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Review

Risk Identification, Assessment, and Allocation in PPP Projects: A Systematic Review

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Abstract: Public private partnerships (PPPs) have gained widespread adoption as an innovative way of procuring public infrastructure projects over the last two decades. Risk identification, assessment, and allocation have received considerable attention from researchers due to the risk heavy nature of PPP projects. Adoption of PPPs has triggered a sudden increase in research interest in the area in recent years. This study attempts to provide an updated systematic review of literature related to risks in PPPs using a PRISMA flowchart. The results of the study offer some valuable insights into the future and current state of research. The study found that the focus of research on PPPs has shifted from an overall risk identification and assessment approach to individual risk analysis. Moreover, this research trend is on the rise in developing countries, and that quantitative methods for risk management in PPP research and qualitative methods in practice are preferred. In developed economies, due to negative public sentiments, transparency concerns, and arguments of value for money not being achieved, PPPs are becoming less popular. For these reasons a shift to availability-based payment mechanisms such as in Design-Build-Finance-Maintain (DBFM) from traditional revenue-based mechanisms as in Build-Operate-Transfer (BOT) has been observed. These shifts in research trends and practice offer researchers future opportunities to investigate these relatively newer approaches.

Keywords: Public Private Partnership (PPP); infrastructure; risk identification; risk allocation; risk assessment

Citation: 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. https://doi.org/10.3390/buildings12081109

Academic Editor: Xianbo Zhao

Received: 12 June 2022
Accepted: 21 July 2022
Published: 27 July 2022

1. Introduction

Infrastructure development has always been seen as a driver for economic growth of a country [1]. With the increasing urban population worldwide, the need to develop social and economic infrastructure has become even greater in the recent years. Previous research in infrastructure development suggests that there is a need to invest more in this area to cover the infrastructure gap [2–5]. A study by Iyer and Purkayastha [6] reported that an infrastructure investment of approximately 50 trillion USD is required in the next ten years across the globe. However, governments all over the world are facing problems keeping up with such huge investments. Therefore, seeking help from the private sector in terms of finances and the extent of private sector involvement resulted in innovative project delivery schemes, one of them being public private partnerships [7]. PPPs among these methods have particularly caught the public sector's attention worldwide, especially after the global economic recession [8].

Involving the private sector in procurement of public infrastructure has led to improved levels of project performance [9]. The ultimate reason for achieving better

performance in such schemes is that interests of both public and private parties are aligned in these kinds of ventures. These factors, combined with others, incite the public sector to involve private sector in the delivery of infrastructure projects. Therefore, PPP has surfaced as a favorable and effective method of infrastructure provision particularly when a large investment is required such as road infrastructure projects [10].

There is plenty of evidence available in favor of PPPs delivering better performance than traditional procurement systems where the public sector is solely responsible for delivering the project [11,12]. However, the other facet of public private partnerships suggests that it is not a panacea due to the complexity of financial arrangements, investor's expectancy of high returns, more extended contract periods, and the risk-heavy nature of projects [13]. Moreover, improper risk allocation and the tendency of the public sector to transfer most of the project risks to the private sector impacts project objectives negatively [14]. Therefore, efficient project risk management is crucial for the successful implementation of PPP projects. Previous PPP studies have focused mainly on risk identification and assessment. Risk allocation received some attention but mainly in the area of preferred risk allocation. In the current study, there is a particular interest in risk allocation in PPP based on the principle of allocating risk to the best party that is in the position to manage it. Therefore, this study reviews extant literature on risk identification, assessment, and allocation to provide further insights for management theory and practice. The study pursues the following objectives:

1. To undertake a systematic review of the related literature on PPPs, including but not limited to the identification of publication trends from 1996 to 2021, leading authors, countries, and institutions in PPP risk management research.
2. To establish through the review findings the primacy of risks identification, assessment, and allocation. It is anticipated that the findings will add to the risk management knowledge base and expound on the management of risk on PPP projects.

2. Theoretical Background

2.1. Primacy of Risk Identification, Assessment, and Allocation

The research interest in PPP has grown significantly over the last decade, given the governments' increasing adoption of PPPs [15]. Researchers have explored areas of financial modelling, economic feasibilities, procurement, risk management, governance, and success criteria within PPPs [1]. Given the extensive amount of literature available in the domain of PPP, many researchers have conducted systematic literature review (SLR) studies on existing PPP research [8,16–19]. Most of these studies have incorporated PPP literature as a whole in their review. For example, Osei-Kyei and Chan [8] conducted their systematic review of literature on critical success factors for PPP. Very few have paid attention to aspects relating to the operationalization of PPPs. A key aspect of PPP successes is in the way and manner that risks are managed on those projects.

Risk management involves systematic identification, response planning, monitoring, and controlling of project risks [20]. The process starts with establishing the overall strategy and defining the roles and responsibilities of key stakeholders followed by the identification of potential project risks. Identifying all the relevant risks is an important step as the subsequent risk management processes are performed on the identified risks. In the next steps, risks are analyzed for their relative importance through qualitative, quantitative, or a combination of both methods. Further analysis can also be carried out on key project risks, which also help in forecasting the costs of managing these risks. This process is followed by risk response planning in which risks are either accepted, transferred, avoided, or reduced through different techniques. A significant aspect of response planning is ensuring that identified risks are appropriately allocated. A common phraseology in response planning is ensuring that the party most appropriate to bear certain risks is allocated such risks [21]. Lastly, risks are monitored and controlled to see the behavior of risks as forecasted in previous steps.

PPP projects are considered risky in nature and risk management is considered an important part of the planning process to deal with these risks [22]. Risk management not only helps reduce the negative effect(s) of certain risks but can also increase the likelihood of positive effects. Due to the extended contract periods of PPP projects, a traditional risk management approach, where the focus on risk management is before the start of the project, has proven to be more challenging and expensive [12]. Therefore, increasing the effectiveness of risk management is crucial for the success of PPP schemes. For this reason, an increasing interest can be observed in the risk management research specifically on identification, assessment, and allocation in recent years [23–28]. Although previous studies provide a review of PPP research, a more recent study reviewing these key aspects of risks in PPP is lacking.

