sustainability

MDPI

Article

Identifying Measures of Effective Risk Management for Public–Private Partnership Infrastructure Projects in Developing Countries

Khwaja Mateen Mazher [1,*], Albert P. C. Chan [2], Rafiq M. Choudhry [3], Hafiz Zahoor [4], David J. Edwards [5,6], Ahmed M. Ghaithan [1], Awsan Mohammed [1] and Mubashir Aziz [7,8]

1 Department of Construction Engineering and Management, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia
2 Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China
3 Construction Engineering and Management, Civil Engineering Department, College of Engineering, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh 11432, Saudi Arabia
4 College of Civil Engineering, National University of Sciences and Technology, Risalpur Campus, Nowshera 24080, Pakistan
5 School of Engineering and the Built Environment, Birmingham City University, Birmingham B4 7BD, UK
6 Faculty of Engineering and the Built Environment, University of Johannesburg, Doornfontein 2028, South Africa
7 Department of Civil and Environmental Engineering, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia
8 Interdisciplinary Research Center for Construction and Building Materials, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia
* Correspondence: khwaja.mazher@kfupm.edu.sa

Abstract: The inadequate risk management of public–private partnership (PPP) projects is a principal cause of project distress or failure. This research seeks to identify and empirically validate measures of effective risk management (ERM) in the context of PPPs in a developing country, a subject that has received scant attention in the extant literature. The research is based on a comprehensive literature review, expert interviews and a questionnaire survey. Mean score ranking and factor analysis were employed to rank and group the identified measures, respectively. Tests were performed to determine the respondents' agreement and establish the reliability and validity of the survey instrument. Analysis results indicate that all identified measures are important, are distributed over the entire project's life cycle and exhibit a multi-organizational focus. The most significant measures focus on PPP-specific artifacts and procurement activities that are vital for ERM. Factor analysis established six critical underlying dimensions for the ERM of PPP projects. The extracted factors generally acknowledge the need for expert public- and private-sector project stakeholders with mature organizational structures, business processes and relevant experience to successfully handle and deliver PPP projects. Furthermore, a comprehensive PPP policy and sound legal and regulatory frameworks are essential for supporting the ERM of PPP projects. The findings will enable a better understanding of factors that influence the quality and outcomes of risk management efforts and promote sustainable infrastructure development via PPPs, where the success of a project strongly relies on positively managing a project's risks in the economic and the social domains.

Keywords: public–private partnerships (PPP); effective risk management; construction project success; sustainable procurement

Citation: Mazher, K.M.; Chan, A.P.C.; Choudhry, R.M.; Zahoor, H.; Edwards, D.J.; Ghaithan, A.M.; Mohammed, A.; Aziz, M. Identifying Measures of Effective Risk Management for Public–Private Partnership Infrastructure Projects in Developing Countries. *Sustainability* **2022**, *14*, 14149. https://doi.org/10.3390/su142114149

Academic Editors: Cristina Coscia and Elena Fregonara

Received: 23 August 2022
Accepted: 24 October 2022
Published: 29 October 2022

1. Introduction

Risk is defined as an uncertain event or condition, the effect of which manifests as either benefit or loss to project objectives (e.g., scope, quality, cost and schedule) and to

specific individual, group or organizational objectives [1,2]. Construction projects are inherently complex and involve significant risks [3]. However, when compared with traditional procurement methods, PPP projects are riskier due to long concession periods, high capital investment, the complexity of contracts, the diversity of motives and interests of various project participants and nonrecourse financing arrangements [4,5]. Additionally, traditional risk management faces greater challenges due to the longer contract periods associated with long-term PPP projects in contrast with the short-term contract periods of traditional projects [6].

Existing literature specifies a systematic approach to implementing risk management and prescribes a range of guidelines, standard processes, tools and techniques to be adopted [2,7–9]. Yet despite all this existing knowledge, PPP projects have occasionally suffered failure due to poor risk management [10,11]. Inefficiencies leading to such outcomes can generally be traced back to individual risk management process (RMP) components and may be generated as a result of: the inadequate specification of risk within the contract; the lack of the identification of risks [12,13]; the poor assessment and allocation of risks [11–13]; re-allocation upon default of a party to shoulder a risk; the lack of contractually allocated risk enforcement in the event of the crystallization of a risk; and high transaction costs in determining the allocation of risks following a risk event [12]. Therefore, effective risk management is a significant driver of PPP project success [2,14,15]. Chapman and Ward [16] contended that ERM involves " . . . *doing the right things with respect to the risk management process (RMP) so that the project is risk efficient in the corporate sense and all other project objectives are achieved*".

Extant literature has identified several factors that may be significant for the ERM of PPP projects, such as: the risk management maturity of project stakeholders; experience delivering and managing projects under PPP arrangements; access to suitable risk mitigation resources; adequate dispute-resolution frameworks; and collaborative risk management [17–24]. These factors represent important environmental, organizational and project parameters and conditions that if absent in the context of a given PPP project can negatively influence the success of risk management efforts. Moreover, these and similar factors have either been reported individually or in clusters in separate studies. Nevertheless, such factors have not been studied comprehensively with the aim of suggesting significant factors that influence ERM in the context of PPPs. Furthermore, extant literature lacks detailed quantitative analysis and does not provide insights into the significance and grouping of factors to achieve ERM, especially in the context of developing countries and emerging markets for PPP infrastructure projects. Given this knowledge gap, this research aims to identify factors and underlying relationships between the factors that influence ERM (henceforth, the measures of ERM), i.e., enable the adequate deployment of the RMP, achieve both PPP stakeholders' and project objectives and promote sustainable infrastructure development.

2. PPP Risk Management Research

Existing literature reveals that PPP risk management has attracted substantial academic attention, where most research conducted focuses upon singular aspects of the generic risk management process including: risk identification and/or analysis [15,25–33] and response planning including risk allocation and mitigation [24,34–39]. A significant focus has been on the identification of risks, mitigation strategies and the development of models for estimating and prioritizing risks and for the assessment of response strategies to select the most efficient response. Fischer et al. [18] argued that in addition to the technical aspects of risk management in PPPs, managerial aspects of risk management also require greater consideration.

Beyond the traditional streams of research on risk management, as alluded to above, various sources have approached the so-called concept of ERM under various alternative themes. Choudhry and Iqbal [40] and Chileshe and Kikwasi [41] explored barriers to ERM and barriers to the implementation of risk assessment and management practices in the

construction industries in developing countries, respectively. The practice standard for project risk management by the project management institute (PMI) enlists various critical success factors (CSFs) for project risk management and each of its component processes [8]. Chileshe and Kikwasi [42] also investigated the CSFs for the deployment of risk assessment and management practices in the construction industry from the perspective of a developing country. Chinyio and Fergusson [43] explored various difficulties in risk analysis and management in private finance initiative (PFI) projects in the UK by interviewing industry experts and presented solutions. Ke et al. [44], while investigating the poor record of risk management on PPP projects in China, identified an absence of a risk management culture as a significant underlying factor. Loosemore and Cheung [11] criticized the traditional reductionist and linear risk management approaches to projects and discussed multiple failed PPP cases. Wibowo and Taufik [19] and Zhao et al. [45] worked towards developing models for the assessment of organizational risk management maturity in different settings. Jin and Zhang [36] studied critical uncertainty factors that influence efficient risk allocation on PPP projects. Marques and Berg [46] stressed efficient risk allocation for regulation by contracts in PPP projects, whereas Lee and Schaufelberger [47] identified main causes and consequences of risk mitigation failure in five case study PPP projects and suggested individual risk mitigation measures in the conclusion.

It is apparent from this review that few studies, if any, have explicitly addressed the issue of ERM holistically in the context of infrastructure PPPs while focusing on developing countries and emerging markets for PPP infrastructure projects. Thus, there is a need to uniquely identify the measures of ERM and assess their relative importance to determine the most significant measures. Furthermore, these measures need to be grouped in a systematic way to understand the principal dimensions of ERM for PPPs.

3. Measures of Effective Risk Management

A comprehensive literature review (and the content analysis of such) sought to understand and identify significant measures that may influence risk management outcomes on PPP projects, for which a diverse range of literature was scrutinized and synthesized (Table 1). The review revealed that substantial support was given to aspects of stakeholders' experience, capacity and maturity that can significantly influence the project's risk profile. In addition, collaboration among stakeholders to augment risk management has received noteworthy attention. Intra- and inter-organization risk communication and reporting are also considered critical for risk management to function optimally. Similarly, continuous commitment by all stakeholders to the risk management function has been advocated as essential. Because risks must be investigated from a life-cycle perspective in PPP projects, which are inextricably linked to projects' and stakeholders' objectives and requirements, a comprehensive risks and requirements evaluation is necessary where the adequate assessment of these risks is possible only by the application of appropriate tools and methods. Scholars have also emphasized the comprehensiveness and quality of project feasibility studies and the financial model. Multiple studies documented the importance of developing and maintaining a project risk management plan and adopting good project management practices. Risk management is also inextricably linked with the development and administration of a sound and clear contract document that protects the associated interests, which should be supported by an efficient negotiation process for incorporating all key stakeholders' perspectives. Reliable risk assessment and mitigation require multiple resources such as historical data, specialist consultants and advisors and risk mitigation instruments. Both the availability and reliability of these aforementioned resources may influence the prospects of ERM for projects. Learning from risks is an important aspect of improving risk management outcomes. Third-party/gateway reviews are also suggested to be valuable for curbing various potential biases (cognitive/motivational) and/or probable errors in project estimates that may undermine risk management outcomes for projects. Based on the review and semi-structured interviews (discussed later), a total of 30 measures for ERM were obtained (Table 2). A brief review of the extracted measures

reveals that the attributes are distributed over the entire project's life cycle and exhibit a multi-organizational focus.

