche*, *Lips area*, *Molo Mediceo*, and urbanization works. In December 2008, building licenses were obtained for the last subdivision, *Arsenal* [54].

Also in 2007, an important document was established—the *Accordo di Programma per lo svilupp e la trasformazione urbanistica dell'ex Cantiere Navale Orlando di Livorno e delle aree portuali limítrofe* (Program Agreement for the development and urban transformation of the former *Orlando* shipyard in Livorno and surrounding port areas). The document includes all the entities involved in the tourist port area, establishing the role of each one [55]. The agreement was an important step towards the division of tasks between the entities, but no progress was made in terms of developing the tourist port. Regarding the agreement, interviewee 03 stated that "*this program agreement in which objectively were clearly defined not only at the initial stage, but also afterward, what each did. However, this is a defect of public bodies. . . you should have these agreements, twenty years pass, updated*" (translated from Italian).

On 20 March 2008, *Porta a Mare* transferred to *Società Porta Medicea srl* all the areas involved in the real estate project, with the obligation on the part of the purchaser to respect all the urban planning and contractual restrictions stipulated between the Municipality of Livorno and *STU Porta a Mare.* At the time of the purchase contract, *Società Porta Medicea* was 80% owned by *IGD.* On 30 March 2009, Azimut Benetti sold its shares in *Porta Medicea Srl* (20%) to *Cooperare Sviluppo S.p.A.* [54].

Two of the five phases of the project initially proposed have been completed. The *Piazza Mazzini* area was opened in 2014, while the *Officine Storiche* was opened in 2023 [56]. The other three areas—the *Molo Mediceo, Arsenale* area, and the *Lips* area—are still in the development phase and under review due to the pandemic period (IGD SiiQ, n.d.A).

Although the urban project, now under the responsibility of *Porta Medicea*—and therefore under the responsibility of *IGD*—has not yet been completed, the interviewees give the company a positive evaluation. Interviewee 05 states that "*IGD is a great structure of cooperatives in the world of Italian cooperatives. . . although IGD has not yet finished doing what it is supposed to do, because what has been accomplished is still a part of the total real estate operation and it will continue along with the construction of the Tourist Port*" (translated from Italian).

3.2.4. STU and Project Porta a Mare

Although not completely finished yet, the *STU* process and the urban regeneration carried out were evaluated positively by the interviewees, despite the presence of some aspects that could be improved. Interviewee 01 stated that "*it still hasn't gone, it's going well… in such a heavy process, however new activities have come into being because in any case, it has entered new inductees in those areas, so it has produced a by side of richness and redevelopment…*" (translated from Italian). The interviewee also referred to the importance of the opening of the waterfront for the city, stating that "*the Livornese slowly got to know more of the port side and was thus able to become known, to appropriate even a part of the territory from which he felt rejected… It was difficult to reach … had few desirable activities to take a walk that little went into the port. Instead now so many times they go for walks there*" (translated from Italian).

Some important criticisms were pointed out, especially regarding the urban and architectural results. Concerning the urban results, the connection between the regenerated area and its surroundings was pointed out as an aspect that could be better addressed, with reference to some urban mobility issues. Interviewee 03 referred to this aspect, stating that "*the main idea was valid, but if there was one thing that we needed to deepen, it was to frame it, in a more coherent way, with the external urban fabric, that is. I mean because of the rush to do it … but for example the relationship with the Waterfront, the minor boating, Mazzini Square, the city layout, the waterfront … make a more valid master plan on the waterfront*" (translated from Italian). Regarding the mobility, interviewee 04 pointed out that the area "*became a new polarity that wasn't there before… and this has impacted the viability*" (translated from Italian).

The architectural style adopted for the new buildings has been criticized, as it does not correspond to or relate to the historic buildings in the area, which feature very different styles and materials. On this point, interviewee 03 said that the project "*was quite innovative as an overall design, even as a destination of use. What I don't agree with is really the architectural choice and the execution*" (translated from Italian).

The amount of new construction, the number of new functions concentrated in a single area, and the absence of green spaces have also raised criticism. On this issue, interviewee 04 demonstrated concern about the issue, stating, "*I think there's too many functions all at once, too much density of functions and volumes… and I'm also a little afraid of whether it will continue to work or not… or whether at some point it will open up something somewhere else and no one will go there anymore*" (translated from Italian).

The absence of the tourist port is another important element, since the port would give more significance to the transformation that has taken place, as well as the new functions. Interviewee 05 strongly emphasized this issue: "*What is it that is not working? What is not working is the fact that, as of today, year 2025 open, the foundation stone has not yet been placed to build the tourist port, which is one of the essential components of this whole project. This project made sense because it was supposed to free up the Mediceo port, the older part and put in this big Marina that has been talked about in Livorno for 50 or 60 years, but the rhythms of this city and Italy are like that … that is, it takes years and years for any project and we are going through it*" (translated from Italian).

Finally, concerning the STU process, a very relevant criticism refers to the lack of involvement of the local population, for example, through participatory processes. The participatory process related to the *Porta a Mare* area was only carried out in 2015, when decisions about the *STU* and the project were already established and ongoing. The participatory process, called "*Il futuro è dietro la Porta! (a Mare)*" (The future is behind the Door! at sea), encouraged the citizens of Livorno to begin formulating strategies and operational projects for the development of the Porta a Mare area and the surrounding neighborhoods.

Interviewee 04 described the main moments during the participatory process, which included "*two walks, two workshops in the schools, the site survey, and then workshops—some reserved for technicians, so architects, engineers, geometers, and some reserved for citizens. And then the last ones were brought together, citizens and technicians*" (translated from Italian). The interviewee also summarized the objectives of the process: "*The initial claim was to understand what was happening in that area. The final one was instead to be able to make proposals*" (translated from Italian).

The results of the participatory process included 41 proposals, which were handed over to the municipality. Concerning the proposals and whether any changes were observed in the area as a result of the participatory process, the interviewee stated "*A little something, however, it is hard to say this came from that participatory path. I have in mind a very small and punctual intervention that is very significant, though, which restored the continuity of a pedestrian path. Now, I don't want to say that this is the impact, because it's actually a little more than that*" (translated from Italian).

Despite this, the interviewee highlighted an important impact of the process, stating that "*however, there has been a positive impact on citizens instead, because that pathway has given rise to many other small initiatives, even from the bottom up, of activities in the neighborhoods*" (translated from Italian).

4. Discussion

The analysis considered the external environment and the internal environment of the PPP project. The clusters and factors related to the external environment—enabling environment and exogenous factors—were used to discuss the Italian context concerning PPP arrangements. The clusters and factors related to the internal environment—preparatory phase, procurement phase, and contract management phase—were used to analyze the specific case of the urban regeneration project *Porta a Mare* and the *STU Porta a Mare*, the institutionalized PPP responsible for the project.

From the analysis, it was possible to identify the CSFs in the Italian context and in the case of the *Porta a Mare* PPP project, as well as the critical points that could be better developed to facilitate and improve the implementation and development of PPP arrangements and provide better value for money.

4.1. Italian Context

In the Italian context, the legal framework for PPP arrangements aligns with the European level regarding contractual and institutionalized PPPs. Additionally, a third category of PPP arrangements can be found in Italy—negotiable PPPs. In the field of urban regeneration, the legal framework is mostly developed at the regional level, which makes it difficult to achieve homogeneity at the national level.

Also concerning PPP arrangements in the Italian scenario, some elements are particularly noteworthy, as follows: the Department of Planning and Coordination of Economic Policy, as the agency responsible for ensuring support and assistance to the public sector in the development of PPP arrangements; the availability of a standard model for PPP contracts, and finally, the guidelines made available on the monitoring of PPP contracts. These elements assist the public sector in developing and implementing partnerships and strengthening its leadership.

