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Review of studies on risk allocation and sharing in public-private partnership projects for infrastructure delivery

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Public-private partnerships (PPPs) continue to grow globally as a means of procuring essential infrastructure and services to meet the ever-increasing demands of rising population and enhanced service delivery standards. Adequate risk allocation and sharing (RAS) is considered a critical success factor in PPP project delivery, however, it is exceptionally complex to establish and structure, difficult to monitor, and demands effort to properly enforce it in PPP contracts. This study aims to systematically review the existing PPP research in the RAS domain to explore the *status quo*, trends, and gaps in research. A thorough search and a meticulous shortlisting of academic literature resulted in 80 relevant journal articles published since the start of the 21st century whereafter a systematic content analysis was performed on these articles. Frequency analysis showed that nearly half of the reviewed papers were published by three journals including the journal of construction engineering and management, international journal of project management and construction management and economics journal. Furthermore, China and Australia seem to be the most active contributors accounting for 42 articles. Researchers extensively relied on case studies, literature review and surveys among other research methodologies for RAS research. The review further categorized the articles in five subcategories for in depth analysis. Most of the research reviewed falls in the “risks allocation and sharing preferences, practices, and models” category and accounts for 49% of the journal articles reviewed whereas the second largest category “government support and guarantees” accounts for 29% of the articles reviewed. Several research gaps were identified, and it is hoped that the results will motivate future research and enhance the body of knowledge in the domain of RAS in PPPs.

KEYWORDS

public-private partnership, PPP, risk allocation, risk sharing, risk transfer, risk exposure, risk retention, review

1 Introduction

PPPs for infrastructure delivery provide a medium to exploit private sector expertise and enable an increased integration of design, finance, construction, operation and maintenance

phases of an infrastructure project into a single contract (Yescombe, 2007; Marques and Berg, 2011). Therefore, PPPs are arguably an efficient means of fulfilling public infrastructure needs (DLA Piper, 2009; Raisbeck et al., 2010; Bansal, 2012). Evidence also exists against PPPs, terming these arrangements expensive to taxpayers when compared to traditional procurement strategies (Ng and Loosemore, 2007; Guasch et al., 2008; Beckers et al., 2013; Kurniawan, 2013). This dichotomy exists partly because of the inherent and diverse risks that exist over the lifecycle of a project, which are attributable to complex multistakeholder financial arrangements and the long-term nature of the underlying contract (Grimsey and Lewis, 2002; Dey and Ogunlana, 2004; Zhang, 2005; Chan et al., 2011). Therefore, effective risk management on such projects is a critical success factor (Thomas et al., 2006). The management of these diverse lifecycle risks must be carefully allocated to the public and the private sector stakeholders where each stakeholder has a unique perspective driven by their objectives (Figure 1). The public sector is concerned about risks that can influence a PPP project's viability in terms of achieving and maintaining value for money (VfM) and the provision of social welfare. Risks can also hit an equity investor's prospects of making an acceptable return whereas the lenders have a downside risk of potentially not being able to recover the issued debt (Grimsey and Lewis, 2002; Yescombe, 2007). Osei-Kyei and Chan (2015) identified appropriate risk allocation and sharing among the most reported critical success factors for PPP project implementation. Despite its importance, multiple studies have shown that risks are poorly allocated and shared on PPP projects (Arndt, 2000; Zou et al., 2008; Marques and Berg, 2011; HM Treasury, 2012). Poor RAS may negatively influence competitive tendering by reducing the number of prospective bidders and by supporting opportunism. It may also lead to increased risk premiums, higher incidence and severity of risks, inefficient risk management, conflicts, and disputes (Zitron, 2006; Ng and Loosemore, 2007).