Table 1. Reference source/type and frequency.

Publication Source/Type	Frequency
Journal of Construction Engineering and Management	12
International Journal of Project Management	6
Construction Management and Economics	6
Engineering, Construction and Architectural Management	2
Journal of Management in Engineering	2
Journal of Infrastructure Systems	2
Built Environment Project and Asset Management	2
Industrial Management and Data Systems	2
Journal of Financial Management of Property and Construction	2
Construction Innovation	1
Engineering Project Organization Journal	1
International Journal of Construction Management	1
International Journal of Sustainable Construction Engineering and Technology	1
Journal of Business Economics and Management	1
Journal of Civil Engineering and Management	1
Journal of Professional Issues in Engineering Education and Practice	1
Public Money & Management	1
Research in Engineering Design	1
Tsinghua Science & Technology	1
Conference papers	3
Books/book chapters	6
Theses	5
Reports and others (government + industry)	6
Total	66

Table 2. Measures of ERM with reference source and frequency.

ID	Measures of ERM	Reference Sources	No. of References
MERM_12	The risk management maturity of project stakeholders	[21,42,44,47–55]	12
MERM_22	A flexible and collaboration-supportive contract	[22,37,47,56–63]	11
MERM_17	Experience of the private partner in conducting similar projects	[7,10,20,21,48,49,64–66]	9
MERM_10	Risk communication and reporting	[8,22,48,67–72]	9
MERM_30	Stakeholders' risk management commitment	[8,12,21,43,48,50,53,72,73]	9
MERM_1	The identification of the project's and key stakeholders' objectives and requirements	[8,10,18,20,22,42,59,67,71]	9
MERM_8	The quality of the project's pre-feasibility/feasibility study	[46,65,67,71,74–77]	8
MERM_7	The adequate administration/management of the contract between the public and private sectors (concession agreement)	[18,46,50,57,58,67,74,78]	8
MERM_11	Collaborative risk management	[8,56,58,70,79–82]	8
MERM_18	Risk management personnel training and development	[41–44,48,72,78]	7
MERM_24	Increased confidence, trust and cooperation among the partners	[21,22,42,47,51,77,83]	7
MERM_4	Comprehensive life-cycle-based risk identification and assessment	[8,10,13,18,53,54,71]	7
MERM_5	Explicit risk allocation in the contract	[7,46,47,67,70,79]	6
MERM_26	Careful bid evaluation by the public authority	[10,46,59,65,74,81]	6
MERM_9	The quality of the project's financial model	[67,74,84–86]	5
MERM_16	The experience of the public sector in managing PPP projects	[23,48,77,87,88]	5
MERM_21	The consideration of interrelations between risks	[8,10,11,89,90]	5
MERM_29	Learning from risks	[50,59,81,91]	4
MERM_13	Third-party review	[53,58,74,75]	4
MERM_14	The experience, skills and maturity of financial institutions (debt/equity providers, insurance companies)	[18,50,58,69]	4
MERM_20	The availability of historical data on previous projects	[22,43,44,48]	4
MERM_6	Efficient contract negotiations	[7,18,20,67]	4
MERM_25	The availability of reliable specialist consultants/external advisors	[41,42,74,92]	4
MERM_19	The application of appropriate risk analysis tools and techniques (RATTs)	[10,42,44]	3
MERM_15	The availability of reliable risk mitigation tools and instruments (guarantees, insurances, hedges/swaps, etc.)	[17,22,50]	3
MERM_3	A comprehensive project risk management plan	[8,67,74]	3
MERM_2	A well-established project management scheme	[8,18,42]	3
MERM_28	Retaining the contract negotiation personnel for contract administration	[78,93]	2
MERM_23	The effectiveness of dispute resolution	[22]	1
MERM_27	Explicit risk pricing in the bid	[94]	1

4. Research Methodology

An exploratory, sequential, and mixed-methods design was adopted for this research [95]. Qualitative methods were first employed for the development of measures of ERM from the in-depth literature review and semi-structured interviews. This was followed by a quantitative questionnaire-based data collection approach in order to: determine the relative importance of the measures and establish underlying relationships, to reduce the number of measures [96,97].

4.1. Questionnaire and Sample

Semi-structured interviews were conducted with eight experts in Pakistan to identify factors that significantly influence risk management on projects, the ambition being to complement the literature review findings with expert opinion. These experts came from the public (5) and private (3) sectors, had 5–15 years' experience handling PPP power and transport infrastructure projects, and had undertaken various roles within the industry such as: deputy director; director; financial analyst; infrastructure specialist and chief operating officer. Keeping in view the experience of the interviewees in having managed or currently managing multiple projects and their representation of both public- and private-sector interests from multiple infrastructure sectors, the responses obtained were deemed sufficient. Due to restrictions on time and an inability to solicit the commitment of more experts, the interviews were limited to eight only. The interviewees suggested ten factors including: proper planning and joint risk management; experience and institutional capacity of the public/private sector in managing PPP projects; expertise of foreign financial institutions; public sector's contract administration skills (concession agreements); characteristics of the project sponsor (foreign/local, experience, risk attitude, capacity to absorb risks, etc.); the quality of feasibility studies; the availability of risk mitigation instruments; the availability of reliable historical data on projects; the development and use of comprehensive risk management plans; and the availability of reliable specialist consultants and advisors, as reported by Mazher et al. [98]. These identified factors concurred with the findings from the literature review. The draft questionnaire developed was piloted with and reviewed by five experts from the interview panel in order to ensure the comprehensiveness, suitability and adequacy of the questionnaire. Two other experts, one senior academic from Hong Kong with experience in PPP research and one industry expert representing a large-transaction advisory firm in Australia with 25 years of experience working on PPP projects, were invited to review and comment on the identified measures of ERM. The respondents broadly agreed with the relevance of the factors identified and suggested only minor revisions. The finalized questionnaire comprised multiple sections and included definitions for all identified measures of ERM to facilitate consistent understanding by the respondents. It was then distributed to PPP infrastructure experts in Pakistan for completion. Purposive sampling and semi-snowballing [99] were adopted to ensure that respondents had sufficient working experience (implementation and/or execution) on at least one PPP infrastructure project and possessed relevant exposure to dealing with PPP-specific transactions and risks incurred. This combined sampling approach suited the local context well as there were no comprehensive directories listing PPP experts and their attributes; therefore, referrals from purposively identified experts were used to expand the data collection envelope [14]. All the experts who participated in the interviews and those who responded to the survey did so voluntarily. Following ethical considerations, it was explicitly communicated to the experts that any data collected for the purpose of this research would be used for academic purposes only and that the identities of the participating experts would be kept anonymous.

4.2. Data Analysis

The software tool Statistical Package for Social Science (SPSS) v 23.0 was employed for various analyses such as mean score ranking, agreement analysis, tests for reliability and validity and factor analysis.

4.2.1. Mean Score Ranking

Mean score ranking (MSR) was employed to compute the relative importance of the measures of ERM. A 7-point Likert scale (where one is not important and seven is extremely important) was used for all items on the questionnaire [100].

4.2.2. Agreement Analysis

Since the total number of attributes being evaluated was more than seven, chi-square was used instead of Kendall's coefficient of concordance to determine the agreement between respondents [101]. Furthermore, in order to check the agreement in rankings between respondents from different sectors (public or private), Spearman's rank correlation coefficient was determined [23,25,42,97]. If the chi-square and test (r_s) coefficients are significant at or above critical values at a predetermined significance level (0.05), then there is no significant disagreement between the respondents both within a group and between the groups [101].

4.2.3. Factor Analysis

Factor analysis (FA) assists in identifying a smaller number of factors that can explain most of the variances observed by simplifying a larger matrix of correlations [102]. The appropriateness of applying FA for the extraction of factors was determined by evaluating multiple indices including: correlation coefficients; Bartlett's test of sphericity; an anti-image correlation matrix; and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (MSA) [103].

4.2.4. Reliability and Validity

It is important to establish the reliability and validity of a questionnaire instrument in research driven by questionnaire-based data collection. For internal consistency and reliability, Cronbach's coefficient test was applied [104]. According to Wong and Aspinwall [105], content validity cannot be judged numerically and can only be subjectively assessed by the researchers. Construct validity was established by testing the extracted factors for unifactoriality [106]. These approaches to testing reliability and validity were also adopted by Yang et al. [97].