However, it is important to note that the PPP standardization model is only designed for contractual PPPs. The lack of standardization of the process for institutionalized and negotiable PPPs is a weakness in the Italian context that deserves attention to improve these practices.

Regarding exogenous factors, the Italian financial and capital market is still limited, offering no diversified options. In addition, socio-economic factors differ greatly between Italian regions, especially in the north and south of the country. Community support, in turn, needs to be strengthened through the commitment of the public and private sectors. Finally, GDP per capita growth and inflation rates do not currently point to a macroeconomic scenario that favors the development of PPPs. In this sense, the scenario concerning exogenous factors is not favorable for the development and implementation of PPP arrangements and could hinder these practices.

4.2. "Porta a Mare" Case Study

Concerning the *STU Porta a Mare* and the different phases—the preparation phase, the procurement phase, and the contract management phase—some aspects should be highlighted.

As a result of the shipyard crisis, the public sector considered that a PPP agreement could be a solution for the area. In other words, the PPP arrangement proposed and established was clearly aimed at solving the problem of the crisis and the underutilized area resulting from the crisis.

Furthermore, with the division of the area into an industrial part (privately owned and managed) and an urban part (the object of the PPP arrangement), it was possible to return a waterfront area to the city. It should also be noted that the proposed division and new urban functions for the area were already under study and planned by the public administration, i.e., the use of a PPP arrangement was the means found to carry out previously planned intervention.

In this sense, the public sector was committed to the preparation phase. This commitment led to the dedication of professionals and a series of deliberations responsible for defining responsibilities and roles, the scope of the project, etc. Also important were the pre-feasibility studies carried out during the preparation phase, which later formed the basis of the company established.

Furthermore, the public sector's commitment is also reflected in the contracting phase and the speed with which the process was carried out. Despite this, it is important to note that the public sector has limited the private sector selection tender to only companies that own land within the perimeter of the project, or to companies in the process of acquiring land. This limitation compromises the transparency and competitiveness of the process.

In fact, the luxury yacht company Azimut Benetti was already established as a private partner before the selection notice, which was a mere formality as far as the process was concerned. Despite this, the selected private sector was also committed to the partnership, which reflects a good relationship between the parties.

The commitment of the public and private sectors is also evident in the contract management phase. The company Azimut Benetti solved the shipyard and jobs crisis in the industrial part (i.e., outside the *STU* area). The urban part, however, was transferred from the *STU Porta a Mare* to the *STU Porta Medicea*, under the responsibility of *IGD.* Although the entire project has not been completed, *Porta Medicea* and *IGD* remain committed to completing the regeneration of the area.

Public and private partners are very committed to its development concerning the PPP arrangement responsible for the *Porta a Mare* project. However, a critical point in the PPP process analyzed is the limitations regarding the choice of the private partner, which reduced the possibilities for other companies to participate and practically pushed for the choice of the Azimut Benetti company. Another important criticism is the lack of public participation, since public participation was only enabled in 2015, when the *STU* and the project were already well-defined.

From a project perspective, criticism has been expressed about the lack of connectivity and relationships between the new area and its surroundings, the new buildings' architecture, the excessive construction and new functions, and the absence of urban green space. Finally, the absence of the tourist port, which has not yet been built—and which would give more meaning to the whole proposed urban area—is also a critical point.

Despite this, overall, the *STU* and the *Porta a Mare* project have achieved important results. Firstly, the problems related to the shipyard crisis and the maintenance of jobs were solved, which was only possible with the selection of an economically strong private partner. A second positive aspect was the opening up of the city to the waterfront area, which until then had been reserved exclusively for industrial activity and closed in on itself.

5. Conclusions

Focusing on PPP arrangements in urban regeneration projects, this study analyzed the topic in the specific Italian context and the specific case of the *Porta a Mare* partnership in Livorno. Furthermore, it aimed to understand the CSFs in the Italian context and the case study, as well as the issues that could be improved.

To this end, the research was based on a pre-established framework of CSFs for PPPs in urban regeneration projects. The framework divides the external environment of the PPP arrangement and the internal environment, considering the different phases of the PPP project. Thus, this framework facilitates the analysis of the Italian context concerning PPP arrangements and the specific case study concerning the *Porta a Mare* partnership. To carry out the study, data were collected from official documents, laws and decrees, available academic literature, and promotional information. In addition, interviews were conducted with actors involved in the *Porta a Mare* PPP and project.

This study analyzes a specific context and case to better understand the best practices associated with PPP arrangements in urban regeneration projects. From a practical point of view, the analysis of the Italian context and the case of *Porta a Mare* emphasizes some elements that can be recommended to political decision-makers regarding PPP arrangements in urban regeneration projects.

Clear legal frameworks are important for developing an enabling environment for PPPs in urban regeneration projects. Specific agencies and documents that guarantee process standardization can also enhance the enabling environment. A clear legal framework, specific agencies for this purpose, and standardized processes help guarantee the public sector's leadership position.

Regarding PPP arrangements and the projects resulting from the partnership, it is important that there is a clear delimitation of the area to be managed and that there is in-depth knowledge of the area—even at a pre-contractual phase, it is important to understand all the needs to be addressed. Choosing a private partner that is strong enough to meet the needs of the project is crucial. Moreover, the leadership of the public sector in these processes is also crucial.

Strong public sector leadership must be attentive to the different interests of the parties involved and affected. The local population's involvement is important from the start of the process, helping understand the real needs of the area to be regenerated and producing benefits for everyone. Involving the different stakeholders also helps avoid conflicts. In the case of conflicts, there must also be effective management to prevent further damage to the process and the development of the project.

Finally, it is important to highlight that the success of a PPP arrangement in urban regeneration projects refers to different elements, including not only the management of the contract and its fulfillment, but also the urban, economic, and social outcomes

resulting from this process and the urban regeneration carried out. It is, therefore, a complex process, involving different areas of study that must be planned and developed by multidisciplinary teams.

Despite meeting the initial objective, the study has limitations. The first limitation concerns the availability of data that can be used for analyzing the different factors identified by the framework. Some factors are particularly difficult to analyze since not all the data are fully available or easy to identify. More subjective factors, such as good governance or open and constant communication among the stakeholders, are also not easily analyzed.

A second limitation refers to the analysis of only one partnership, which does not represent the entire country's context. Furthermore, using only one case does not effectively validate the pre-established framework, and it is necessary to apply it to other case studies.

Another limitation is the lack of quantitative data to reinforce the results obtained. The inclusion of quantitative data would be an asset to the analysis of the case study and the application of the framework.

A last limitation is that the project has not yet been fully completed. Nevertheless, so far, the case of *Porta a Mare* presents very interesting elements regarding PPP agreements in urban regeneration projects.

In this sense, future studies could apply the proposed framework to explore other partnerships or even other contexts, including using quantitative data or other qualitative data. The analysis of other contexts and specific cases will further expand knowledge about the implementation and management of this type of partnership, contributing to the achievement of better results from both a financial and a social point of view.

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Review

Building Urban Community Resilience against Hazards through Public-Private Partnerships: A Review of Critical Resilience Strategies

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Abstract: The need for governments and stakeholders to find urgent solutions to address the destructive effects of disasters in urban areas has led to the call for cross-sector collaborations such as public-private partnerships to assist with the development of urban community resilience in this modern era. This paper comprehensively reviews studies on the critical strategies in using public-private partnerships as a collaboration mechanism in building urban community resilience. Through a two-stage systematic literature review process, 83 publications related to PPPs and urban community resilience were retrieved for thorough content analysis. Based on an analysis of the literature, 35 critical resilience strategies for using PPPs in building urban community resilience were derived. These strategies were further categorized into nine major groupings. These groups include vulnerability and risks assessment, information gathering, database, legal, monitoring and evaluation, resilience capacity, communication and coordination, financial incentives, and business continuity. Furthermore, a theoretical framework was developed. These resilience strategies can be adopted by states and communities that intend to use the PPP concept to build the resilience of their urban communities. It also opens the international debate on the suitability of the PPP model for community resilience building.