This article will be helpful for other academics to understand the present state of studies on PPP risk management. In addition, project managers, core PPP project partners, and decision-makers will gain insights to expand their knowledge of PPP risk management. The remainder of the article covers three sections: the research methodology used to select and examine the relevant literature for this study, results and discussion, and study conclusion.

3. Materials and Methods

A research technique is the foundation of any study since it acts as a plan for guiding the investigation from beginning to conclusion [29]. A literature review is an effective approach to acquire insight into a study topic and understanding the current body of knowledge on the subject [30]. Thus, Systematic Literature Review (SLR) is employed to fulfill the current research's objectives, which is supported by many previous researchers in the area of PPPs [8,10,31,32]. SLR is a more principled and unbiased approach of choosing relevant prior research for a current study, followed by a comprehensive critical analysis [33]. This study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart, as shown in Figure 1, to retrieve, select, accept, and assess target papers. Historically, this approach to conducting SLR was most commonly used in medical research [34], but over time it has gained popularity among construction management researchers [15,19].

In total, 87 papers published in peer-reviewed journals related to PPP risk management have been reported and systematically analyzed to achieve these objectives.

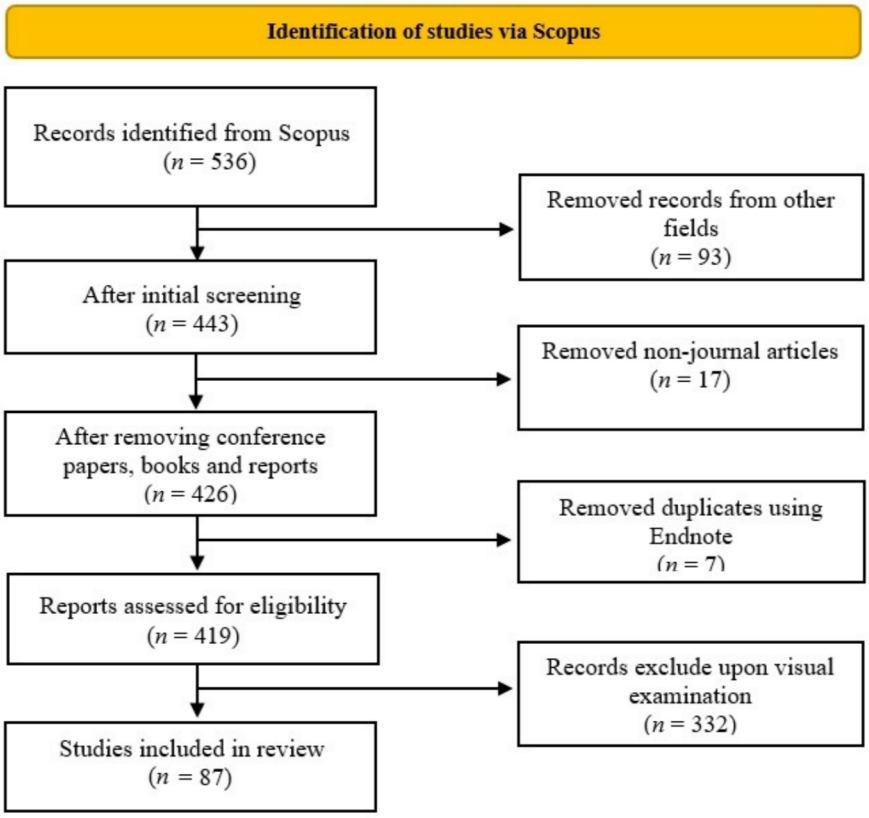

Figure 1. Research process.

3.1. Retrieval of Relevant Papers

After establishing the clear objectives of this study, the study's next steps were to select a relevant database for obtaining the research articles and finalize the search string to be used to search the database. In the first step of this stage, a comprehensive desktop search related to risk management in the PPP was carried out using the Scopus search engine. Scopus was selected due to its widespread use by other researchers in this field [10,15] and for other reasons such as its ease of use, comprehensive coverage, effectiveness, and precision of the search results [18]. Moreover, Scopus is more popular among PPP risk management research circle than other search engines like Google Scholar and Web of Science because of its broad coverage and article search accuracy [29].

Keywords for the Scopus search were carefully selected and finalized considering the research objectives and previous literature. Keywords included relevant terms such as critical risk factors, risk identification, risk assessment, and risk allocation. This search was limited to subject areas by using keywords like "public private partnership" and "PPP infrastructure". Papers that had these terms in the title, abstract, or keywords were deemed to have satisfied the initial criteria for further investigation. Furthermore, the period of publication was limited to 25 years between 1996 and 2021. This search range was chosen to encompass all the relevant studies on this topic with the first one published in 1996. The authors consider the period appropriate since the advent of modern PPPs took place with the start of project finance initiative (PFI) in UK in 1992 (45). The search string used in Scopus is given below:

(TITLE-ABS-KEY ("critical risk factors" OR "risk factors" OR "critical risks" OR "risk assessment" OR "risk identification" OR "risk allocation" OR "CRFs") AND TITLE-ABS-

KEY ("public private partnership" OR "PPP" OR "public infrastructure")) AND DOCTYPE (ar OR re) AND PUBYEAR > 1995 AND PUBYEAR < 2022 AND (LIMIT-TO (SUBJAREA,"BUSI") OR LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"DECI") OR LIMIT-TO (SUBJAREA,"ECON") OR LIMIT-TO (SUBJAREA,"ENER")) AND (LIMIT-TO (LANGUAGE,"English")).