5. Data Analysis and Results

5.1. Questionnaire Survey Results

In total, 140 questionnaires were distributed to experts who agreed to participate upon initial contact, and responses were collected via mail (post), e-mail and in-person. Some investigator-administered questionnaire sessions were also conducted to improve the response rate and obtain contextual details on how and why certain perceptions exist. In total, 90 completed questionnaires were received, giving a response rate of 64.3%. The response rate was deemed acceptable and in line with previous studies [23,25]. Table 3 reproduces respondent characteristics including designation, sector affiliation and years of experience. The participating experts belonged to a vast array of organizations including: PPP units (federal/provincial); public authorities; lending institutions; investors; consultants and project sponsors/companies. Nearly half, 47.8%, of experts had more than 5 years of working experience on PPP projects, while nearly 36% had processed 10 or more projects during their career. Given the inherent limitations of questionnaire surveys, diverse participation from an array of key PPP stakeholders, an acceptable response rate and the sufficient working experience of participants cumulatively support the authenticity and reliability of the survey responses.

Table 3. Experts' profile.

Attribute	Distribution	Frequency	Percentage (%)
Sector	Public	35	38.83
	Private	55	61.17
Total		90	100
Years of experience (working and/or research in PPPs)	Less than or equal to 5	47	52.20
	6–10	21	23.30
	11–15	12	13.30
	16–20	7	7.78
	21 and above	3	3.33
Total		90	100
Number of PPP projects handled			
	Less than 10	58	64.44
	More than or equal to 10	32	35.56
Total		90	100

5.2. Descriptive Statistics and Agreement Analysis for Measures of ERM

The data collected on rankings of the measures of ERM was subjected to MSR analysis to obtain the relative importance of the measures and determine the most significant measures. Table 4 illustrates that all of the identified measures were ranked from moderately to extremely important (on average), while no measure was rated less important (on average). Quality of the project's financial model (MERM_9) was ranked as the most significant measure for ERM, whereas a flexible and collaboration supportive contract (MERM_22) received the lowest rating of 4.87. The adequate administration/management of the contract between the public and private sectors (concession agreement) (MERM_7), a comprehensive project risk management plan (MERM_3), the identification of the project's and key stakeholders' objectives and requirements (MERM_1), careful bid evaluation by the public sector (MERM_26) and efficient contract negotiations (MERM_6) are other measures that received an average rating of at least very important (6). Comparisons of chi-square (442.441) and Spearman's rank correlation (0.827) coefficients (at 0.05 significance), with critical values of 42.557 and 0.306, respectively (at 29 degrees of freedom), indicated consistency among the respondents and a consensus among the public- and private-sector respondents on the rankings and thus the significance of the measures of ERM.

Table 4. Descriptive statistics of the measures of ERM.

Identifier	Measures	Mean	Standard Deviation	Rank
MERM_9	The quality of the project's financial model	6.18	1.03	1
MERM_7	The adequate administration/management of the contract between the public and private sectors (concession agreement)	6.07	0.92	2
MERM_3	A comprehensive project risk management plan	6.04	0.85	3
MERM_1	The identification of a project's and key stakeholders' objectives and requirements	6.04	1.14	4
MERM_26	Careful bid evaluation by the public sector	6.02	1.01	5
MERM_6	Efficient contract negotiations	6.01	0.95	6
MERM_5	Explicit risk allocation in the contract	5.96	0.91	7
MERM_2	A well-established project management scheme	5.87	0.99	8
MERM_8	The quality of project's pre-feasibility/feasibility study	5.83	1.22	9
MERM_17	The experience of the private partner in conducting similar projects	5.76	0.98	10
MERM_23	The effectiveness of dispute resolution	5.74	0.94	11
MERM_14	The experience, skills and maturity of financial institutions (debt/equity providers, insurance companies)	5.73	1.12	12
MERM_24	Increased confidence, trust, and cooperation among parties	5.72	1.03	13
MERM_25	The availability of reliable specialist consultants/external advisors	5.70	0.94	14
MERM_4	Comprehensive life-cycle-based risk identification and assessment	5.57	1.11	15
MERM_15	The availability of reliable of risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)	5.56	0.90	16
MERM_29	Learning from risks	5.50	0.97	17
MERM_27	Explicit risk pricing in the bid	5.44	1.07	18
MERM_12	The risk management maturity of project stakeholders	5.43	0.81	19
MERM_11	Collaborative risk management	5.43	0.93	20
MERM_10	Risk communication and reporting	5.41	0.91	21
MERM_16	The experience of the public sector in managing PPP projects	5.36	1.22	22
MERM_30	Each stakeholder's risk management commitment	5.30	1.03	23
MERM_28	Retaining the contract negotiation team for contract administration	5.24	1.21	24
MERM_18	Risk management personnel training and development	5.23	1.08	25

Table 4. *Cont.*

Identifier	Measures	Mean	Standard Deviation	Rank
MERM_21	The consideration of interrelation between risks	5.11	0.90	26
MERM_19	The application of appropriate risk analysis tools and techniques (RATT's)	5.03	1.08	27
MERM_20	The availability of historical data on previous projects	5.02	0.98	28
MERM_13	Third-party review	4.98	1.02	29
MERM_22	Flexible and collaboration supportive contract	4.87	1.04	30

5.3. Factor Analysis for Measures of ERM

To reduce the large number of measures into fewer independent factor groups or components, FA was performed. Correlation coefficients for most of the measures were found to be above 0.3, ensuring sufficient interrelationships [103]. Bartlett's test of sphericity returned a large value of 1553.67 (at $p = 0.000$), and the KMO measure of sampling adequacy was 0.753, which is considered acceptable and provides evidence of factorability [107]. The MSA values on the diagonal of the anti-image correlation matrix were also found to be higher than 0.5 and ranged from 0.544 to 0.903, thus obviating the need to remove any factors. A clean solution was obtained with a 6-factor model that had a low number of cross-loadings, individual factor loadings above 0.3 and factor groups containing at least 3 items. The factor loading cut-off point is usually set at 0.4; however, for more significant factors, a cut-off at 0.5 was set. The extracted factor model explained 62.471% of total variance. Table 5 reports upon the six factor groups along with their component factors, factor loadings, eigenvalues and other attributes.

Table 5. Results of factor analysis.

Identifier	Factor Loading	% of Variance Explained	% of Variance Explained (Cumulative)
ERM factor group 1: Knowledge driven risk management			
MERM_28 Retaining the contract negotiation team for contract administration	0.758	32.723	32.723
MERM_30 Stakeholder's risk management commitment	0.720		
MERM_29 Learning from risks	0.682		
MERM_25 The availability of reliable specialist consultants/external advisors	0.659		
ERM factor group 2: Comprehensive requirements and risks evaluation			
MERM_26 Careful bid evaluation by the public sector	0.797	8.409	41.132
MERM_9 The quality of the project's financial model	0.723		
MERM_1 The identification of the project's and key stakeholders' objectives and requirements	0.573		
MERM_12 The risk management maturity of project stakeholders	0.572		
ERM factor group 3: Public sector risk management			
MERM_27 Explicit risk pricing in the bid	0.789	6.799	47.931
MERM_13 Third-party review	0.686		
MERM_16 The experience of the public sector in managing PPP projects	0.667		
ERM factor group 4: Risk assessment quality			
MERM_20 The availability of historical data on previous projects	0.767	5.412	53.343
MERM_18 Risk management personnel training and development	0.728		
MERM_10 Risk communication and reporting	0.622		
MERM_8 The quality of a project's pre-feasibility/feasibility study	0.587		
MERM_19 The application of appropriate risk analysis tools and techniques (RATTs)	0.525		
ERM factor group 5: Post-contract risk management			
MERM_22 Flexible and collaboration supportive contract	0.766	4.873	58.216
MERM_23 The effectiveness of dispute resolution	0.735		
MERM_24 Increased confidence, trust, and cooperation among parties	0.597		
MERM_15 The availability of reliable of risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)	0.555		
MERM_11 Collaborative risk management	0.504		
ERM factor group 6: Well documented structured management approach			
MERM_2 A well-established project management scheme	0.789	4.255	62.471
MERM_7 The adequate administration/management of the contract between the public and private sectors (concession agreement)	0.573		
MERM_3 A comprehensive project risk management plan	0.553		
MERM_6 Efficient contract negotiations	0.524		

5.4. Reliability and Validity Test for Factor Analysis

The overall Cronbach's alpha was 0.926, indicating the good internal consistency and reliability of the instrument since values above 0.7 are regarded as sufficient [104]. Content validity was confirmed by conducting a detailed literature review, semi-structured interviews and a pilot study in order to merge expert experience with the information extracted from the published literature. Construct validity was established by subjecting each extracted component to FA individually. If all the variables form a single factor again, then the factor is valid as a construct [106]. All six extracted factors were demonstrated to be unifactorial with satisfactory KMO values and a significant percentage of variance explained. In addition, internal consistencies of the extracted factors were also evaluated using Cronbach's alpha, and all the values exceeded 0.7 (Table 6).

Table 6. Unifactorial test.