Keywords: urban community; resilience; PPP; resilience strategies; systematic review

1. Introduction

The resilience of urban infrastructure is reflected in the continuity of key services and rapid recovery during disruptive events and unknown changes. Urban communities represent the synergistic blend between engineering, economic, and social structures [1]. Urban community resilience is the capacity of a community to adapt to change in ways that result in positive impacts on their wellbeing [2]. In recent years, cross-sector collaboration has advocated for including public-private partnerships (PPPs) in urban community resilience [1]. Chen et al. [3] also contends that PPPs are essential for preparing for, responding to, and recovering from large-scale natural disasters. In the United States, for instance, PPPs and resilience are closely linked to urban community resilience [4].

In this study, public-private partnership (PPP) is defined as a collaboration between the public and private sectors, working together to achieve a common goal while combining resources and sharing risks as well as benefits [5]. The PPP concept applied to resilience building and disaster management is slightly different from the usual PPP concept applied to infrastructure development and projects [6]. PPP for disaster management and resilience building focuses more on cross-collaboration on information, knowledge, and resources sharing [6]. In fact, PPP provides a positive strategic, operational. and tactical impact in

urban community resilience [4]. Reliance on PPP to build urban community resilience is due to the high proportion of privately owned critical infrastructure and the financial benefits that it generates [7]. Public- and private-sector institutions play critical roles in urban community resilience by enhancing community capacity and its critical infrastructure to adapt to disruptive events [8]. Essentially, a functioning partnership between the public and private sectors pools together diverse resources to enhance the preparation of urban communities and their infrastructure for their response and recovery from disasters [9,10]. Failing to utilize PPP mechanisms in developing urban community resilience could increase the post-disaster consequences because public sector institutions are largely incapable of handling and developing effective urban community resilience [1].

PPP has become critical in developing urban community resilience in the last few years. This is because, through collaborations between the public and private sectors, governments are able to better manage urban disruptions using technological innovations. Usually, the private sector possesses the technological skills required to respond quickly to urban disruptions and disasters, and this could be implemented through PPPs [11]. Importantly, with the increasing interest in PPPs in urban community resilience, many authors have attempted to explore some critical issues related to this field in the last decade. For example, Chi et al. [12] conducted research on partnerships for community resilience, garnering perspectives from the Los Angeles County community disaster resilience project. Hahn [13] also examined how public-private partnerships are useful for business continuity in urban communities. Marana et al. [14] developed a framework that defines and describes the successful characteristics of public-private-people partnerships (4P) in the city resilience-building process. They found 14 characteristics, including commitment, coordination, interdependence, trust, flexibility, user friendliness, etc. Cui and Li [15] measured community resilience using a social network analysis. Wang et al. [16] analyzed four exemplary cases of resilient urban communities while examining the resilient strategies of the urban communities. Onyeagoziri et al. [17] identified the mechanisms influencing the level of understanding of community resilience in a vulnerable community. Chen et al. [18] measured the comprehensive resilience level in different types of communities. Rapaport et al. [19] examined the extent of different forms of resilience among varying community types. Their study assessed five factors of perceived community resilience, including leadership, preparedness, collective efficacy, trust, and attachment to the place. Eadie and Su [20] explored the impact of disaster rehabilitation interventions on bonding social capital in a community in the Philippines. Nop and Thornton [21] explored the current climate-related hazards and their impacts on urban livelihoods in selected urban communities in Phnom Penh. The risks of climate-related hazards in Phnom Penh included heat waves, floods, storms, flooding, landslides, and vector-borne diseases. The impact of these hazards included health problems or disease, damage to infrastructure, damage to houses and other properties, loss of lives and jobs, and damage to crops and farms. Kammouh et al. [22] proposed an indicator-based method for measuring urban community resilience. In their study, the researchers developed a tool that can be used to quantify the resilience of urban communities using the PEOPLES framework structure. The tool was further tested using a case study. Mohamad et al. [23] used a qualitative approach to localize the resilience community indicators to measure the resilience level of the urban community. In their study, they developed resilience indicators based on three broad themes, namely social capital, environmental capital, and economic capital. These indicators were tested using a case study. Argyroudis and Mitoulis [24] investigated the vulnerability of urban critical infrastructure such as flood-critical bridges against unexpected hazards. The findings of the study provided reliable risk assessments of bridges against potential hazards. Similarly, adopting a case study (i.e., Californian highway bridges), Forcellini [25] also developed a model to assess the seismic resilience of bridges. Lastly, Osei-Kyei et al. [11] adopted a systematic literature review to explore the indicators of urban community resilience. However, the authors failed to investigate how PPP can be applied to urban community resilience. More importantly, the findings do not provide any

implications regarding the strategies to adopt when adopting PPPs for urban community resilience.

Although the findings of previous studies are useful, they fail to holistically investigate how the PPP concept can be applied to building urban community resilience. More importantly, past studies have failed to review and develop a clear set of strategies or best practices, which are critical for the development of urban community resilience through PPP. In fact, such research is imminent, considering the rise in unexpected urban events and disruptions. A detailed set of critical strategies for PPPs in building urban community resilience will provide clear directions and information to both governments and private stakeholders on how urban communities can continue to function after serious unexpected events. Currently, no study has conducted a comprehensive review to unravel the salient strategies required to build urban community resilience through PPPs.

Against this background, this study aims to systematically review and develop critical resilience strategies for building urban community resilience through public-private partnerships.

The findings of this study will inform policymakers and stakeholders of the salient strategies to implement to build urban community resilience against unexpected events such as pandemics. Furthermore, the findings of this study provide a solid theoretical foundation for the formulation of relevant hypotheses for future empirical investigations in urban community resilience through PPP.

Following the introduction section is the research methodology. The third section is the Results and Discussion. The fourth section is the conceptual framework. The fifth section describes the knowledge gaps and future directions. The last section is the Conclusions and Implications section.

2. Research Methodology

This study adopted the systematic literature review methodology used by Osei-Kyei and Chan [26], Akomea-Frimpong et al. [27], and Tijani et al. [28]. The systematic review method is adopted because it is the most suitable methodological approach to gain in-depth insights into an emerging research domain such as PPP in urban community resilience [29]. More importantly, the systematic review method uses a research protocol that reduces the effects of probabilities and increases the validity and authority of the evidence identified in the review [30].

Following the research methodology protocol adopted by Osei-Kyei and Chan [26], a systematic literature review was conducted to analyze the literature to assemble the critical resilience strategies that are useful for using PPPs to build urban community resilience. The Scopus online database was used to search for relevant literature because it covers a wide range of academic journals from different disciplines [31]. Notwithstanding, Scopus is by far the most used database for systematic literature reviews in construction management and PPP research ([26,27]). Therefore, it is considered suitable and appropriate to use this database in this research. Figure 1 shows the systematic review process adopted for this study. The figure shows two stages of the review process, i.e., Stage 1—literature selection and stage 2—analysis of the targeted papers. The details of the stages are explained below.

2.1. Stage 1—Literature Selection

The search for the literature was conducted in three phases in order to not miss any relevant publications. The first literature search employed keywords on urban community resilience and PPP. The second literature search employed keywords on urban resilience and resilience. The third literature search employed only keywords regarding PPP and critical success factors. The combinations of keywords for each literature search at each stage were used to identify any publications whose research contents could help in achieving the aim of this study. It should be mentioned that the key differences between the three literature search phases were the different keywords used for the search.