The initial search using the above string yielded 536 papers. Some irrelevant papers still appeared in the search from other subject areas such as medicine, psychology, physics, agriculture, and neuroscience. A potential reason for this could be that these papers were listed in more than one subject area due to their cross-disciplinary nature. These subject areas were manually removed from the search results as they did not meet the requirements of this study. Search results were further scrutinized by manually defining the source type of relevant papers in the search options to 'journal'. This reduced the number of papers to 426. These search results were then downloaded from Scopus in the form of an Excel spreadsheet which included author names, title of the articles, year of publication, source title/journal, location/affiliation, keywords, and paper abstracts. Further, seven papers were removed from the list due to being duplicates when imported into EndNote software, bringing the number of papers down to 419.

3.2. Identifying Relevant Papers

Not all the 419 papers initially selected were relevant to the objectives of this study; many of them were not related to PPP risk identification, assessment, and allocation. This was revealed after careful visual examination of the abstracts of these papers. Some of these papers were not filtered out in the initial screening process due to the terms "risk", "PPP", and "infrastructure" being very common in some other fields as well. For example, PPP in medical sciences refers to plant protection products. Therefore, a thorough visual examination was carried out, and irrelevant papers were filtered out. A total of 87 papers were deemed valid after this last stage of filtration. The sample size of 87 papers was considered satisfactory for a review study. A previous well-established review study by Osei-Kyei and Chan [8] considered 27 papers for a review study on critical success factors in PPP. The number of pertinent papers selected from various journals having two or more publications is summarized in Table 1 along with CiteScores of these journals obtained from Scopus. CiteScore is an important metric used by some researchers in the field to gauge the quality of research. International Journal of Project Management has the highest CiteScore of 16.4 with five articles. Highest number of papers were published by the Journal of Construction Engineering and Management (eleven papers), followed by Construction Management and Economics, Journal of Infrastructure Systems and Sustainability (MDPI) having published seven papers each. The remaining papers were spread across various other journals. Twenty-four out of the thirty-eight journals had only one publication.

Table 1. Key journals in PPP risk management research.

Source Title	Number of Papers Relevant	CiteScore
Journal of Construction Engineering and Management	11	6.4
Construction Management and Economics	7	5.6
Journal of Infrastructure Systems	7	4.8
Sustainability (Switzerland)	7	3.9
International Journal of Project Management	5	16.4
Engineering, Construction and Architectural Management	5	4.0
Advances in Civil Engineering	4	1.7
Journal of Cleaner Production	3	13.1
International Journal of Construction Management	3	4.7
Journal of Civil Engineering and Management	3	5.4
Expert Systems with Applications	2	12.7

Journal of Facilities Management	2	3.1
International Journal of Critical Infrastructures	2	0.9
Journal of Engineering, Project, and Production Management	2	N/A

3.3. Assessing Target Papers

For assessing the author scores of target papers, the formula proposed by Howard, Cole [35] was used as shown in Equation (1). This formula was adopted due to its extensive use by similar studies in the past for its reliability [29,36].

$$\text{Score} = \frac{1.5^{n-i}}{\sum_{i=1}^{n} 1.5^{n-i}} \quad (1)$$

where n = total authors in paper; and i = order of author in paper

The formula gives each author a score for their contribution based on total number of authors and position in the paper. The formula considers the sequence of authors to compute their contribution in the paper by assuming that the first author has more contribution than the second and so on. Using this formula, Table 2 was developed for multi-author papers. These scores were then used to calculate and rank different authors for their contribution in the field and establish the country ranking from their affiliation.

Table 2. Score matrix for assessing author contribution

No. of Authors	**Order of Authorship**					
	1	**2**	**3**	**4**	**5**	**6**
1	1					
2	0.6	0.4				
3	0.47	0.32	0.21			
4	0.42	0.28	0.18	0.12		
5	0.38	0.26	0.17	0.11	0.08	
6	0.36	0.24	0.16	0.105	0.075	0.05

4. Results

The following section presents the result of this study. The section is structured to present results relating to reviewed publications such as annual publication trend, author affiliations, and country of research. A similar approach of presenting similar results has also been observed in many previous review studies [1,8,31,37].

4.1. Publication Analysis of Selected Papers

4.1.1. Annual Publication Trend

A yearly publication trend presented in Figure 2 was constructed during the study period to demonstrate how academics' interest has evolved in risks associated with PPP. No study was published in 1996, and just a handful of studies were carried out in the first half of the study period. Between the periods of 1996 and 2009, only two years saw the publication of more than one study related to the research topic of this study. However, this trend changed quickly after 2010. Almost 75% of the publications included in this literature review were conducted in the second half of the study period. The year 2020 saw the greatest number of studies conducted in a year reaching 20 papers.

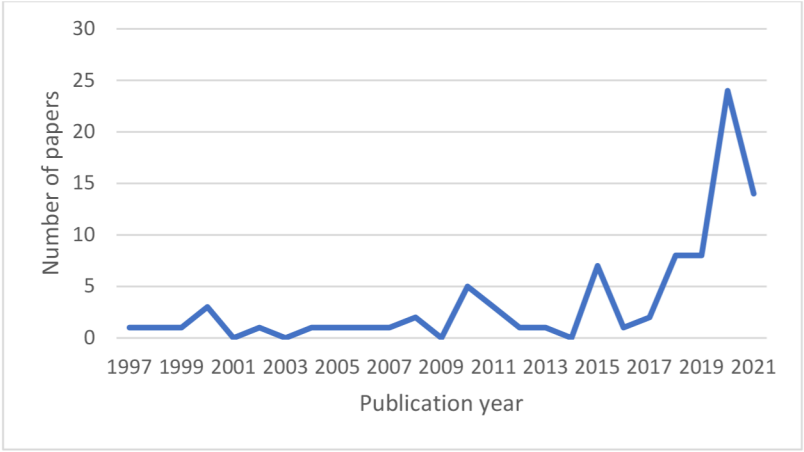

Figure 2. Annual publication trend.

Moreover, an upward trend during these years can be seen, showcasing an increasing research interest in this area. This trend is consistent with the increasing adoption of PPP to procure public infrastructure projects, especially in developing countries where the government balance sheets are strained [38]. This trend is expected to increase in the upcoming years as governments are ill-placed in their current situation due to the ongoing pandemic to spare budget for constantly increasing infrastructure demand [39,40].