Identifier	Number of Variables	KMO	Eigenvalue	Variance Explained (%)	Cronbach Alpha
ERM factor group 1: Knowledge driven risk management	4	0.792	2.498	62.441	0.797
ERM factor group 2: Comprehensive requirements and risks evaluation	4	0.732	2.320	57.996	0.752
ERM factor group 3: Public sector risk management	3	0.661	1.944	64.805	0.726
ERM factor group 4: Risk assessment quality	5	0.823	2.944	58.881	0.819
ERM factor group 5: Post-contract risk management	4	0.702	2.518	50.360	0.799
ERM factor group 6: Well documented structured management approach	3	0.737	2.434	60.839	0.783

6. Discussion

The MSR results show a strong perception of Pakistani PPP experts towards the importance of measures of ERM. All the identified measures were ranked from moderate to extremely important (on average) for the ERM of PPP infrastructure projects. The Pakistani PPP market is dominated with projects in the power generation and highway infrastructure sectors [108]. The knowledge, experience and maturity of public- and private-sector stakeholders to sustainably implement and manage PPP projects vary considerably across different regions and different infrastructure sectors (economic and social) and subsectors (energy, municipal solid waste, transport, water and sewerage, etc.). Similarly, there may be difficulties in accessing essential resources for ERM in terms of historical performance data on PPP projects, reliable specialist consultants/external advisors, essential regulations and institutional frameworks, and risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.). This may be an issue for the ERM of PPP projects in Pakistan because ERM measures that pertain to the knowledge, experience and maturity of public- and private-sector stakeholders and the availability of essential resources all rank high for enabling ERM. The Infrascope index [109–111], which evaluates the capability of countries to implement efficient and sustainable infrastructure PPPs, ranks many developing countries in the low-maturity performance categories, including Pakistan. The index is based on the evaluation of several indicators in five key domains including an assessment of enabling laws and regulations, institutional frameworks, transparency and accountability and the maturity and experience of governments with PPPs and finance, among others. Issues with any shortfalls in these domains/indicators are now known to be impediments to the ERM of PPPs. This conclusion is based on the findings from the reviewed literature and the survey conducted for this research. It can be argued that many of these indicators overlap with ERM measures identified in this research; therefore, by extension, it can be safely assumed that similar perceptions of the importance of the measures of ERM will exist in other developing countries as well. For mature countries/markets, the perceptions of PPP

experts of the importance of the ERM measures are expected to be different. This may be attributable to the differences in the nature of challenges faced in the implementation of efficient and sustainable infrastructure PPPs in developed countries/markets.

The FA resulted in identifying six critical underlying dimensions for the ERM of PPP projects. It is clear from the results that the implementation of risk management processes alone by each stakeholder may not maintain a project that is well shielded from the effects of risks. In the absence of: deep knowledge of critical project aspects, the comprehensive understanding of stakeholder requirements, a mature public-sector client, the availability of resources for high-quality risk assessments, adequate mechanisms for post-contract risk management and mature business processes of project stakeholders, the superficial risk management application by key stakeholders will lead to suboptimal decisions and leave the project exposed to the effects of risks over its life cycle. The underlying dimensions originating from the FA are prescriptive in nature (explained later), as these dimensions suggest essential requirements for the ERM of PPPs. Therefore, the outcomes of the FA may be generalized in a broader sense and may be applicable and interpreted beyond the confines of any specific country/PPP market boundaries.

6.1. ERM Factor Group 1: Knowledge Driven Risk Management

This factor group explains 32.723 percent of the total variance in the FA and consists of 4 factors. Knowledge of various aspects of the project is the key to achieving ERM outcomes. The requisite knowledge may be either tacit or explicit in nature, and it may be leveraged from different sources. Longer contract periods associated with long-term PPP projects, usually spanning several decades, lead to complications in developing a structured and accessible memory of all project events. Knowledge pertaining to identified risks and formally approved risk management strategies resides in written contracts, risk registers and other forms of formal project documentation. However, the backend inter- and intra-stakeholder negotiations (between the public-sector client, equity investors/sponsors, debt financiers, design and/or construction contractors and subcontractors, operators, etc.), meetings, discussions and any short- and long-term commitments made are not always well documented and/or communicated. Moreover, the personal experiences of the project officials and stakeholders and any contextual learning about a project's issues and circumstances occurs over the life cycle of the project, most of which cannot be effectively documented and/or transferred. All of this knowledge is vital in supporting the critical risk management processes of risk planning and risk monitoring and control. Thus, the continuity of the project team may be the only viable solution.

From an organizational perspective, retaining project procurement officials for project implementation may be important when focusing on the tacit knowledge aspect of the project. From a long-term and explicit knowledge perspective, PPP project organizations including the public-sector client and the consortium members must enable systematic learning from projects to capture and learn from experiences and become effective for risk management on projects. Robinson et al. [112] and Virginia Public–Private Partnerships [9] stressed the importance of knowledge transfer and capturing and feedback lessons learned, respectively, in order to strengthen the risk management function for PFI/PPP projects. A more superior source of knowledge that may be leveraged for ERM is reliable external legal, technical and financial consultants/advisors who can bring their vast experience of working with similar projects. This may be especially beneficial for countries with limited experience with private investment in public infrastructure development. Asenova and Beck [92] contended that financial risk analysis in PFI (or PPP) projects relies heavily on external advisors, but occasionally their lack of experience and/or communication problems led to a lack of satisfaction with the information provided by them.

6.2. ERM Factor Group 2: Comprehensive Requirements and Risks Evaluation

This factor group accounts for 8.409 percent of the total variance in the analysis and comprises 4 factors. PPP projects are composed of a large team of primary stakeholders

and influence a vast array of secondary stakeholders because these projects primarily exist for providing public services. Hence, the adequate development of all objectives and requirements by all the primary stakeholders to define and deliver true value is a challenging task. It is also essential because risks are inherently linked to the identified objectives and requirements. Consultation with stakeholders may serve as an important source of information and can assist the government authority as it may potentially improve risk outcomes and assist in risk–response planning and control [9,113]. The realization of these objectives is linked to the RMPs through predefined success criteria [67]. Organizations with a high level of risk management maturity (and concomitant policies and processes) can better identify and assess the requirements and their associated risks effectively.

The careful evaluation of the expression of interest and tenders by the public sector is also necessary for establishing the financial and technical capabilities of the consortium along with the level of understanding of the client's requirements and to assess the consortium's risk management capabilities [67,114]. The financial model is used for preliminary due diligence by lenders and also assists relevant stakeholders in: analyzing the impact of risks; assessing a project's returns, cash flows and financial robustness; negotiating risk allocation among the parties and monitoring the PPP project over the concession period [85,115].

6.3. ERM Factor Group 3: Public Sector Risk Management

This factor group explains 6.799 percent of the total variance with 3 factors. The public-sector client, being the main stakeholder in PPP projects, significantly controls the risk management performance on PPP projects because risk management starts with them. It is the client that lays the foundation of the project risk management framework in the project contract. At the time of structuring contracts for PPP projects, it is decided which risks will be retained by the public sector. The public-sector client can effectively decide on risk transfer implications if the private sector can explicitly and separately price risks in their tenders that they consider unsuitable for transfer to them [94]. It is also possible that a lack of experience and knowledge of the public-sector client (in PPP-based project delivery) may result in a poor evaluation of a project's actual risk exposure and the acceptance of unwanted risks to attract investment, resulting in higher cost to the government and default on payments [23]. Apart from the issue of proper risk structuring, the motivation of a government in pursuing PPP projects may be questionable. Bruzelius et al. [116] and Matsumoto [58] argued that politicians can have an influence in biasing forecasts (in feasibility studies for project selection) to support project approvals. This directly impacts the management of risks. Accountability and transparency can be enhanced by providing detailed audit points at each stage of a PPP project life cycle and by specifying third-party evaluations, " . . . *thereby preventing sloppy risk management and opaque decision-making processes*" by concerned government organizations [58]. Experience delivering PPP projects and comprehensive frameworks for accountability and transparency takes time and effort to develop and mature; therefore, these are well-anticipated challenges for emerging PPP markets and developing economies.

6.4. ERM Factor Group 4: Risk Assessment Quality

This factor group explains 5.412 percent of the total variance in the analysis and includes 5 factors. Another important underlying dimension for ERM is the quality of risk assessment, which requires objective and reliable data and trained risk analysts who know what they are doing when it comes to PPP projects. The quality of risk assessments will depend on: the quality of the input data and information; the nature of assumptions made in the analysis; the tools employed; and the availability of knowledge and skills to make the best use of the available resources and methods. Chinyio and Fergusson [43] argued that training programs, conferences and seminars can help organizations to enhance their risk assessment skills and could overcome the limited supply of experts on PFI (or PPP) risk assessment. This may be especially true for PPPs in emerging markets. Another issue,

again more applicable to emerging PPP markets, is the lack of availability of historical data on previous projects. This poses a significant hurdle as it leads to the inadequate modeling and analysis of risks [15,43]. Apart from the issue of the lack of historical data, poor and biased technical feasibility, social and environmental sustainability assessments provide a poor basis for risk analysis. Kumaraswamy and Morris [76] and Ng and Loosemore [71] presented multiple case studies of PPP projects whose failure was attributed in part to overly optimistic feasibility studies.