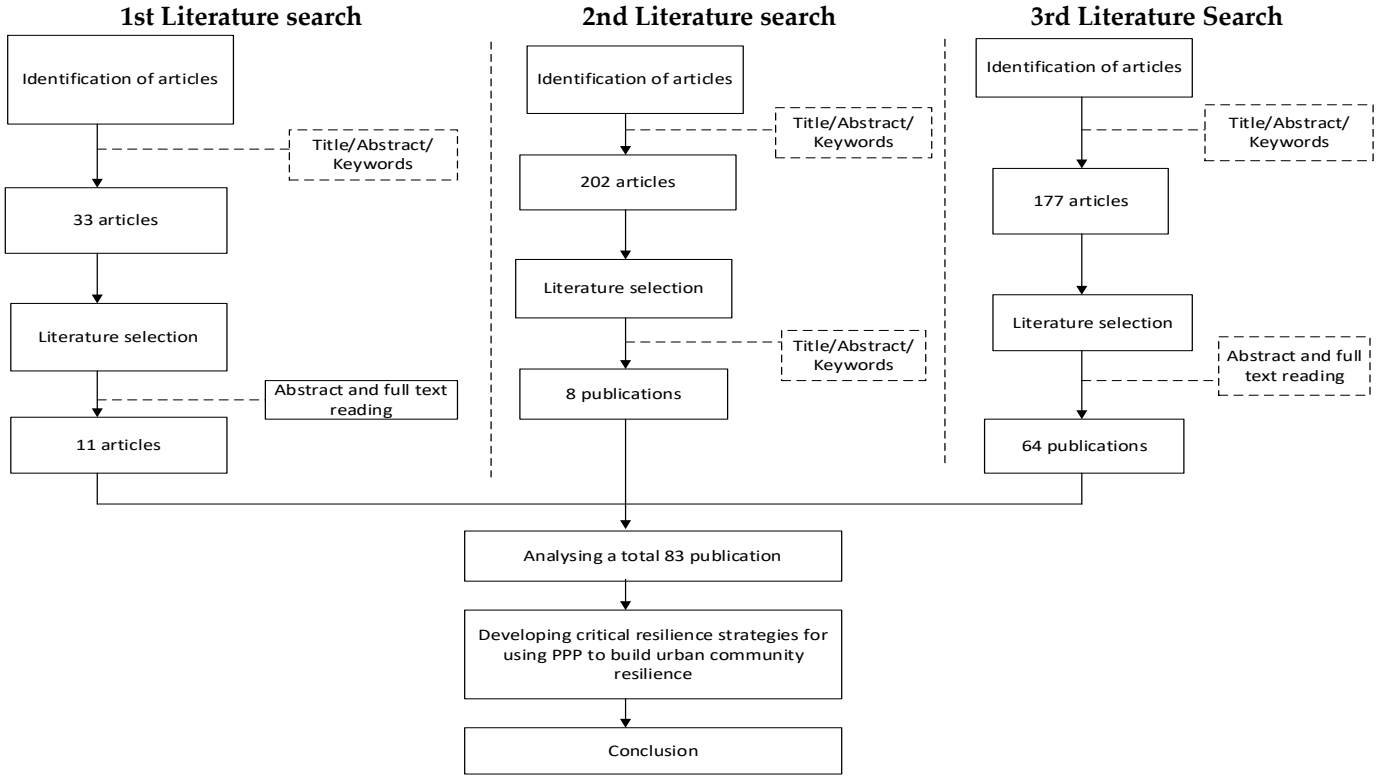

Figure 1. Research Process.

In the first literature search, the two research domains, i.e., PPP and urban community resilience, were put together to retrieve relevant publications for analysis. The title, abstract, and keywords (TAK) bar in the Scopus database was used for the literature search using relevant keywords. There were no year limitations. The full search code used was as follows: (TITLE-ABS-KEY ("public private partnership" OR "PPP") AND TITLE-ABS-KEY ("city resilience" OR "urban resilience" OR "community resilience") AND TITLE-ABS-KEY ("resilience" OR "resilience strategies" OR "resilience improvement measures" OR "policies")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p"))

This search code generated 34 documents. After reading the abstracts, introductions, and conclusions of the 34 papers, only 11 journal articles had their contents aligned to PPPs in urban community resilience.

In the second phase of the literature search, keywords grounded in only the urban community resilience research domain were used. The essence of this literature search was to identify any literature on urban community resilience that may have provided implications or recommendations relating to the use of PPPs as a mechanism to build urban community resilience. Also, this stage was critical to ensure that all relevant papers were included in this review study. The full search code used in the second stage of the literature search was as follows: (TITLE-ABS-KEY ("urban community") AND TITLE-ABS-KEY ("resilience" OR "resilience strategies" OR "resilience improvement measures" OR "resilience policies")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p"))

The search code generated 202 documents. Similar to the first literature search, after thoroughly reading the abstracts, introductions, and conclusions of the 202 publications, only 8 journal articles were relevant, as they provided some practical measures or recommendations for using PPPs to build urban community resilience. It should be emphasized that at this phase, many of the publications from the first search appeared in the second

literature search. Therefore, all the duplicated papers were removed to derive the final 8 journal articles.

A third literature search was conducted in which only PPP-related keywords were used. The keywords were restricted to "critical success factors". The understanding of critical resilience strategies in this study originates from the concept of critical success factors in PPP, where critical success factors are dependent factors that influence the likelihood of using the PPP mechanism in urban community resilience. The third search was conducted to identify any relevant papers that have discussed or investigated the critical success factors or strategies for PPPs. The search code used for the third stage of the literature search was as follows: (TITLE-ABS-KEY ("critical success factors") AND TITLE-ABS-KEY ("PPP" OR "public-private partnership" OR "public private partnership")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p"))

This search code generated 177 documents. Only 64 publications had research contents that were relevant to critical success factors for PPP.

It should be emphasized that the final papers selected in each of the three stages were based on a thorough review of the abstracts and conclusions in relation to the keywords used. Although a thorough search was conducted to retrieve relevant papers, it should be mentioned that not all publications may have been included in this study. This limitation has been highlighted in past papers that adopted systematic review methods; for example, see [26,28,32]. Notwithstanding, the large number of publications retrieved were enough to achieve the objectives of this study.

2.2. Stage 2—Analyzing Target Papers

Combining all the search results from Stage 1, a total of 83 publications were selected and subjected to thorough content analysis through full text reading to glean critical resilience strategies for using PPPs to build urban community resilience [32]. The target articles were selected based on their inherent features and characteristics to PPPs in urban community resilience. For instance, critical success factors in PPPs from the 3rd literature search that aligned with urban community resilience were retrieved. The list of 83 publications is detailed in Appendix A.

It should be mentioned that despite the wide coverage of the literature search in three different phases, some papers that may have mentioned PPPs in urban community resilience would have been missed. Therefore, the findings of this review paper should be interpreted within the context of the selected papers. Notwithstanding, this paper did not seek to review the entire population of papers on PPP in urban community resilience but rather to explore the salient strategies that are required for developing urban community resilience through PPP. Thus, the number of selected papers is considered adequate to draw meaningful conclusions for future reference.

3. Results and Discussion

3.1. Critical Resilience Strategies for Using PPPs as a Mechanism to Build Urban Community Resilience

Building community resilience is a complex and important task that requires effective partnerships [33]. Following a thorough content analysis of the 83 publications, a set of strategies that are relevant for building urban community resilience through PPP was developed. The strategies were developed based on the conclusions and findings of the selected 83 publications. First, relevant words and statements were retrieved based on the examination of the papers. Subsequently, the extracted items were coded, and similar coding patterns were grouped into relevant themes [27,32]. Table 1 shows the major groupings of the critical resilience strategies and their sub-factors from literature. The list of critical resilience strategies is directly applicable and has significant implications for urban community resilience. The developed critical resilience strategies for urban communities in Table 1 should guide stakeholders in ensuring that communities withstand and recover

from disruptive events. Subsequent sections discuss the major groupings for the list of critical resilience strategies.