4.1.2. Authors and Country of Research

To understand the researcher's interest in different countries relative to the study title, the contribution score of each nation was computed based on the scoring matrix in Table 2. The ranking of these countries based on the scoring matrix is exhibited in Figure 3, which was developed using the Microsoft Excel tool "Geographical Heat Map". The nations that contributed to PPP risk management research along with the number of researchers from each nation during the period studied were identified. Research publications arranged by their origin on a certain issue may indicate the degree of industry practices and progress on the topic in specific places, the contributions of various nations to researching the risks in PPP projects must be examined. Therefore, it is of importance to find out the level of research being carried out in certain areas to gather helpful information into the scope of risk management activities on PPP projects in particular locations. The matrix of author scores in Table 2 was used to calculate each country's contribution score.

Country	Researchers	Score
China	47	22.61
Hong Kong	12	14.83
Australia	21	7.57
India	11	6.68
UK	13	5.49
Iran	8	4.28
Singapore	5	4.21
USA	7	2.92
Egypt	6	2.82
Italy	5	2.12
Nigeria	6	2
Turkey	3	2
Greece	3	1.68
Taiwan	2	1
Austria	1	1
Indonesia	3	1
Spain	2	1
Pakistan	3	0.73
Colombia	2	0.7
Saudi Arabia	3	0.595
South Africa	2	0.53
Vietnam	1	0.47
Lithuania	1	0.42
Norway	1	0.32
Chile	2	0.3
Ghana	2	0.25
Puerto Rico	1	0.21
Netherlands	1	0.11
Malaysia	1	0.105

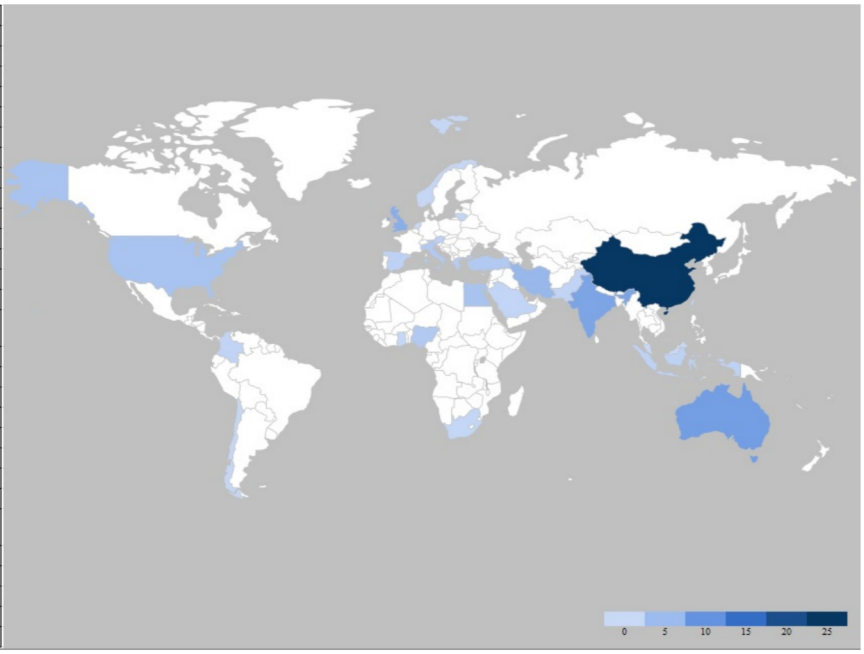

Figure 3. PPP researchers map by country.

Table 3 demonstrates that the risks in PPP projects have been investigated by both developed and developing nations, indicating that this is an issue of interest worldwide. China, Hong Kong, and Australia are the top three countries, with scores of 22.61, 14.83, and 7.57, respectively. In China, 47 researchers from several institutions published papers discussing risk factors in PPP projects, followed by 21 researchers from Australia and 12 from Hong Kong. The Ke and Wang [28] study on research trends in PPP research showed that PPP researchers were very active in developed economies such as the UK having 82 researchers from 42 different institutions compared to developing economies. However, the results of this study show otherwise, indicating a shift in the focus of PPP research from developed to developing nations. Heavy research interest in a developing country such as China can be explained because during the last decade, there has been an increase in the PPP method of project delivery in developing regions. Moreover, the data is consistent with the declining interest in a developed nation such as the UK for the use of PPP by showcasing a decrease in the research trend.

Table 3. Contribution of authors and ranking.

Author	Number of Papers	Affiliation	Country	Score
Chan A.P.C.	19	The Hong Kong Polytechnic University	Hong Kong	6.43
Ameyaw E.E.	11	The Hong Kong Polytechnic University, Coventry University	Hong Kong, UK	4.27
Wang S.Q.	9	National University of Singapore, Tsinghua University, Nanyang Technology University	Singapore, China	2.54
Xu Y.	4	Southeast University	China	1.57
Li Y.	4	China University of Mining and Technology	China	1.2
Tiong R.L.K.	4	National University of Singapore, Nanyang Technology University	Singapore	1.12
Ke Y.	4	Tsinghua University, University of Newcastle	China, Australia	1.07

The most renowned and active researchers with multiple publications and securing a score of greater than one during the study period are shown in Table 4. Some key authors may have not made the list due to the limitations inherent in the formula used above to calculate author contributions. The formula considers the number of researchers and place of each researcher in a publication. Hence, if some key author collaborates with a number of other researchers and is placed later in the author list, they might not receive a high score. The top two most active researchers scored 6.43 and 4.27, respectively, which happen to be from recent publications and have worked and collaborated on most of these publications are A.P.C. Chan having 19 and E.E. Ameyaw having 11 publications. For most of these publications, their affiliation is with the Hong Kong Polytechnic University. Recognizing the leading contributors in research may offer other researchers some possible options for collaborations.

4.2. PPP Risk Management Findings

The findings relating to risk management in PPP are presented in this section. Findings on the risk management processes from this study have been presented in two sections.