6.5. ERM Factor Group 5: Post-Contract Risk Management

The total variance explained by this factor group amounts to 4.873 percent, and it is composed of 5 factors that are relevant to post-contract risk management. The contract administration of PPP projects spans long periods of time, usually amounting to decades. This long-term nature of PPP contracts calls for special attention to the programming of informal and formal interparty relationships to support joint risk management. Moreover, risk management at the post-contract stage can be more effective if the PPP projects are supported by well-established and transparent legal and regulatory frameworks and assistance from mature financial institutions, both of which can provide cover to contractual parties from excessive and uncertain risk exposure. Changes in a PPP contract may be initiated as a result of modifications in laws and regulations, private-partner-initiated modifications, project enhancements or revisions in service requirements [57]. Therefore, PPP contracts should be flexible with an aim to provide options for adjustments in face of future uncertainty [113,115] and carefully manage the risk exposure of contractual parties. In case of a failure of the contractual mechanisms to address a change, options available for conflict and dispute resolution will aim to redistribute the risks among contractual partners. Here, the comprehensiveness of the applicable legal and regulatory frameworks to a project will ensure fair and equitable resolutions and the fair sharing of risks and rewards. Doloi [83] contended that levels of trust and confidence among parties influence the joint management of risks. Hence, increased confidence, trust and cooperation among parties may go a long way towards enabling ERM on projects.

Risk mitigation instruments such as hedging instruments, credit/export credit guarantees and political risk insurance are used as risk transfer strategies at the post-contract stage; however, their availability and associated costs depend upon a variety of factors that may become an important consideration for ERM [117,118]. This factor could be of particular concern for PPP projects in emerging markets and developing economies.

6.6. ERM Factor Group 6: Well Documented Structured Management Approach

This factor group accommodates four factors and accounts for 4.255 percent of the total variance in FA. This last factor group calls attention to an overall mature management approach by both the public- and the private-sector project stakeholders. This is important because the management and the administrative frameworks of the project stakeholders' enterprises act as a container for the individual risk management processes. Fischer et al. [18] argued that risk management can only operate effectively as part of a well-established project management scheme. RMPs do not operate in siloes as they interact with other project management processes to obtain inputs and provide outputs. Any strategies made to counter and contain the impacts of risks are documented in the risk management plan and the contracts and later enforced via contracts to ensure protection against risk exposure. For the purpose of establishing these contracts, efficient contract negotiations become important in the context of equitable sharing of risks and rewards. Each party needs to appreciate and understand the interests of and risks to others to conduct efficient negotiations [18]. Not being able to implement an effective contract management strategy is a project risk in itself, and many parties fail at it; hence, it must be managed to avoid failure in meeting contractual obligations [119].

7. Conclusions and Recommendations

PPP projects globally have suffered performance issues and occasionally failure for reasons attributed to ineffective risk management. While existing guidelines and risk management processes, tools and techniques enable the systematic execution of risk management on projects, their optimum deployment is dependent upon many environmental, project and organizational parameters that determine their effectiveness. Given the deficiencies in the existing literature, this research sought to explicitly highlight and quantitatively assess the specific measures that can influence the effectiveness of risk management efforts in the context of PPP projects. The measures identified were validated using a comprehensive research methodology based on literature review, interviews and a survey of industry experts. Based on the MSR, the most critical measures for ERM include: quality of the project's financial model (MERM_9); the adequate administration/management of the contract between the public and private sectors (concession agreement) (MERM_7); a comprehensive project risk management plan (MERM_3); the identification of the project's and key stakeholders' objectives and requirements (MERM_1); careful bid evaluation by the public sector (MERM_26); and efficient contract negotiations (MERM_6)—all of which achieved an average rating of at least very important.

FA revealed six critical underlying dimensions that influence ERM. Out of 62.471% of total variation explained, the factor knowledge-driven risk management accounts for 32.723%, which emphasizes harnessing the potential of acquired experiences, lessons learned and risk management knowledge gained from projects. Other identified factor groups point towards the significance of: a comprehensive evaluation of the stakeholders' and project's requirements and the quality of risk assessments in relation to meeting the requirements; elements critical to post-contract risk management; a well-documented and structured management process and the roles of government institutions (and their project execution arms) for managing risks effectively.

The critical measures exhibit multi-organizational characteristics such that both the public- and private-sector stakeholders can contribute to their successful implementation on projects and influence the entire project life cycle. For example, the experience of the stakeholders and their maturity are aspects that would influence risk management outcomes across the project life cycle and are also relevant to all the stakeholders involved whether in the public or the private sector. Therefore, in order to provide a structure, the identified measures were organized based on the life cycle framework, with project phases as defined by European PPP Expertise Centre [120] and further indicated in terms of their relevance to the public and/or private party and the relevant risk management processes (Figure 1). It should be noted from this mapping that some of the measures only benefit the public-sector stakeholder (e.g., the careful evaluation of bids) by enhancing risk management outcomes and perhaps protecting and/or improving value for money and other government objectives. There is not a single measure that applies only to the private sector; most of the measures potentially benefit both the stakeholders. Moreover, focused efforts are required from the very beginning of the project's life cycle because many of the identified measures are relevant from the beginning of the project-related efforts. For countries with limited experience procuring infrastructure projects using the PPP mode of project delivery, the identified measures highlight aspects that need due consideration.

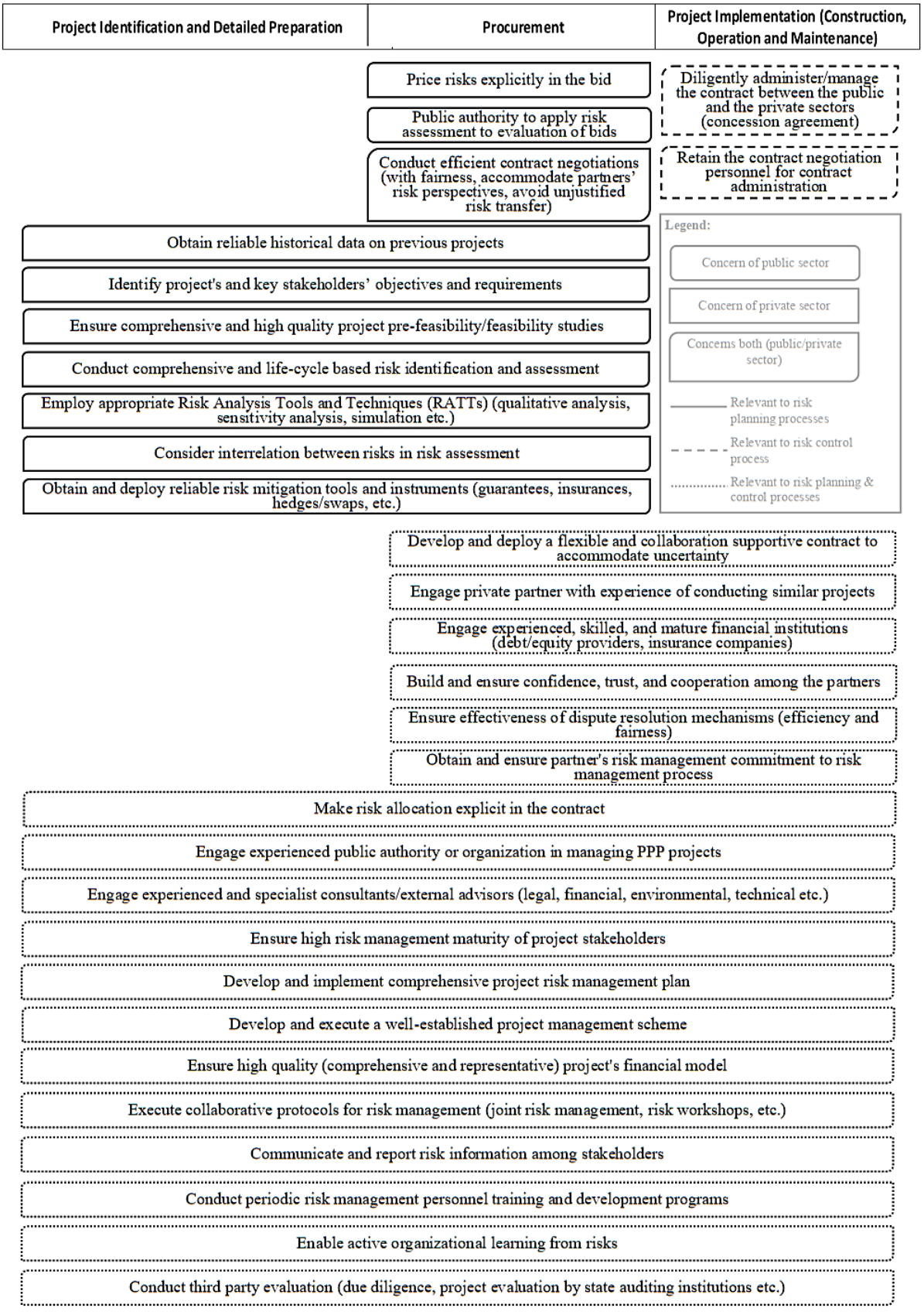

Figure 1. Mapping of measures of effective risk management.