Table 1. List of critical resilience strategies for PPPs in urban community resilience.

S/N	Category	Critical Resilience Strategies	Publications in Appendix A List
1	Vulnerability and risks assessment	Conduct community needs assessment	1
		Practice preparedness actions	4
		Vulnerability assessment	82
2	Information gathering	Provide homes in risk-prone areas with seals of approval or risk scores based on their susceptibility to different hazards	10
		Develop community maps delineating current and future risk	10
		Information accessibility	2, 6, 7
		knowledge co-production	8, 12
		Efforts to locally contextualize disaster management information, including greater understanding of local vulnerability and resilience	17, 81
		Develop community risk awareness program	9, 10
3	Database	Development of resource database	3, 4, 11
		Documentation and formalization of community-level disaster management planning, processes, and coordination within existing disaster management arrangements	9
		Enablement of community feedback and contribution to the development of a disaster management database	9,83
4	Legal	Reasonable legal framework	19–21, 23–31, 33–36, 39–50, 52–55, 59–63, 71–74, 77–79
		Stable political system	19, 21–23, 25, 26, 28, 29, 34, 38–40, 44–47, 49, 53–55, 58–63, 65, 67, 72, 75–77
		Credibility of government policies	18
		Governance and institutional capacity	15, 24, 28
		Well-structured legal dispute resolution mechanism	30, 32, 36
		Government support	24, 26, 33, 39, 72, 80
		Policy/strategy formulation	5
		Defined roles and responsibilities	7
		Well-structured PPP urban community resilience policy	38
		Clarity of roles and responsibilities among parties	23, 40
5	Monitoring and evaluation	Consistent urban community resilience performance monitoring	38, 39, 41, 46, 77, 57
		PPP agencies for monitoring and controlling	43
6	Resilience capacity	Qualified and skilled expertise are employed in the project service delivery	30
		Employment of highly skilled and competent workmanship in service operations	37, 38

Table 1. *Cont.*

S/N	Category	Critical Resilience Strategies	Publications in Appendix A List
7	Communication and coordination	Strengthening partnerships with non-governmental organizations	1, 6
		Shared responsibility	4
		Efficient communication and coordination	9, 11, 17
		Building information sharing platform	68
		Establish mechanisms for community input	1
		Publishing/disseminating the objectives, benefits, and implications of resilience strategies to all urban communities	22
8	Financial incentives	Financial support	4
		Insurance	10
9	Functional performance	Business continuity	3, 9

3.1.1. Vulnerability and Risks Assessment

Risk assessments involve identifying and understanding the vulnerabilities that urban communities are subjected to and identifying the proper measures to implement resilience strategies [34]. The critical resilience strategies in this category include conducting needs assessments; vulnerability assessments; practicing preparedness actions; and processing and coordinating within existing disaster management arrangements. In addressing the risks to urban communities, there is the need to identify the vulnerability of the urban communities before implementing the necessary adaptive capacity strategies [35]. For instance, a partnership between New Orleans, Veolia, and Swiss Re was formed to implement a urban resilience strategy [36]. The unique feature of the partnership between Veolia and Swiss Re in New Orleans was the assessment of critical infrastructure for vulnerabilities. A strategic roadmap with detailed action plan was subsequently developed to reduce the vulnerabilities and their impact in New Orleans [36]. A team of experts were commissioned to identify and quantify each site's vulnerabilities in terms of flood threat. Understanding the impacts of the cascading effects of disruptive events on urban communities is critical for planning urban community resilience [37]. A vulnerability assessment is a needs assessment that relates to the identification of long-term disruptive events and the implementation of risk-reduction strategies [38]. Proactive assessment of urban community susceptibility to disruptive events leads to the identification of the post-disaster actions that are important for recovery [39]. In the process of a needs assessment, different disruptive scenarios can be simulated to identify resilience gaps in urban communities [40]. Advanced simulation techniques for the scenario analysis add valuable insights about what could happen during the occurrence of disruptive events [34]. In addition, effort must be made to locally contextualize disaster management information and ensure the understanding of local vulnerability and resilience of the urban community. Modelling and simulation analyses provide the tools for the quantification of urban community resilience and allow for the evaluation and comparison of the effectiveness of different resilience strategies that are proposed to avoid and reduce the adverse consequences of disruptive events [34].

3.1.2. Information Gathering

The critical resilience strategies for this category include providing homes in risk-prone areas with seals of approval or risk scores based on their susceptibility to different hazards; knowledge co-production; developing community maps that delineate current and future risks of urban communities; information accessibility; efforts to locally con-

textualize disaster management information, including a greater understanding of local vulnerability and resilience; developing risk-awareness programs. Resilience capacity enhancement strategies must be identified and disseminated to the urban communities both the infrastructure operators and residential inhabitants [40]. Knowledge gained regarding risk hazards must include multi-hazard risk information identification to enhance interactions between scientists, municipal staff, and community members [37]. Multi-hazard risk mapping serves as a co-production activity and a medium for cross collaboration to occur between disciplinary boundaries and the boundaries of science and practice. The capacity of residents to respond to and recover from disaster requires that they have access to timely information about the threat and appropriate response mechanisms [41]. Information on vulnerable communities needs to be disseminated among the inhabitants [41]. Information gathering must be a continual effort to locally contextualize disaster management, including a greater understanding of local vulnerability and resilience [33]. Information sharing refers to the extent to which information is communicated to other partners, allowing task to be completed more effectively [14]. Public-private partnerships are a collective response to resilience-related issues in urban communities to help build the resilience of the urban community [42]. Clear communication protocols and timely notification of new or updated information among the public and private institutions and to the urban communities are valuable assets to urban community resilience [43]. This makes it possible to identify needs and resources that the urban communities require for timely intervention to reduce the impacts caused by any disruptive events [44].

3.1.3. Database

The critical resilience strategies for this category include the development of a resource database; the documentation and formalization of community-level disaster management planning, processes and coordination within existing disaster management arrangements; and the enablement of community feedback and contribution to the development of disaster management initiatives. A database may be developed to gather information on the urban community to identify the vulnerable group in the area [15]. The information gathered must be locally interpreted and disseminated [33]. Developing community maps that depict the current hazard hotspots in the community will inform stakeholders of the urban community on which resilience strategy will be appropriate [45]. Promoting risk understanding and acceptance of technical risk information is essential and must be undertaken by both the private and public sectors [45]. Historical event data collection in urban communities can support ex ante and ex post mitigations and decisions [46]. A catalogue of hazards and predicted hazards will require the public and private sectors to pool their resources together to develop it.

3.1.4. Legal

The critical resilience strategies within this category are a reasonable legal framework, a stable political system, the credibility of government policies, governance and institutional capacities, a well-structured legal dispute resolution mechanism, government support, policy/strategy formulation, a well-structured PPP urban community resilience policy, defined roles and responsibilities, and the clarity of the roles and responsibilities. Clear regulatory guidance defines the general regulations for the operational work of public and private sectors in urban community resilience [47]. Resilience policies need strong legal backing and political support to ensure their sustainability during a change in government [48]. In fact, the concept of PPPs in urban community resilience can only be successful if all stakeholders understand the positive impact of having legal regulation and are ready to invest resources into its development [49]. Also, defined roles and responsibilities for the public and private institutions in a partnership will help ensure decisive and timely responses to disruptive events [50]. In general, it should be emphasized that well-defined and updated legislation results in infrastructure that is safer and better prepared to prevent a crisis [51]. Furthermore, the public sector plays a significant role

in urban community resilience because it has the authority and capacity to increase the awareness of and commitment to resilience-building processes [51].