4.2.1. Risk Identification and Assessment in PPPs

Risk management is a systematic process of identifying and managing risks to reduce losses by carefully examining potential future scenarios. Various professional and organizational standards for risk management can be found in the Project Management Institutes' risk management guidelines having received widespread acclaim from industry professionals and researchers alike.

Construction projects are risky in nature, PPPs not only involve construction, but the operation, maintenance, and financing are also embedded into its system. This, in turn, introduces additional risks. Ibrahim and Price [41] suggested that all the parties involved in PPPs need to understand these risks to achieve project milestones. Therefore, risk identification and assessment were found to be a common theme in many of the papers studied in this review. The risk assessment process lets project stakeholders decide the areas of project management that need to be focused on to achieve optimal results. Therefore, the need for practical and objective risk assessment approaches has been stressed in the existing literature on PPP [42]. Moreover, assessing the overall impact of various similar risks lets project managers plan remedial measures more effectively while saving time and cost [43].

Risks can be classified during the risk identification and assessment stage based on their inclination towards private or public sector. Mazher [44] explored this type of categorization in which risks were classified into country, market, and project level risks. Country-level risks include risks related to the macro environment of a country and allocated to public sector. As the name indicates, project-level risks were related to project objectives of cost, time, and design, and allocated to the private sector. Market-level risks included interest, inflation, and demand, and hence these are shared between both parties. Further classifications have also been proposed by other researchers based on the project lifecycle phases. Akomea-Frimpong and Jin [29] classified the PPP project risks into groups of pre-construction, construction, operation, maintenance, and market level risks.

Bing, et al. [45] identified the risks present in UK's private finance initiative (PFI) projects using a questionnaire survey. They categorized the risks based on certain aspects of project such as design, delays, cost, and performance. The perceptions of lenders and contractors were sought based on these categories. Results showed that respondents had different perceptions from each other based on their own interests. Similarly, by reviewing PPP literature, Wu, et al. [46] identified 37 risks related to PPPs. They further proceeded to develop categories of these risks. These categories consist of risks related to construction, operation, maintenance, legal, and economic issues. Hwang, et al. [47] also studied 42 significant risks in Singapore's PPP projects by reviewing the literature

comprehensively. Their analysis showed that "lack of governmental support" was the most significant risk suggesting inadequacy of government's experience.

Table 4. Risks related to PPP from the literature.

Risks	Risk Group	Risk Owner	Frequency	References
Interest rate changes	RG1	Private/Shared	9	1–9
Political interference	RG2	Public	8	1,2,4–9
Financial constraints	RG1	Private	8	1,3,4–9
Force majeure	RG5	Shared	8	1,2,4–9
Expropriation	RG2	Public	7	1,2,4–8
Asset risk	RG1	Shared	7	1,2,4–8
Public disapproval	RG4	Public	7	1,3,4,6–9
Communication risk	RG3	Shared	7	1,2,4,5,7–9
Construction time overrun	RG3	Private	7	1,2,4–6,8,9
Approval issues	RG3	Public	7	1,2,4,5,7–9
Weather	RG5	Shared	7	1,2,4–6,8,9
Geological settings	RG3	Shared	7	1,2,4–6,8,9
Change in taxes	RG1/3	Public	6	1,2,4,5,7,8
Corruption	RG2	Public	6	1,3,4,5,7,8
Environment	RG3	Shared	6	1,4,5,7–9
Inflation	RG1	Shared	6	1,3,4,5,7,8
Construction cost overrun	RG3	Private	6	1,5–9
Legal problems	RG3	Private	6	1,2,4,7–9
Design flaws	RG3	Private	6	1,3,5,6,8,9
Unstable government	RG2	Public	6	1,3,5,7–9
Government support	RG2	Public	5	3,4,7–9
Low productivity	RG3	Private	4	1,5,7,8
Technical risk	RG3	Private	4	1,5,7,8
Demand risk	RG1	Shared	4	1,3,4,9
Material risk	RG3	Private	4	1,2,4,9
Testing new practices	RG3	Private	4	1,2,4,9
Lack of PPP experience	RG3	Private	4	1,6,8,9
Contractual changes	RG3	Shared	4	1,7–9
Site availability	RG3	Shared	3	1,4,9
Safety and security	RG3	Shared	3	1,3,9
Commitment issues	RG3	Unspecified	3	1,2,9
High finance cost	RG1	Private	2	1,9
Scope Changes	RG3	Shared	1	4
Insufficient authority	RG1/2	Unspecified	1	1
Poor workmanship	RG3	Private	1	1

References: 1 = Bing, Akintoye [45]; 2 = Ng and Loosemore [48]; 3 = Li and Zou [49]; 4 = Xu, Yeung [50]; 5 = Hwang, Zhao [47]; 6= Ameyaw and Chan [43]; 7= Chou and Pramudawardhani [51]; 8 = Wu, Xu [46]; 9 = Rybnicek, Plakolm [52].

Other studies adopted methods such as literature reviews, cause and effect analysis, brainstorming, and expert opinions to develop a list of risks. This current study identified 35 key risks from nine most referred studies in this review, presented in Table 4. These studies were carefully chosen to extract these risks for their credibility among other researchers. Many of the pre-2015 studies among these are observed to act as a risk identification checklist/base for some of the newer studies in the area. On the other hand, a few studies included in this review identified as many as 50 risks making the process exhaustive and resulting in some of the risks identified to be very similar in nature to some other risks. For this reason, 35 risks were considered satisfactory for this study. Moreover, five risk groups (RG1 = Financial, RG2 = Political, RG3 = Project specific, RG4 = Social, RG5 = Uncontrollable) were identified, based on previous studies for each of the identified risk.

4.2.2. Risk Allocation in PPPs

Many researchers have argued in favor of PPPs for offering value for money. The basis of this argument is PPP's ability to transfer most of the project risk to private parties who are better equipped and experienced to manage risks [53]. Failure to transfer and share reasonable amount of risk to the private sector also goes against the principles of using PPP [54]. Reasonable transfer of risk helps in achieving better performance which leads to overall project success.