The findings reflect the perceptions of respondents from a developing country with low maturity in PPP project implementation. Hence, the findings may be generalizable to other similar geographical locations i.e., emerging PPP markets and developing economies. The measures of ERM may be further explored in mature PPP markets to determine any similarities and/or differences. Efforts in this direction may involve a more rigorous research regime that utilizes a larger panel of experts and/or case studies to explore the level of implementation of these measures on actual projects to further validate the findings.

Author Contributions: Conceptualization, K.M.M. and A.P.C.C.; methodology, K.M.M., A.P.C.C., R.M.C. and H.Z.; validation, R.M.C., D.J.E., A.M.G. and A.M.; formal analysis, K.M.M., H.Z. and M.A.; investigation, K.M.M. and A.P.C.C.; resources, K.M.M., A.P.C.C. and D.J.E.; data curation, K.M.M.; writing—original draft preparation, K.M.M. and R.M.C.; writing—review and editing, A.P.C.C., R.M.C., D.J.E., H.Z., A.M.G., A.M. and M.A.; visualization, H.Z. and M.A.; supervision, A.P.C.C.; project administration, K.M.M. and A.P.C.C. funding acquisition, K.M.M. All authors have read and agreed to the published version of the manuscript.

Funding: The APC of the article was funded by the Deanship of Scientific Research (DSR), King Fahd University of Petroleum and Minerals, KFUPM, Saudi Arabia.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors wish to acknowledge and appreciate the support of King Fahd University of Petroleum and Minerals (KFUPM), Saudi Arabia.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Loosemore, M.; Raftery, J.; Reilly, C. *Risk Management in Projects*, 2nd ed.; Taylor and Francis: Abingdon, UK, 2006.
2. Project Management Institute. *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*; Project Management Institute: Newtown Square, PA, USA, 2017.
3. Smith, N.J.; Merna, T.; Jobling, P. *Managing Risk in Construction Projects*; Wiley-Blackwell: Chichester, UK, 2014.
4. Yang, W.H.; Dai, D.S. Concession decision model of BOT projects based on a real options approach. In Proceedings of the International Conference on Management Science and Engineering (ICMSE '06), Lille, France, 5–7 October 2006; pp. 307–312.
5. Zhang, X. Financial Viability Analysis and Capital Structure Optimization in Privatized Public Infrastructure Projects. *J. Constr. Eng. Manag.* **2005**, *131*, 656–668. [CrossRef]
6. Xiong, W.; Zhao, X.; Yuan, J.-F.; Luo, S. Ex Post Risk Management in Public-Private Partnership Infrastructure Projects. *Proj. Manag. J.* **2017**, *48*, 76–89. [CrossRef]
7. Akintoye, A.; Beck, M.; Hardcastle, C. *Public-Private Partnerships: Managing Risks and Opportunities*; Blackwell Science: Oxford Malden, MA, USA, 2003.
8. Project Management Institute. *Practice Standard for Project Risk Management*; Project Man-agement Institute: Newtown Square, PA, USA, 2009.
9. Virginia Public-Private Partnerships. *P3 Risk Management Guidelines*; Commonwealth of Virginia: Virginia, USA, 2015.
10. Dey, P.K.; Ogunlana, S.O. Selection and application of risk management tools and techniques for build-operate-transfer projects. *Ind. Manag. Data Syst.* **2004**, *104*, 334–346. [CrossRef]
11. Loosemore, M.; Cheung, E. Implementing systems thinking to manage risk in public private partnership projects. *Int. J. Proj. Manag.* **2015**, *33*, 1325–1334. [CrossRef]
12. Arndt, R.H. Getting a Fair Deal: Efficient Risk Allocation in the Private Provision of Infrastructure. Ph.D. Thesis, The University of Melbourne, Melbourne, Australia, 2000.
13. Zou, P.X.; Wang, S.; Fang, D. A life-cycle risk management framework for PPP infrastructure projects. *J. Financ. Manag. Prop. Constr.* **2008**, *13*, 123–142. [CrossRef]
14. Osei-Kyei, R.; Chan, A.P.C. Developing a Project Success Index for Public–Private Partnership Projects in Developing Countries. *J. Infrastruct. Syst.* **2017**, *23*, 04017028. [CrossRef]
15. Thomas, A.V.; Kalidindi, S.N.; Ganesh, L.S. Modelling and assessment of critical risks in BOT road projects. *Constr. Manag. Econ.* **2006**, *24*, 407–424. [CrossRef]
16. Chapman, C.; Ward, S. *Project Risk Management: Processes, Techniques and Insights*; Wiley: Chichester, UK, 2003.
17. Chowdhury, A.N.; Chen, P.-H.; Tiong, R.L. Credit enhancement factors for the financing of independent power producer (IPP) projects in Asia. *Int. J. Proj. Manag.* **2015**, *33*, 1576–1587. [CrossRef]

18. Fischer, K.; Leidel, K.; Riemann, A.; Alfen, H.W. An integrated risk management system (IRMS) for PPP projects. *J. Financ. Manag. Prop. Constr.* **2010**, *15*, 260–282. [CrossRef]
19. Wibowo, A.; Taufik, J. Developing a Self-assessment Model of Risk Management Maturity for Client Organizations of Public Construction Projects: Indonesian Context. *Procedia Eng.* **2017**, *171*, 274–281. [CrossRef]
20. Yeo, K.; Tiong, R.L. Positive management of differences for risk reduction in BOT projects. *Int. J. Proj. Manag.* **2000**, *18*, 257–265. [CrossRef]
21. Jin, X.-H. Determinants of Efficient Risk Allocation in Privately Financed Public Infrastructure Projects in Australia. *J. Constr. Eng. Manag.* **2010**, *136*, 138–150. [CrossRef]
22. Jin, X.H.; Zuo, J. Critical uncertainty factors for efficient risk allocation in privately financed public infrastructure projects in Australia. *Int. J. Constr. Manag.* **2011**, *11*, 19–34.
23. Ke, Y.; Wang, S.; Chan, A.P.; Cheung, E. Understanding the risks in China's PPP projects: Ranking of their probability and consequence. *Eng. Constr. Arch. Manag.* **2011**, *18*, 481–496. [CrossRef]
24. Cherkos, F.D.; Jha, K.N. Enabling Successful Application of PPPs in New (Inexperienced) Markets: Implications of PPPs' Success and Failure in Toll Roads. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2020**, *12*, 05020015. [CrossRef]
25. Chan, A.P.C.; Yeung, J.F.Y.; Yu, C.C.; Wang, S.Q.; Ke, Y. Empirical Study of Risk Assessment and Allocation of Public-Private Partnership Projects in China. *J. Manag. Eng.* **2011**, *27*, 136–148. [CrossRef]
26. Ehrlich, M.; Tiong, R.L.K. Improving the Assessment of Economic Foreign Exchange Exposure in Public–Private Partnership Infrastructure Projects. *J. Infrastruct. Syst.* **2012**, *18*, 57–67. [CrossRef]
27. Kokkaew, N.; Chiara, N. Modelling completion risk using stochastic critical path?envelope method: A BOT highway project application. *Constr. Manag. Econ.* **2010**, *28*, 1239–1254. [CrossRef]
28. Shen, L.Y.; Wu, Y.Z. Risk Concession Model for Build/Operate/Transfer Contract Projects. *J. Constr. Eng. Manag.* **2005**, *131*, 211–220. [CrossRef]
29. Bakhtawar, B.; Thaheem, M.J.; Arshad, H.; Tariq, S.; Mazher, K.M.; Zayed, T.; Akhtar, N. A Sustainability-Based Risk Assessment for P3 Projects Using a Simulation Approach. *Sustainability* **2021**, *14*, 344. [CrossRef]
30. Rasheed, N.; Shahzad, W.; Khalfan, M.; Rotimi, J.O.B. Risk Identification, Assessment, and Allocation in PPP Projects: A Systematic Review. *Buildings* **2022**, *12*, 1109. [CrossRef]
31. Liu, Z.; Jiao, Y.; Li, A.; Liu, X. Risk Assessment of Urban Rail Transit PPP Project Construction Based on Bayesian Network. *Sustainability* **2021**, *13*, 11507. [CrossRef]
32. Ahmadabadi, A.A.; Heravi, G. Risk assessment framework of PPP-megaprojects focusing on risk interaction and project success. *Transp. Res. Part A Policy Pract.* **2019**, *124*, 169–188. [CrossRef]
33. Zhang, Y.; Tsai, C.-H.; Liao, P.-C. Rethinking Risk Propagation Mechanism in Public–Private Partnership Projects: Network Perspective. *J. Infrastruct. Syst.* **2020**, *26*, 04020011. [CrossRef]
34. Bing, L.; Akintoye, A.; Edwards, P.J.; Hardcastle, C. The allocation of risk in PPP/PFI construction projects in the UK. *Int. J. Proj. Manag.* **2005**, *23*, 25–35. [CrossRef]
35. Carbonara, N.; Costantino, N.; Pellegrino, R. Revenue guarantee in public-private partnerships: A fair risk allocation model. *Constr. Manag. Econ.* **2014**, *32*, 403–415. [CrossRef]
36. Jin, X.-H.; Zhang, G. Modelling optimal risk allocation in PPP projects using artificial neural networks. *Int. J. Proj. Manag.* **2011**, *29*, 591–603. [CrossRef]
37. Pellegrino, R.; Ranieri, L.; Costantino, N.; Mummolo, G. A real options-based model to supporting risk allocation in price cap regulation approach for public utilities. *Constr. Manag. Econ.* **2011**, *29*, 1197–1207. [CrossRef]
38. Shrestha, A.; Tamošaitienė, J.; Martek, I.; Hosseini, M.R.; Edwards, D.J. A Principal-Agent Theory Perspective on PPP Risk Allocation. *Sustainability* **2019**, *11*, 6455. [CrossRef]
39. Martiniello, L.; Morea, D.; Paolone, F.; Tiscini, R. Energy Performance Contracting and Public-Private Partnership: How to Share Risks and Balance Benefits. *Energies* **2020**, *13*, 3625. [CrossRef]
40. Choudhry, R.M.; Iqbal, K. Identification of Risk Management System in Construction Industry in Pakistan. *J. Manag. Eng.* **2012**, *29*, 42–49. [CrossRef]
41. Chileshe, N.; Kikwasi, G.J. Perception of barriers to implementing risk assessment and management practices by construction professionals in Tanzania. In Proceedings of the 29th Annual ARCOM Conference, Reading, UK, 2–4 September 2013; Smith, S.D., Ahiaga-Dagbui, D.D., Eds.; Association of Researchers in Construction Management: Reading, UK, 2013; pp. 1137–1146.
42. Chileshe, N.; Kikwasi, G.J. Critical success factors for implementation of risk assessment and management practices within the Tanzanian construction industry. *Eng. Constr. Arch. Manag.* **2014**, *21*, 291–319. [CrossRef]
43. Chinyio, E.; Fergusson, A. A construction perspective on risk management in public-private partnership. In *Public-Private Partnerships: Managing Risks and Opportunities*; Akintoye, A., Beck, M., Hardcastle, C., Eds.; Blackwell Science Ltd.: Oxford, UK, 2003; pp. 93–126.
44. Ke, Y.; Wang, S.; Chan, A.P.C. Risk management practice in China's Public-Private Partnership projects. *J. Civ. Eng. Manag.* **2012**, *18*, 675–684. [CrossRef]
45. Zhao, X.; Hwang, B.-G.; Low, S.P. Developing Fuzzy Enterprise Risk Management Maturity Model for Construction Firms. *J. Constr. Eng. Manag.* **2013**, *139*, 1179–1189. [CrossRef]