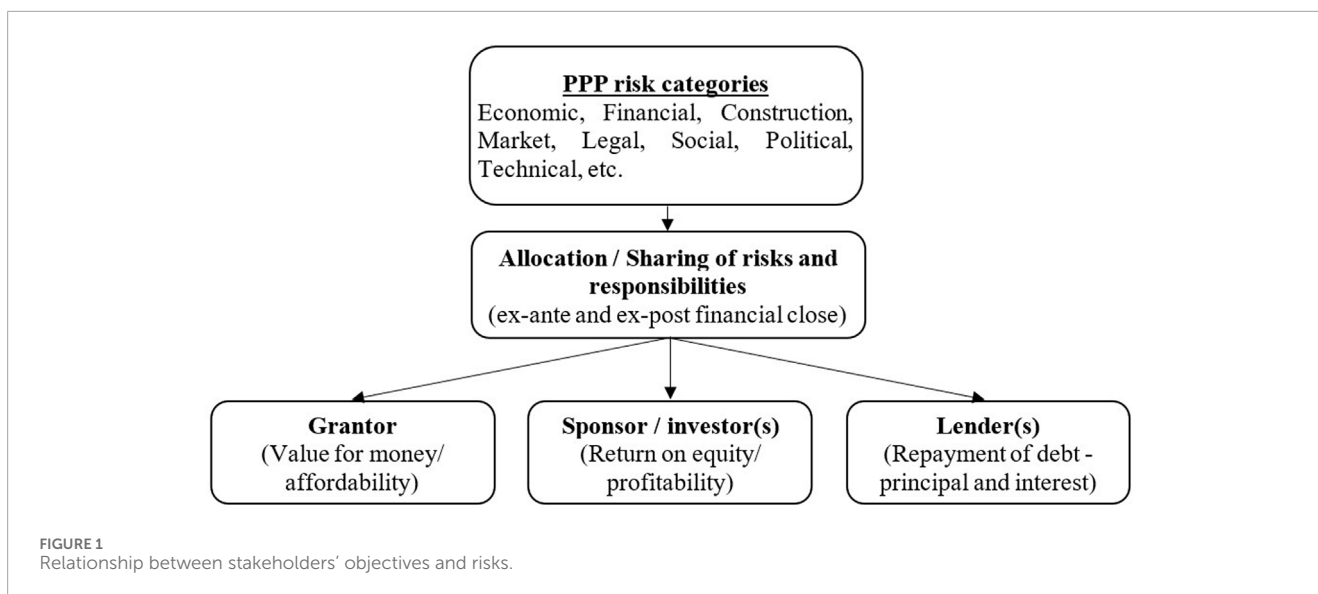
Existing reviews on research in PPPs have treated the subject as a single domain and as such render themselves as high-level summaries that demonstrate the research activity in PPPs over a few decades. Tang et al. (2010) reviewed PPP studies published in top six journals in the construction field and classified them into various categories and subcategories, where risks management was one of the categories. Ismail (2011) performed a qualitative meta-analysis and concluded that among investigations on other issues, past literature on PPP has mostly focused on its concepts and application and risk management and performance. Osei-Kyei and Chan (2015) reviewed research on critical success factors for PPP project implementation from some selected top tier academic journals. In a bibliometric analysis of PPPs and PFIs, de Castro e Silva Neto et al. (2016) argued that a large portion of the existing body of knowledge focused on aspects of contract design, risk sharing, and analyzing the contract performance and benefits. Zhang et al. (2016) conducted a comparative review between PPP research progress and status in publications in Chinese journals and international journals and determined several active research topics. Cui et al. (2018) reviewed the existing PPP research to explore the *status quo*, trends, and gaps in research for PPP infrastructure projects. They classified popular research topics in six categories. Bao et al. (2018) analyzed the research status and possible future studies from the viewpoint of PPP project life cycle. Xiong et al. (2019) conducted a systematic review of case study literature on

PPP governance and proposed a governance framework. Set within the context of developing countries, Almeile et al. (2024) conducted a state-of-the-art systematic review of project-focused literature published in PPP. Some review studies have directly focused on risk management in PPPs. Abd Karim (2011) reviewed the risk factors of PPP construction project by mapping previous research works on PPP project around the world and provided the frequency of factors that are considered in the risk allocation of PPP projects. Yu et al. (2018) conducted a systematic review of published journal papers on transnational PPPs critical risk factors. Tallaki and Bracci (2021) examined risk and risk management in PPP/PFI through a systematic literature review. Osei-Kyei et al. (2023) reviewed the trend of research studies on risk management in PPPs and evaluated the focus of the published studies on the key areas of the conventional risk management framework process. Such summaries of the published PPP literature are good to understand generally where the interests of PPP research community lie and what are the latest trends in PPP research. Despite their useful contributions, upon further investigation, it is clear that PPP research in the sub-domain of RAS has emerged as a huge body of knowledge in itself that deserves a dedicated review to understand the related trends and concerns. In particular, this research sets out to achieve the following objectives: (i) to identify the research sub-themes contributing to knowledge on the broad subject of RAS in PPPs, (ii) to determine the most common research methods employed in studying RAS in PPPs, and (iii) to identify gaps in research with reference to RAS in PPPs.

The paper is organized into several sections to facilitate a structured presentation of information. After the introduction section wherein the significance of RAS in PPPs is discussed, the methodology section presents the stepwise procedure adopted to search and retrieve relevant literature for a systematic review. The third section contains a bibliometric analysis of the reviewed journal articles. The fourth section presents the discussion of classification of the retrieved literature into five sub-categories. This is followed by the last section where conclusions are formalized and suggestions for future research are provided which are derived from the knowledge gaps identified in this review exercise.