However, some of the well-established studies have been tabulated below in Table 5 to showcase their focus of research. The term preferred risk allocation reflects the practice of allocating risks based on majority opinion to the party best able to manage it [55]. These studies reinforce the importance of proper risk identification as that paves the way for a good risk allocation strategy.

Table 5. Main ideas in risk management research.

Focus of Research	Main Ideas	Authors
Allocation	Developed risk categories for UK PFI project, conducted questionnaire survey to find out preferred allocation of risks	[45]
Identification and allocation	identified and studied risk allocation criteria and actual risk allocation in Sydney railway project	[48]
Identification, assessment, and allocation	Identified risk from literature, risk assessment and allocation achieved by survey in Chinese PPP projects	[56]
Identification, assessment, and allocation	Identified risks from literature review, ranking and assessment generate by mean value analysis of survey responses, preferred risk allocation by respondent's views in Singapore	[47]
Identification and assessment	Risk factors identified for PPP water projects, shortlisted significant risks by survey from Ghana, quantitative analysis of significant risks using fuzzy approach	[43]
Identification, comparison, and allocation	Identified, compared, and categorized risk from literature, preferred risk allocation using mean value analysis of survey responses	[51]
Identification and assessment	Risk identification from literature, risk assessment using probability impact values	[46]

Different modeling techniques have been employed by researchers to model the allocation of risks in PPP projects as of late instead of the previously used method of preferred risk allocation where expert opinions were mainly used to determine which party is responsible for managing the risk [57]. These include but are not limited to: Analytical Hierarchy Process (AHP) [42,58]; Fuzzy Set Theory (FST) [59,60]; System Dynamics (SD) [61]; and Game Theory [62,63]. Ameyaw and Chan [64] in their study about risk allocation argue in favour of such risk allocation decision-making models as they take into account the risk management capability of parties involved as opposed to preferred method of allocating risks which is based on decision maker's perception of the risks [47].

5. Discussion

Table 4 presented the most commonly identified risks in PPP risk management literature. Among these, risks of interest rate changes, inflation rate, and change in taxes have received considerable attention from researchers [25,52,65]. These risks are related to the macroeconomic environment of a country. Such risks are of special importance in developing economies where PPPs are becoming increasingly popular [66], whereas developed countries may not be affected by these adversely, as they have stable economies [67]. Moreover, due to the long-term nature of PPPs, such financial risks need to be managed in great detail as even very small changes in the probability of occurrence can pose major threats to the project deliverables [43]. An example of this would be the higher cost of debt-servicing for project financing.

Another risk that has received considerable attention from researchers in the reviewed articles, especially in developing countries, is political interference [50,68]. Political influence such as making design changes in the construction stage, changing subcontractors due to political motives, and renegotiating contracts by the newly-elected government have been identified as factors leading to delays in the project and incurring additional money to the public balance sheet [69]. In most of the reviewed studies that have developed risk ranking, political interference is ranked in the top five risks [30,65,68,70]. Some of the studies report this risk to be one of the reasons for failure of projects as well [71]. Lack of professionals consulted during the planning stage, unnecessary pressure on private consortia to adjust user charges, and poor allocation of some key risks have been cited as reasons for increased public sector interference [72]. Another reason for this risk to have been given significant importance by researchers could be that it is also linked to other political risks such as expropriation, corruption, political opposition, and government instability.

Methods used to assess the risk involved in PPP projects are either qualitative or quantitative. Research indicates that the selection of the method depends on some factors such as: information available about risks, risk management capabilities of parties involved, and maturity of the PPP market [44]. A previous review by Zhang, et al. [73] shows that PPPs in developed countries prefer to use quantitative risk approaches, and qualitative risk assessment practices prevail in developing nations. However, the findings of this study indicate that this is not the case anymore. With the progression of the PPP model over time, newer and more complex approaches to assess the risks of PPPs have been proposed by various researchers. Some of the qualitative methods employed in practice are expert judgement, risk urgency analysis, and risk categorization [74]. These methods have an element of subjectivity in them as they rely on individual opinions in assessing the risks [75]. Quantitative analyses which are less common in practice but more emphasized by researchers include but are not limited to sensitivity analysis, Monte Carlo simulation, risk probability and impact matrix, meta-network approach, and fuzzy logic [73,75].

Apart from risk identification and assessment, risk allocation in PPP has also received considerable attention from researchers in this area. The risk allocation process seeks to establish appropriate risk transfer and risk sharing practices between public and private sector parties. This study identified three main themes for discussion of risk allocation in PPP, which are presented in the following subsections.

5.1. Actual and Preferred Risk Allocation in PPP

Appropriate risk transfer and sharing have been identified as key success factors by a handful of studies conducted in PPP research [76]. Risks are allocated to parties based on their ability to identify, plan, and control them. That is why it is not feasible to transfer or allocate all the project risks to the private sector. However, assessing a prospective risk, the owner's ability to manage a certain risk is subjective in nature, involving a high level of complexity which in turn makes the whole process of risk allocation vague and results in misallocation of risks. Alonso-Conde, et al. [77] proposed that incentives offered by the public sector help counter this complexity and help achieve value for money.

To study the allocation of risks, many researchers have performed studies which compare the actual allocation of risks on PPP projects with the preferred allocation driven from expert opinion mostly through a questionnaire survey. Participants are provided with a number of risks and asked to allocate the risk to a certain party or choose a combination of sharing mechanisms in which both parties share the risk equally or one party is given more share than the other. Ke, et al. [57] studied the preferred risk allocation in Chinese PPP projects and found that most of the risks were shared among the public and private sector. They studied the allocation of 37 risk, and only one of the risks was allocated solely to one party with the rest being shared. Results of such studies show that there is a considerable difference between the actual and preferred allocation of risks on PPP projects which have led to inefficiencies in risk allocation on PPP projects.