46. Marques, R.C.; Berg, S. Revisiting the Strengths and Limitations of Regulatory Contracts in Infrastructure Industries. *J. Infrastruct. Syst.* **2010**, *16*, 334–342. [CrossRef]
47. Lee, N.; Schaufelberger, J.E. Risk Management Strategies for Privatized Infrastructure Projects: Study of the Build–Operate–Transfer Approach in East Asia and the Pacific. *J. Manag. Eng.* **2014**, *30*, 05014001. [CrossRef]
48. Keci, J.; Mustafaraj, E. Practices, barriers and challenges of risk management implementation in Albanian construction industry. In *ATINER's Conference Paper Series CIV2013-0639*; Athens Institute for Education and Research: Athens, Greece, 2013.
49. Kwak, Y.H. Analyzing Asian Infrastructure Development Privatization Market. *J. Constr. Eng. Manag.* **2002**, *128*, 110–116. [CrossRef]
50. Liu, J.; Li, B.; Lin, B.; Nguyen, V. Key issues and challenges of risk management and insurance in China's construction industry. *Ind. Manag. Data Syst.* **2007**, *107*, 382–396. [CrossRef]
51. Yuan, J.-F.; Deng, X.-P.; Li, Q.-M. The relationship of critical risk factors in Chinese PPP projects: Modeling perspective. In Proceedings of the 2008 International Conference on Information Management, Innovation Management and Industrial Engineering, Taipei, Taiwan, 19–21 December 2008; pp. 151–154.
52. Zhang, X. Concessionaire's Financial Capability in Developing Build-Operate-Transfer Type Infrastructure Projects. *J. Constr. Eng. Manag.* **2005**, *131*, 1054–1064. [CrossRef]
53. Beckers, F.; Chiara, N.; Flesch, A.; Maly, J.; Silva, E.; Stegemann, U. A risk-Management Approach to a Successful Infrastructure Project: Initiation, Financing, and Execution. In *McKinsey Working Papers on Risk*; McKinsey & Company: Hongkong, China, 2013; Number 52.
54. Zou, P.X.W.; Chen, Y.; Chan, T.-Y. Understanding and Improving Your Risk Management Capability: Assessment Model for Construction Organizations. *J. Constr. Eng. Manag.* **2009**, *136*, 854–863. [CrossRef]
55. Zhang, X. Criteria for Selecting the Private-Sector Partner in Public–Private Partnerships. *J. Constr. Eng. Manag.* **2005**, *131*, 631–644. [CrossRef]
56. Clifton, C.; Duffield, C. Improved PFI/PPP service outcomes through the integration of Alliance principles. *Int. J. Proj. Manag.* **2006**, *24*, 573–586. [CrossRef]
57. Garvin, M.J. Enabling Development of the Transportation Public-Private Partnership Market in the United States. *J. Constr. Eng. Manag.* **2010**, *136*, 402–411. [CrossRef]
58. Matsumoto, T. Risk Management and Governance for PFI Project: Technology Policy Lessons from the Case of Japan. Master's thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2012.
59. McDowall, E. Applications of risk management strategies in public-private partnership procurement. In *Public-Private Partnerships: Managing Risks and Opportunities*; Akintoye, A., Beck, M., Hardcastle, C., Eds.; Blackwell Science Ltd.: Oxford, UK, 2003; pp. 183–204.
60. Rahman, M.M.; Kumaraswamy, M.M. Assembling integrated project teams for joint risk management. *Constr. Manag. Econ.* **2005**, *23*, 365–375. [CrossRef]
61. Park, T.; Kim, B.; Kim, H. Real Option Approach to Sharing Privatization Risk in Underground Infrastructures. *J. Constr. Eng. Manag.* **2013**, *139*, 685–693. [CrossRef]
62. Shan, L.; Garvin, M.J.; Kumar, R. Collar options to manage revenue risks in real toll public-private partnership transportation projects. *Constr. Manag. Econ.* **2010**, *28*, 1057–1069. [CrossRef]
63. Ye, S.; Tiong, R.L.K. Effects of Tariff Design in Risk Management of Privately Financed Infrastructure Projects. *J. Constr. Eng. Manag.* **2003**, *129*, 610–618. [CrossRef]
64. Ahadzi, M.; Bowles, G. Public–private partnerships and contract negotiations: An empirical study. *Constr. Manag. Econ.* **2004**, *22*, 967–978. [CrossRef]
65. Jang, G.W. The Bids-Evaluation Decision Model Development and Application for PPP Transport Projects: A Project Risks Modeling Framework. Ph.D. thesis, Colorado State University, Fort Collins, CO, USA, 2010.
66. Visconti, R.M. Multidimensional principal–agent value for money in healthcare project financing. *Public Money Manag.* **2014**, *34*, 259–264. [CrossRef]
67. Cooper, D.; Grey, S.; Raymond, G.; Walker, P. *Project Risk Management Guidelines: Managing Risk in Large Projects and Complex Procurements*; John Wiley & Sons Ltd.: Chichester, UK, 2005.
68. Delhi, V.S.K.; Mahalingam, A.; Palukuri, S. Governance issues in BOT based PPP infrastructure projects in India. *Built Environ. Proj. Asset Manag.* **2012**, *2*, 234–249. [CrossRef]
69. Hardcastle, C.; Boothroyd, K. Risks Overview in Public-Private Partnership. In *Public-Private Partnerships: Managing Risks and Opportunities*; Akintoye, A., Beck, M., Hardcastle, C., Eds.; Blackwell Science Ltd.: Oxford, UK, 2003; pp. 31–57.
70. HM Treasury. *Managing Risks with Delivery Partners: A Guide for those Working Together to Deliver Better Public Services*; Office of Government Commerce, HM Treasury: Norwich, UK, 2004.
71. Ng, A.; Loosemore, M. Risk allocation in the private provision of public infrastructure. *Int. J. Proj. Manag.* **2007**, *25*, 66–76. [CrossRef]
72. Schieg, M. Risk management in construction project management. *J. Bus. Econ. Manag.* **2006**, *7*, 77–83. [CrossRef]
73. Jin, X.-H.; Zhang, G.K.; Yang, R.J. Factor analysis of partners' commitment to risk management in public-private partnership projects. *Constr. Innov.* **2012**, *12*, 297–316. [CrossRef]