3.1.5. Monitoring and Evaluation

The critical resilience strategies for this category are consistent urban community resilience performance monitoring and instituting PPP agencies for monitoring and controlling. Setting up the sensors needed to gather information related to resilience in urban community is the main activity that should be carried out in monitoring any threats against the urban community [51]. Data acquisition and monitoring systems should be implemented throughout the infrastructure to gather information about the state of the infrastructure and to be able to anticipate an incident [51]. Strong monitoring and evaluation of urban infrastructure and systems will certainly ensure the timely prediction of any unexpected events. Furthermore, both the public and private sector can easily share information and knowledge on urban systems [52].

3.1.6. Resilience Capacity

Designing and constructing resilient infrastructure require the capacity of both the government and private sector in ensuring its success [52]. Trained personnel are a requisite in making critical infrastructure both resilient and adaptive to disruptive events [53]. Critical infrastructure operators in the urban community need to be trained to react to and control a disruption to maintain the continuity of essential services needed for the community [40]. Skilled personnel have the operational capacity to institute practices in urban communities that makes them ready to withstand or recover from disruptive events [38]. The coordinated efforts between public and private institutions may help to facilitate the immediate, medium-term, and long-term recovery of urban communities following a disaster [54]. The availability of skilled personnel will help urban communities return to pre-disaster levels of performance in a timely manner [55]. Community competence is the ability of urban communities to recognize, evaluate, and address emerging issues during disruptive events [10]. Community competence, coupled with the efforts of public and private institutions, can build the resilience of urban communities.

3.1.7. Communication and Coordination

The critical resilience strategies under this category include strengthening partnership with non-governmental organizations; efficient communication and coordination; shared responsibility; establishing mechanisms for community input; and publishing and disseminating the objectives, benefits, and implications of resilience strategies to an urban and building information sharing platform. Effective communication and coordination before any disruptive event can reduce the impact of disruptions on the urban community [40]. Engagement through public meetings and forums and daily contact with the community is a medium in which resilience strategies can be communicated. Greater integration of communities with public and private institutions can build trust and increase their participation in emergency preparedness activities [9]. Community collaboration, fostered with public-private collaboration, provides relevant social capital for communities to cope with disasters [15]. An integrated community emergency response command system will also yield positive benefits for the urban community. The responsibility of building the resilience of urban communities can be shared amongst public and private institutions within the community by coordinating roles among the community leaders. Kwok et al. [38] affirms the value of engaging local communities in understanding the broader scope of disaster risks and resilience. The urban communities must be included in critical decision makings about urban resilience [1]. Resilience gaps will not be addressed without cross-sector collaboration between public and private sectors [56]. The responsibility falls on government agencies to ensure an efficient coordination of the all stakeholders [57].

3.1.8. Financial Incentives

The efforts in building the resilience of urban communities must be supplemented with financial efforts [41]. Monetary resources are needed for urban resilience. In this regard, PPP offers the opportunity for public and private sectors to combine monetary resources for urban resilience [51]. In the context of this study, monetary resources are the necessary long-term funds or assets required to build urban community resilience through PPPs. These monetary resources should be available for long-term usage to ensure the effective adoption of PPPs in urban community resilience. In fact, without the necessary monetary resources and government policies such as financial incentives packages from the government, it will be difficult for the adoption of PPPs in urban community resilience to materialize. Generally, financing urban resilience is the responsibility of the government; however, public finances may be insufficient [36]. The availability of private-sector resources should be matched to relevant government financial resources to build enough systems to support urban disruptions and unexpected events [1]. Private developers must be financially incentivized to adopt resilience-based design standards. The relevant authorities should require resilience-based design standards and measurement systems to help in tracking the levels of resilience [56]. Misaligned incentives for risk reduction in urban communities may reduce the mitigation investments by business owners and inhabitants of urban communities [45]. Insurance can play an important role in communicating risks if property owners in urban communities are given information regarding their risk-based premiums [45]. Property owners in urban communities may be reluctant to invest in risk-reduction measures if the upfront costs may cause financial strain to the owners [45]. While requiring the public and private sectors to absorb some of the risk-reduction measures, property owners must be required to absorb some of the costs of risk reduction measures for disruption events.

3.1.9. Functional Performance

Business continuity plans must be developed for critical infrastructure within urban communities [58] to ensure continual service delivery for the urban community. Business continuity enables the stakeholders involved in the functional performance of critical infrastructure to be more confident when disruptive events occur and help identify where the plans are inadequate and could be improved. It also ensures the continual functioning of the communities, even amid disruptive events. The business continuity plans must be mandatory, which features the prevention and preparedness measures that infrastructure operators can rely on during disruptive events to ensure the infrastructure maintains functional performance during disruptive events and after disasters [59]. Public-private partnerships offer the ability to operationalize disaster management plans and business continuity for urban communities [1].

4. Theoretical Framework for Critical Resilience Strategies for Building Urban Community Resilience through PPPs

The diffusion of innovation involves communicating new ideas through certain channels [60]. The Rogers framework is an implementation framework that guides policy makers on how to implement the identified critical resilience strategies should they decide to use PPP to build urban community resilience. There are studies that have used Rogers' diffusion of innovation attributes to examine the implementation of technology, policies, etc. Gledson and Greenwood [61] used Rogers' innovation theory to investigate the adoption of 4D BIM in the UK construction industry. Ampratwum et al. [62] also used Rogers' innovation diffusion concept to develop a framework for the implementation of green certification of buildings in Ghana. Shibeika and Harty [63] drew upon the concept of Rogers' diffusion innovation theory in examining the diffusion of digital innovation in construction in the U.K. This section develops a theoretical framework using Rogers' [60] Diffusion of Innovation Theory and the critical resilience strategies developed in the literature. The list of developed critical resilience strategies is considered under the concept

of PPPs. This means the community must first accept PPPs as a medium to build urban resilience. There are studies that have acknowledged the importance of collaboration between public and private institutions to build urban community resilience. But how can this collaboration among stakeholders to build urban community resilience happen? By using Rogers' diffusion of innovation attributes, these identified critical resilience strategies in PPPs in building urban community resilience can be used to demonstrate their viability. In this theory, the factors influencing PPP adoption for urban community resilience are explored and infiltrated into the conceptual framework presented in Figure 2. These influencing factors include relative advantage, compatibility, complexity, trialability, and observability. As mentioned previously, the five factors are borrowed from Rogers' [60] Diffusion of Innovation Theory, and they are considered to be the perceived characteristics of an innovation that affects its adoption. Even though public-private partnerships are not a new concept, their usage in building urban community resilience may be described as a new concept.