5.2. Misallocation of Risks in PPP

Although the principle for allocating risk to the party best equipped to manage it is appropriate to say the least, implementing it in practice is very tricky. This argument is supplemented by various literature citing sub-optimal allocation of risks in practice [44,64]. Some researchers have called this principle effective but also argue that it is vague in its nature [44]. Ng and Loosemore [48] argue that determining the ability of a party to manage risk is not simple and depends on some external factors. These include the bargaining power of the other party, the requirements of various other stakeholders, and the complex capital structure associated with such projects.

Given the importance of risk transfer and risk sharing among public and private sectors in PPP projects, a few researchers have studied ineffective risk allocation and misallocation of risks in PPP projects. Ke, et al. [78] compared and evaluated the risk misallocation impact on project performance in Chinese PPP projects based on the preferred and actual allocation of risks. Their results showed that project performance decreases with higher misallocation of risks. Further investigation revealed that risks of corruption, government intervention, land acquisition, and approvals were the most significant risks which affected project performance. Similarly, Shrestha, et al. [79] conducted a similar study where they used a questionnaire survey to determine the inefficiency in risk allocation by asking respondents the actual and preferred risk allocation in Chinese PPP water supply projects. Their findings revealed that the risks which were solely borne by private were inefficiently allocated. Furthermore, external risks such as political, social, environmental, and demand risk depicted inefficient allocation, which again are borne mostly by the private sector.

5.3. Capability based Risk Allocation

To counter the misallocation of risks, many researchers have come up with optimal risk allocation practices which assess each party's ability/capability to manage the identified risks [64]. Generally referred to as Risk Allocation Criteria (RAC), these practices guide "what, which, and how" of risk allocation, i.e., what risks to allocate, to which party, and how to go about it. These criteria adopted from the reviewed literature for their widespread use in PPP research have been tabulated in Table 6. RAC assess the ability of risk-taking party to manage such risks effectively.

Table 6. Risk Allocation Criteria identified from the literature.

Risk Allocation Criteria (RAC)	Description of the Criteria	Other Examples in Literature
Risk foresight	Ability of the party to identify and assess risk by predicting the probability of occurrence and the impact if that risk occurs.	[44,64,80–82]
Response to risk	Ability of the party to minimize the probability and impact of risk before it takes place.	[44,64,80–82]
Minimize risk loss	Ability of the party to minimize the loss/reduce the impact of the risk in case it occurs.	[44,64,81,83]
Absorb risk impact	The ability of the party to sustain the impact of the risk based on their experience.	[44,64,80,81,83]
Low risk cost	The ability of the party to manage risk in the least possible cost.	[44,64,83]
Obtain risk premium	The ability to receive compensation of a loss borne as a result of risk occurrence.	[44,64,80]
Exploit risk	To take advantage of certain risks due to an organization's capability and experience of dealing with that risk exceptionally well.	[44,64,80,82]
Risk attitude	The attitude of a party towards risk management i.e., risk averse/seeker/neutral/transfer.	[44,64,84]

Due to the unique characteristics of PPP, the focus of research is normally in the context of a specific country or sector. That is why it is difficult to generalize the allocation of these to a certain stakeholder involved in the project. There is a consensus among the researchers of articles reviewed that risk allocation achieved through their studies is in the context of the country involved in the study and the type of PPP project. This argument is supplemented by some other studies in the field of PPP research, which have identified appropriate risk allocation as a critical success factor in different countries [8,85,86]. Different models of PPP such as Build-Operate-Transfer (BOT), Build-Own-Operate-Transfer (BOOT) and Design-Build-Finance-Maintain-Operate (DBFMO) may have different risk allocation in the same country depending on the type of infrastructure project. For this reason, further analysis of the allocation of risks identified in this review has not been undertaken but could be useful in future research.

PPP arrangements involve multiple stakeholders, long contract periods and complex financial undertakings. All these factors result in additional risks which if not handled appropriately may result in failure of these schemes. Hence, the uniqueness and complexity of PPP projects demand comprehensive risk management. Based on the findings of this study and literature reviewed, a conceptual RAC based risk management process is presented in Figure 4 which aims to achieve effective risk management by improving risk allocation. This, coupled with other success factors, increases the chances of project success.

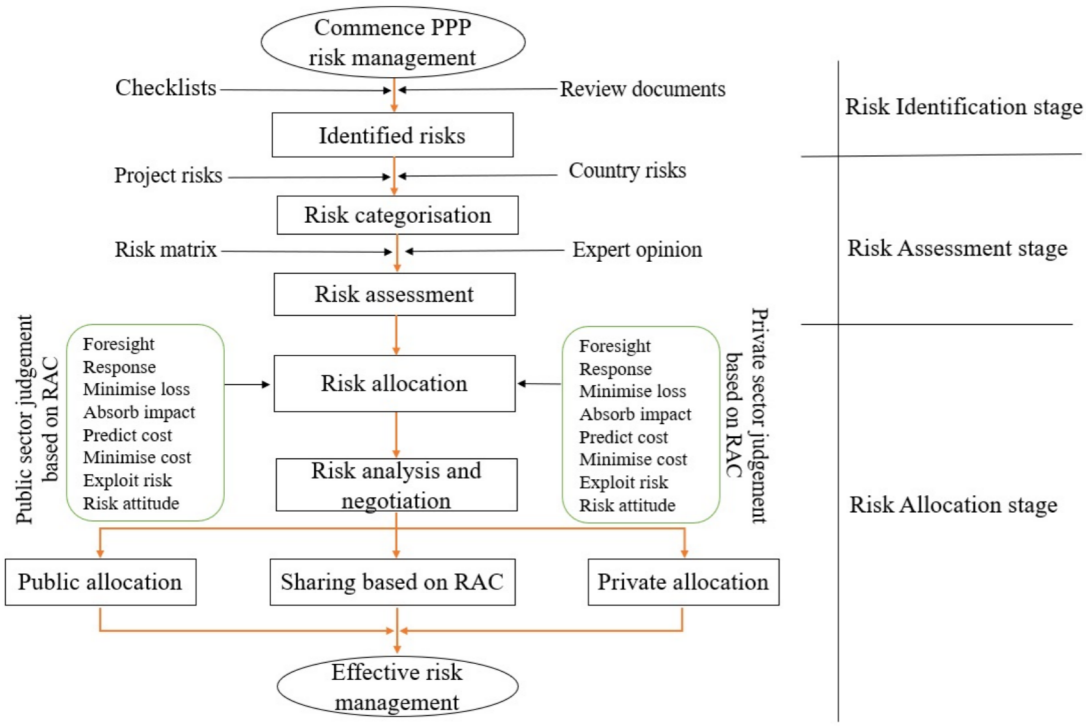

Figure 4. RAC-based risk management process.