74. Akintoye, A.; Beck, M.; Hardcastle, C.; Chinyio, E.; Asenova, D. A framework for the risk management of private finance initiative projects. In *Public-Private Partnerships: Managing Risks and Opportunities*; Blackwell Science Ltd.: Oxford, UK, 2003; pp. 385–414.
75. Flyvbjerg, B. Quality control and due diligence in project management: Getting decisions right by taking the outside view. *Int. J. Proj. Manag.* **2013**, *31*, 760–774. [CrossRef]
76. Kumaraswamy, M.M.; Morris, D.A. Build-Operate-Transfer-Type Procurement in Asian Megaprojects. *J. Constr. Eng. Manag.* **2002**, *128*, 93–102. [CrossRef]
77. Soomro, M.A.; Zhang, X. Evaluation of the Functions of Public Sector Partners in Transportation Public-Private Partnerships Failures. *J. Manag. Eng.* **2016**, *32*, 4015027. [CrossRef]
78. Monteiro, R.S. *Public-Private Partnerships in the Czech Republic: Setting Up a Proper Risk Management System at the Project Level (Twinning Project CZ/2005/IB/FI/04)*; Ministerstvo financí: Prague, Czech Republic; Parpública, SA, Portugal, 2008.
79. da Cruz, N.F.; Marques, R.C. Delivering Local Infrastructure through PPPs: Evidence from the School Sector. *J. Constr. Eng. Manag.* **2012**, *138*, 1433–1443. [CrossRef]
80. Lehtiranta, L. Collaborative risk management processes: A constructive case study. *Eng. Proj. Organ. J.* **2013**, *3*, 198–212. [CrossRef]
81. Lehtiranta, L.; Junnonen, J.-M. Stretching risk management standards: Multi-organizational perspectives. *Built Environ. Proj. Asset Manag.* **2014**, *4*, 128–145. [CrossRef]
82. Zou, W. Relationship Management in Public Private Partnership Infrastructure Projects. Ph.D. Thesis, The University of Hong Kong, Pokfulam Road, Hong Kong SAR, China, 2012.
83. Doloi, H. Relational partnerships: The importance of communication, trust and confidence and joint risk management in achieving project success. *Constr. Manag. Econ.* **2009**, *27*, 1099–1109. [CrossRef]
84. Ke, Y.; Liu, X.; Wang, S. Equitable Financial Evaluation Method for Public-Private Partnership Projects. *Tsinghua Sci. Technol.* **2008**, *13*, 702–707. [CrossRef]
85. Kurniawan, F. An Integrated Project Evaluation Tool for Public-Private Partnership Projects. Ph.D. thesis, Heriot-Watt University, Edinburgh, Scotland, 2013.
86. Pantelias, A.; Zhang, Z. Methodological Framework for Evaluation of Financial Viability of Public-Private Partnerships: Investment Risk Approach. *J. Infrastruct. Syst.* **2010**, *16*, 241–250. [CrossRef]
87. Asian Development Bank. *Assessment of Public–Private Partnerships in Cambodia: Constraints and Opportunities*; Asian Development Bank: Mandaluyong, Philippines, 2012.
88. Soomro, M.A.; Zhang, X. Analytical review on transportation public private partnerships failures. *Int. J. Sustain. Constr. Eng. Technol.* **2011**, *2*, 62–80.
89. Iyer, K.C.; Sagheer, M. Hierarchical Structuring of PPP Risks Using Interpretative Structural Modeling. *J. Constr. Eng. Manag.* **2010**, *136*, 151–159. [CrossRef]
90. Marle, F.; Vidal, L.-A. Project risk management processes: Improving coordination using a clustering approach. *Res. Eng. Des.* **2011**, *22*, 189–206. [CrossRef]
91. Carrillo, P.M.; Robinson, H.S.; Anumba, C.J.; Bouchlaghem, N.M. A Knowledge Transfer Framework: The PFI context. *Constr. Manag. Econ.* **2006**, *24*, 1045–1056. [CrossRef]
92. Asenova, D.; Beck, M. A financial perspective on risk management in public-private partnership. In *Public-Private Partnerships: Managing Risks and Opportunities*; Akintoye, A., Beck, M., Hardcastle, C., Eds.; Blackwell Science Ltd.: Oxford, UK, 2003; pp. 127–151.
93. Loosemore, M.; McCarthy, C.S. Perceptions of Contractual Risk Allocation in Construction Supply Chains. *J. Prof. Issues Eng. Educ. Pract.* **2008**, *134*, 95–105. [CrossRef]
94. Clayton UTZ. Successfully allocating risk and negotiating a PPP Contract. In *6th Annual National Private Public Partnerships Summit*; Clayton Utz.: Sydney, Australia, 2006.
95. Creswell, J.W.; Plano-Clark, V.L.; Gutmann, M.L.; Hanson, W.E. Advanced mixed methods research designs. In *Handbook of Mixed Methods in Social and Behavioral Research*; Tashakkori, A., Teddlie, C., Eds.; Sage: Thousand Oaks, CA, USA, 2003; pp. 209–240.
96. 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. *Habitat Int.* **2012**, *36*, 423–432. [CrossRef]
97. Yang, R.; Shen, Q.; Ho, C.M.; Drew, D.S.; Chan, A.P.C. Exploring critical success factors for stakeholder management in construction projects. *J. Civ. Eng. Manag.* **2009**, *15*, 337–348. [CrossRef]
98. Mazher, K.M.; Chan, A.P.C.; Zahoor, H. A research framework for effective risk management in public-private partnership (ppp) infrastructure projects in Pakistan. In Proceedings of the 13th International Postgraduate Research Conference (IPGRC 2017), Salford, UK, 14–15 September 2017; Pathirage, C., Kulatunga, U., Ji, Y., Gameson, R., Udeaja, C., Trillo, C., Takhtravanchi, M., Allali, B., Eds.; University of Salford: Salford, UK, 2017.
99. Saunders, M.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*; Pearson: Harlow, UK, 2012.
100. Ameyaw, E.E.; Chan, A.P. Evaluating key risk factors for PPP water projects in Ghana: A Delphi study. *J. Facil. Manag.* **2015**, *13*, 133–155. [CrossRef]
101. Siegel, S.; Castellan, N.J. *Nonparametric Statistics for the Behavioral Sciences*; McGraw-Hill: New York, NY, USA, 1988.
102. Kline, P. *An Easy Guide to Factor Analysis*; Routledge: Abingdon, UK, 1994.
103. Hahs-Vaughn, D.L. *Applied Multivariate Statistical Concepts*; Routledge: New York, NY, USA, 2016.

104. Andrew, D.P.S.; Pedersen, P.M.; McEvoy, C.D. *Research Methods and Design in Sport Management*; Human Kinetics: Champaign, IL, USA, 2011.
105. Wong, K.Y.; Aspinwall, E. An empirical study of the important factors for knowledge-management adoption in the SME sector. *J. Knowl. Manag.* **2005**, *9*, 64–82. [CrossRef]
106. Black, S.A.; Porter, L.J. Identification of the Critical Factors of TQM. *Decis. Sci.* **1996**, *27*, 1–21. [CrossRef]
107. Field, A. *Discovering Statistics Using SPSS*, 2nd ed.; SAGE Publications Ltd.: London, UK, 2005.
108. The World Bank. *Private Participation in Infrastructure (PPI) Database*; World Bank Group: Washington, DC, USA, 2022.
109. The Economist Intelligence Unit. Evaluating the Environment for Public-Private Partnerships in Eastern Europe, Central Asia and the Southern and Eastern Mediterranean. In *The 2017 Infrascope*; The Economist Intelligence Unit: London, UK, 2017.
110. The Economist Intelligence Unit. Evaluating the Environment for Public-Private Partnerships in Asia. In *The 2018 Infrascope*; The Economist Intelligence Unit: London, UK, 2018.
111. The Economist Intelligence Unit. *Evaluating the Environment for Public-Private Partnerships in Latin America and the Caribbean*; The Economist Intelligence Unit: New York, NY, USA, 2019.
112. Robinson, H.; Carrillo, P.; Anumba, C.J.; Patel, M. *Governance and Knowledge Management for Public-Private Partnerships*; Wiley-Blackwell: Chichester, West Sussex, 2010.
113. APMG International. Managing the contract—Strategy, delivery and commissioning. In *The APMG PPP Certification Program Guide*; APMG International: High Wycombe, UK, 2016.
114. World Bank; Asian Development Bank; Inter-American Development Bank. *Public Private Partner-Ships Reference Guide Version 2.0*; World Bank Publications, The World Bank Group: Washington, DC, USA, 2014.
115. Hong Kong Institute of Surveyors. *Practical Guide to Public Private Partnership (PPP) Projects*; Hong Kong Institute of Surveyors (HKIS): Hong Kong SAR, China, 2009.
116. Bruzelius, N.; Flyvbjerg, B.; Rothengatter, W. Big decisions, big risks. Improving accountability in mega projects. *Transp. Policy* **2002**, *9*, 143–154. [CrossRef]
117. Croce, R.D.; Paula, J.; Assab, A. *Selected Good Practices for Risk Allocation and Mitigation in Infrastructure in APEC Economies*; Organization for Economic Co-operation and Development: Paris, France, 2017.
118. Mandri-Perrott, C.; Menzies, I. *Private Sector Participation in Light Rail-Light Metro Transit Initiatives*; World Bank: Washington, DC, USA, 2010.
119. Partnerships Victoria. *Contract Management Guide*; Partnerships Victoria: Melbourne, Australia, 2003.
120. European PPP Expertise Centre. *The Guide to Guidance: How to Prepare, Procure and Deliver PPP Projects*; European PPP Expertise Centre: Luxembourg, 2012.