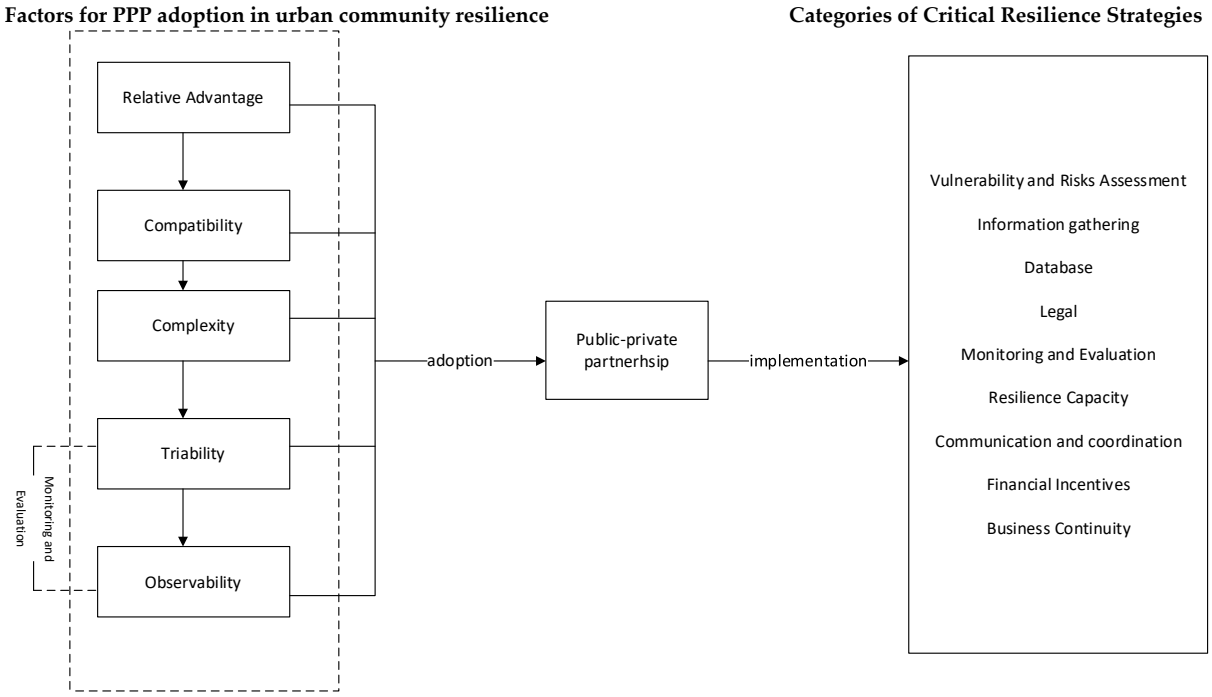

Figure 2. Conceptual framework for using PPPs in building urban community resilience.

The conceptualization of Rogers' [60] characteristics of innovation adoption for adopting PPPs to build urban community resilience has been discussed, as described below.

1. Relative advantage: The use of PPPs to build the resilience of urban communities must provide the potential of public and private institutions or agencies in partnership with the understanding that PPPs will yield fruitful results in urban community resilience rather than siloed efforts.
2. Compatibility: The use of PPPs in urban community resilience must be demonstrated to potential public and private institutions or agencies, showing that adopting the PPP strategy will yield the desired outcomes. It must be demonstrated to them how collaborating with each other will be consistent with the resilience gaps in their urban communities.
3. Complexity: The collaboration between the public and private institutions or agencies must not be complex. To increase the likelihood of collaboration between more public institutions and private agencies, the rules or responsibilities of each party need to be easily understood. In addition, the critical resilience strategies needed for using PPPs to build urban community resilience must be understood and easily implemented.

4. Trialability: Companies are more likely to invest in strategies that have been tested on a trial basis. An urban community can be selected for collaboration between public and private institutions or agencies on a trial basis. Under this collaborative PPP, the identified critical resilience strategies in this study can be replicated with constant monitoring and evaluation of the results. Positive outcome may increase the likelihood of other urban communities adopting PPPs to build the resilience of their urban communities.
5. Observability: Using PPPs as a medium to build urban community resilience needs to be presented in a way that the results will be recognizable to stakeholders. This implies that the public and other external stakeholders should be able to understand the benefits and relative advantages of adopting PPPs in building urban community resilience. Certainly, if the general community and external stakeholders can realize the benefits of PPPs in building urban community resilience, they will be willing to contribute and support the adoption of the PPP concept in building resilience.

5. Implications for Practice and Research

Practically, the outcomes of this study, particularly its strategies, will serve as a management decision guide for key decision makers and stakeholders with the responsibility of building urban community resilience.

First, it is recommended that both the public and private parties conduct a thorough risk assessment prior to the use of PPPs in urban community resilience. This is very important, because it will enable both parties to explore any potential setbacks affecting the partnership.

Second, governments should provide financial support in the form of tax rebates and incentives to the private sector for the building of community resilience in urban areas.

Lastly, information sharing and communication among parties are very critical to the effective adoption of PPPs in building urban community resilience. Essentially, the rapid sharing of information will lead to timely and quick responses to situations within urban communities.

For future research, the outcomes add to the urban community resilience literature by expanding discussions on the application of new partnerships and collaboration models or concepts such as PPPs in building disaster management and community resilience.

In addition, the findings provide a solid knowledge base for the formulation of hypotheses for future empirical research.

6. Conclusions

This study sought to explore the critical resilience strategies adopted when using PPPs as a medium to build urban community resilience. This study presented a systematic review of 83 articles to identify relevant strategies that align with critical resilience strategies in using PPPs to build urban community resilience. The aim of this study was to analyze the literature to assemble the critical resilience strategies useful in using PPPs to build urban community resilience. This study generated 35 critical resilience strategies, which were grouped into 9 categories. The categories included are vulnerability and risk assessments, information gathering, databases, legal, monitoring and evaluation, resilience capacity, communication and coordination, financial incentives, and business continuity. Using Rogers' theory of diffusion and its strategies, a conceptual model for adopting PPPs in urban community resilience was developed.

After a thorough analysis of the literature on PPPs in urban community resilience, the following are the limitations of this study and the proposed future research.

First, the critical resilience strategies identified in this study are yet to be empirically tested. Therefore, it is suggested that a mixed methodology using semi-structured interviews and questionnaire surveys should be adopted to explore the criticality of the nominated strategies. Furthermore, analytical techniques such as the fuzzy synthetic evaluation technique and structural equation modeling should be used for data analysis to

understand the relationship between the PPP adoption factors and the strategies. Also, the relationships among the strategies should also be examined.

Second, other critical issues such as risks allocation and performance assessment of PPPs for urban community resilience have been unexplored. These two critical concepts are essential in ensuring the successful implementation of PPPs in urban community resilience. Considering this, future research studies should explore the relationship between the critical strategies identified in this study and performance indicators of PPPs in urban community resilience.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. List of Selected Publications

S/N	Authors	Title	Year	Source Title
1	Chi G.C., Williams M., Chandra A., Plough A., Eisenman D.	Partnerships for community resilience: Perspectives from the Los Angeles County Community Disaster Resilience project	2015	Public Health
2	Maraña P., Labaka L., Sarriegi J.M.	We need them all: development of a public private people partnership to support a city resilience building process	2020	Technological Forecasting and Social Change
3	Daniel Hahn	How to create a public-private partnership: A replicable project associated with business continuity	2010	
4	Scott J., Coleman M.	Reaching the unreached: Building resilience through engagement with diverse communities	2016	Journal of business continuity & emergency planning
5	Budiati L.	Local leadership model towards a resilient city in Semarang municipality	2017	Planning Malaysia
6	Chandra A., Williams M., Plough A., Stayton A., Wells K.B., Horta M., Tang J.	Getting actionable about community resilience: The Los Angeles county community disaster resilience project	2013	American Journal of Public Health
7	Marana P., Labaka L., Sarrieg J.M.	A framework for public-private-people partnerships in the city resilience-building process	2018	Safety Science
8	Aguilar-Barajas I., Sisto N.P., Ramirez A.I., Magaña-Rueda V.	Building urban resilience and knowledge co-production in the face of weather hazards: flash floods in the Monterrey Metropolitan Area (Mexico)	2019	Environmental Science and Policy
9	Bajracharya B., Hastings P., Childs I., McNamee P.	Public-private partnership in disaster management: A case study of the Gold Coast	2012	Australian Journal of Emergency Management
10	Kousky C., Kunreuther H.	Risk Management Roles of the Public and Private Sector	2018	Risk Management and Insurance Review
11	Cui P., Li D.	A SNA-based methodology for measuring the community resilience from the perspective of social capitals: Take Nanjing, China as an example	2020	Sustainable Cities and Society
12	Bixler R.P., Yang E., Richter S.M., Coudert M.	Boundary crossing for urban community resilience: A social vulnerability and multi-hazard approach in Austin, TX, USA	2021	International Journal of Disaster Risk Reduction