Risk identification and assessment methods are well documented in the literature. Document analysis/literature review and checklist are the preferred tools for risk identification. Risk categorization can help group large items of risks into smaller more manageable risk groups. Identified risks can be better assessed for their criticality based on their chance of occurrence and severity using probability impact matrix. These steps can therefore help in improving risk identification which further compliments other stages (allocation and response planning) of PPP risk management. The traditional practice of risk allocation is by negotiation between the public and private sector participants. Risk

specialists from private and public sector negotiate an agreement for the allocation of risks. There is no neglecting the importance of negotiation in PPPs. However, it is not necessarily always considered the best tool for risk allocation practice as, depending on the stage of the project, one or the other party has more control over the project. For example, at procurement stage the public sector has more authority than the private parties, hence, greater bargaining power. This has been exploited in the past to allocate more risks to the private sector, often more than its capacity. The allocation process proposed in this study allocates certain risks based on the risk management capability of a party which is assessed in light of identified RAC from the literature reviewed in this study [44,64,81–83]. This is also embedded in the rule of risk sharing in PPP which states that risk should be allocated to the party best able to manage it. A better risk allocation can be achieved when each party's risk management capabilities are taken into account, which will ultimately help in achieving efficient risk allocation.

6. Conclusions

PPPs have seen a resurgence in the last decade in implementation as well as have grown more popular among researchers. Such projects have longer than usual lifecycles and are inherently complex because many stakeholders involved are considered riskier than traditional methods of procurement. Moreover, risk-sharing being the primary incentive to adopt such a technique of project delivery demands a more advanced understanding of the risks involved. This study performed an SLR using the PRISMA flowchart to examine the current literature relevant to risk identification, assessment, and allocation in PPP projects internationally from 1996 to 2021. Following a structured approach 87 relevant papers were identified and studied. Initial findings revealed that *The Journal of Construction Engineering and Management* is the leading journal having published approximately 12% of the total papers in this area. The yearly trend of the publications showed that research interest has grown exponentially from just one publication in 1996 to twenty-four publications in 2021. The most recognized researcher in the area and university are Chan A.P.C. and The Hong Kong Polytechnic University. China had the greatest number of researchers working in the risk management area of PPPs. Based on these findings it can be argued that the previously-stated research trend in the literature of PPPs being more popular in developed countries than developing nations is reversing. Developing nations such as China, India, and Iran have seen massive growth in PPP projects and research interest in the last decade. Conversely, PPPs have become less popular in developed countries due to negative sentiments in the general public for not achieving value for money as claimed. Consequently, a shift from more established PPP models such as BOT towards relatively newer design, build, finance, maintain, and operate (DBFMO) models has been observed, which offers the public sector to better control the financing to achieve transparency for public approval.

Risk identification, assessment, and allocation are the major areas studied in this review article. Interest rate changes, political interference, financial constraints, and force majeure are some of the most common risks identified in the reviewed literature. Although most studies have identified these risks, that does not mean they are the most critical. Different researchers have argued differently on the criticality of these risks. Further factors such as location, type, and mode of PPP employed need to be considered to determine critical risks. As the research trend has increased, the methods used for assessment of risk have become more objective with a focus on quantitative modelling. However, findings from the reviewed articles show that there is still a significant gap present in the practical implementation of such assessment techniques. Professionals still rely on qualitative approaches that are more subjective. Risk allocation in PPP projects has also received considerable attention from the research community. Researchers have used various approaches to allocate the risk between the public and private sectors. The two most common approaches identified are preferred risk allocation and capability-based risk allocation. Again, a shift from one to the other can be seen as the literature has developed

over the years. Capability-based risk allocation, which is more objective than preferred risk allocation, has gained popularity over the past decade.

This study has its limitations. The aim of the paper was to provide a general overview of the state of risk identification, assessment, and allocation research on PPPs. A more thorough understanding can be developed by separately reviewing aforementioned stages of risk management. Moreover, most of the reviewed research took a holistic approach to understanding project risks, be it identification, assessment, or allocation. Very few articles have approached an understanding of the most critical project risks individually. Future research can fill this gap by studying individual risks and their relation to other project risks. Further limitations of this research relate to the highly uneven distribution of publications over the study period. Since the last five years have seen more research undertaken in this area compared to the previous twenty years. By limiting the time span for future studies, a better judgment can be drawn for the current state of research. As mentioned previously, relatively newer financing arrangements in developed nations have come into practice to offer more transparency and achieve better value for money, such as the DBFMO mode of PPP employed by the Infrastructure Commission New Zealand. This offers new opportunities for further research.

Author Contributions: Conceptualization, N.R.; methodology, N.R., W.S. and J.O.B.R.; validation, N.R.; formal analysis, N.R.; investigation, N.R.; data curation, N.R., W.S., M.K. and J.O.B.R.; writing—original draft preparation, N.R.; writing—review and editing, N.R., W.S., M.K. and J.O.B.R.; visualization, N.R., W.S., M.K. and J.O.B.R.; supervision, W.S. and J.O.B.R.; project administration, W.S. and J.O.B.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research is an aspect of an ongoing Doctoral programme funded by the Higher Education Commission of Pakistan.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study is available on request from the corresponding author.

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

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