S/N	Authors	Title	Year	Source Title
13	Wang Y.-C., Shen J.-K., Xiang W.-N., Wang J.-Q.	Identifying characteristics of resilient urban communities through a case study method	2018	Journal of Urban Management
14	Williams D.S., Máñez Costa M., Sutherland C., Celliers L., Scheffran J.	Vulnerability of informal settlements in the context of rapid urbanization and climate change	2019	Environment and Urbanization
15	Rodriquez C., Monteiro R., Ceresa P.	Assessing Seismic Social Vulnerability in Urban Centers—the Case-Study of Nablus, Palestine	2018	International Journal of Architectural Heritage
16	Onyeagoziri O.J., Shaw C., Ryan T.	A System Dynamics Approach for Understanding Community Resilience to Disaster Risk	2021	Jamba: Journal of Disaster Risk Studies
17	Chen Y., Liu T., Chen R., Zhao M.	Influence of the built environment on community flood resilience: Evidence from Nanjing City, China	2020	Sustainability (Switzerland)
18	Ullah F., Thaheem M.J., Sepasgozar S.M.E., Forcada N.	System Dynamics Model to Determine Concession Period of PPP Infrastructure Projects: Overarching Effects of Critical Success Factors	2018	Journal of Legal Affairs and Dispute Resolution in Engineering and Construction
19	Ahmadabadi A.A., Heravi G.	The effect of critical success factors on project success in Public-Private Partnership projects: A case study of highway projects in Iran	2019	Transport Policy
20	Wang Y.	Evolution of public-private partnership models in American toll road development: Learning based on public institutions' risk management	2015	International Journal of Project Management
21	Ng S.T., Wong Y.M.W., Wong J.M.W.	Factors influencing the success of PPP at feasibility stage -A tripartite comparison study in Hong Kong	2012	Habitat International
22	Zou W., Kumaraswamy M., Chung J., Wong J.	Identifying the critical success factors for relationship management in PPP projects	2014	International Journal of Project Management
23	Osei-Kyei R., Chan A.P.C.	Review of studies on the critical success factors for public-private partnership (PPP) projects from 1990 to 2013	2015	International Journal of Project Management
24	Mota J., Moreira A.C.	The importance of non-financial determinants on public-private partnerships in Europe	2015	International Journal of Project Management
25	Ngullie N., Maturi K.C., Kalamdhad A.S., Laishram B.	Critical success factors for PPP MSW projects — perception of different stakeholder groups in India	2021	Environmental Challenges
26	Zhang X.	Critical success factors for public-private partnerships in infrastructure development	2005	Journal of Construction Engineering and Management
27	Kwofie T.E., Afram S., Botchway E.	A critical success model for PPP public housing delivery in Ghana	2016	Built Environment Project and Asset Management
28	Almarri K., Boussabaine H.	Interdependency of the critical success factors and ex-post performance indicators of PPP projects	2017	Built Environment Project and Asset Management

S/N	Authors	Title	Year	Source Title
29	Babatunde S.O., Perera S., Zhou L., Udeaja C.	Stakeholder perceptions on critical success factors for public-private partnership projects in Nigeria	2016	Built Environment Project and Asset Management
30	Osei-Kyei R., Chan A.P.C., Ameyaw E.E.	A fuzzy synthetic evaluation analysis of operational management critical success factors for public-private partnership infrastructure projects	2017	Benchmarking
31	Babatunde S.O., Perera S., Zhou L.	Methodology for developing capability maturity levels for PPP stakeholder organisations using critical success factors	2016	Construction Innovation
32	Wang L., Zhang P., Zhang P., Li R., Zhang Y., Wu Y.	A systematic approach for public-private partnership projects CSFs evaluation	2018	Engineering, Construction and Architectural Management
33	Osei-Kyei R., Chan A.P.C.	Empirical comparison of critical success factors for public-private partnerships in developing and developed countries A case of Ghana and Hong Kong	2017	Engineering, Construction and Architectural Management
34	Babatunde S.O., Perera S.	Cross-sectional comparison of public-private partnerships in transport infrastructure development in Nigeria	2017	Engineering, Construction and Architectural Management
35	Ameyaw E.E., P.C. Chan A.	Critical success factors for public-private partnership in water supply projects	2016	Facilities
36	Osei-Kyei R., Chan A.P.C.	Perceptions of stakeholders on the critical success factors for operational management of public-private partnership projects	2017	Facilities
37	Alteneiji K., Alkass S., Abu Dabous S.	Critical success factors for public-private partnerships in affordable housing in the United Arab Emirates	2020	International Journal of Housing Markets and Analysis
38	Osei-Kyei R., Tam V., Ma M.	Effective strategies for developing retirement village public-private partnership	2021	International Journal of Housing Markets and Analysis
39	Ishawu M., Guangyu C., Adzimah E.D., Mohammed Aminu A.	Achieving value for money in waste management projects: determining the effectiveness of public-private partnership in Ghana	2020	International Journal of Managing Projects in Business
40	Dithebe K., Aigbavboa C.O., Thwala W.D.D., Hayhow S., Talebi S.	Stakeholder management in the alleviation of legal and regulatory disputes in public-private partnership projects in South Africa	2021	Journal of Engineering, Design and Technology
41	Kavishe N., Chileshe N.	Critical success factors in public-private partnerships (PPPs) on affordable housing schemes delivery in Tanzania: A qualitative study	2019	Journal of Facilities Management
42	Ameyaw E.E., Chan A.P.C., Owusu-Manu D.-G.	A survey of critical success factors for attracting private sector participation in water supply projects in developing countries	2017	Journal of Facilities Management
43	Dithebe K., Aigbavboa C.O., Thwala W.D., Oke A.E.	Factor analysis of critical success factors for water infrastructure projects delivered under public-private partnerships	2019	Journal of Financial Management of Property and Construction

S/N	Authors	Title	Year	Source Title
44	Węgrzyn J.	The perception of critical success factors for PPP projects in different stakeholder groups	2016	Entrepreneurial Business and Economics Review
45	Chan A.P.C., Lam P.T.I., Chan D.W.M., Cheung E., Ke Y.	Critical success factors for PPPs in infrastructure developments: Chinese perspective	2010	Journal of Construction Engineering and Management
46	Osei-Kyei R., Chan A.P.C.	Model for predicting the success of public-private partnership infrastructure projects in developing countries: a case of Ghana	2019	Architectural Engineering and Design Management
47	Kahwajian A., Baba S., Amudi O., Wanos M.	Identification of Critical Success Factors (CSFs) for Public Private Partnership (PPP) construction projects in Syria	2014	Jordan Journal of Civil Engineering
48	Almarri K., Boussabaine H.	The Influence of Critical Success Factors on Value for Money Viability Analysis in Public-private Partnership Projects	2017	Project Management Journal
49	Kuru K., Artan D.	A canvas model for risk assessment and performance estimation in public-private partnerships	2020	International Journal of Construction Management
50	Cheung E., Chan A.P.C., Lam P.T.I., Chan D.W.M., Ke Y.	A comparative study of critical success factors for public private partnerships (PPP) between Mainland China and the Hong Kong Special Administrative Region	2012	Facilities
51	Budayan C.	Analysis of critical success factors in public private partnership projects by triangulation method: Turkey perspective [Kamu özel sektör işbirliği ile yapılan projelerdeki kritik başarı faktörlerinin çeşitleme ile incelenmesi: Türkiye'deki inşaat sektörü perspektifi]	2018	Journal of the Faculty of Engineering and Architecture of Gazi University
52	Muhammad Z., Sik K.K., Johar F., Sabri S.	An overview of critical success factors of publicprivate partnership in the delivery of urban infrastructure and services	2016	Planning Malaysia
53	Debela G.Y.	Critical success factors (CSFs) of public-private partnership (PPP) road projects in Ethiopia	2019	International Journal of Construction Management
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