2 Methodology

This research employed a (SLR) methodology to identify research trends and themes in the domain of RAS in PPPs. As illustrated by Ke et al. (2009) and Osei-Kyei and Chan (2015), there are many possible keywords to search for PPP relevant literature. Also, there are several scholarly search engines and databases that can be used to search for the relevant academic literature. Following the precedence set by Ke et al. (2009), Osei-Kyei and Chan (2015), Bao et al. (2018), Yu et al. (2018), and Zhang et al. (2016) in writing reviews on PPP research, this research also adopted the Scopus search engine to scour various academic databases. The search time frame was set between the years 2000 and 2023 (both years inclusive). The reason for excluding the decade before the year 2000 is that the number of relevant PPP RAS publications is too small in that period. This is evident from the review on PPP studies conducted by Cui et al. (2018). The search string employed to enable a title/abstract/keywords-based search via the Scopus search engine is as follows:



[TITLE-ABS-KEY ("risk allocation" OR "risk sharing" OR "risk transfer" OR "risk retention" OR "risk structuring" OR "risk exposure") AND TITLE-ABS-KEY ("public-private partnership" OR "private finance initiative" OR "private infrastructure" OR "public infrastructure" OR "ppp" OR "pfi" OR "bot" OR "boot" OR "dbfo" OR "dbfom" OR "ppp/pfi" OR "p3" OR "3p")] AND PUBYEAR >1999 AND PUBYEAR <2024 AND [LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENER") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "DECI")] AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND [LIMIT-TO (LANGUAGE, "English")] AND [LIMIT-TO (SRCTYPE, "j")].

The search keywords used to obtain risk allocation and sharing related studies included "risk allocation," "risk sharing," "risk transfer," "risk retention," "risk structuring," and "risk exposure." The search keywords used to ensure that only studies relevant to PPPs show up in the search included "public-private partnership," "private finance initiative," "private infrastructure," "public infrastructure," "PPP," "PFI," "BOT," "BOOT," "DBFO," "DBFOM," "PPP/PFI," "P3," and "3P." The search results were restricted to the subject areas of "engineering," "environmental science," "business," "energy," "econometrics, finance, and economics," "social sciences" and, "decision sciences." The document type in the search was restricted to 'article or review'. The search was conducted on 18 September 2023. Furthermore, the search only targeted documents published in English language.

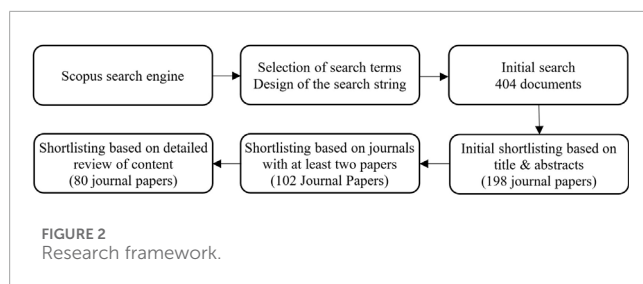
The search initially resulted in 444 documents. A brief review of the titles and abstracts resulted in identifying and removing invalid search results leaving 198 documents. In the next step of shortlisting, only journal articles were retained while removing conference papers, review papers, and others during the shortlisting process. It was found that a total of 109 different journals had published the 198 articles included in the initial shortlist. It was further observed that many journals had only one paper relevant to the search query. It was decided to keep the review exercise

limited to journals that frequently publish works on RAS. Therefore, following the methodology adopted for shortlisting by [Darko and Chan \(2016\)](#) and [Osei-Kyei and Chan \(2015\)](#), only those journals that had published at least two or more papers in the review horizon were retained for further analysis. This brought the number of results to 102 journal articles. Finally, a detailed content analysis of the 102 journal articles led to identifying another 22 journal articles that were considered irrelevant to the scope of this research, thereby bringing down the number of relevant articles for review to 80. It is imperative to acknowledge here that despite the adoption of a comprehensive search scheme, the shortlisted list of papers may not be exhaustive and inclusive of all the relevant works on the selected subject area of RAS in PPPs. This may be attributable to the limitations of the selected search engine, potentially missing keywords in the search string, and publications coming online after the search period and until the publication of this study, among other factors. Therefore, any analysis presented is solely based on the adopted search methodology. Additionally, the purpose of this review is to review the trend of research in the domain of RAS in PPPs and to classify the trends appropriately. As such the limitations stated above should not negatively influence the outcomes of this review in any significant manner given the large number of studies included in the review (80). The literature search and sampling process following the PRISMA protocol ([Moher et al., 2009](#)) is graphically depicted in [Figure 2](#).

3 Overview and analysis of PPP risk allocation and sharing research

3.1 Number of publications per year

[Figure 3](#) shows the annual publication statistics for research in the domain of RAS in PPPs. There is a clear increase in research interest from the year 2010 however, the number of annual publications does not sustain a regular trend. This



agrees only partially with the trends observed in general PPP research as determined by Zhang et al. (2016). In the first 5 years of the review period (2000–2005), research studies only came out of China, Hong Kong, Singapore, India and the United Kingdom with the highest number of studies published in the construction management and economics (CME) journal. In the next 5 years (2006–2010), most of the studies were published in the international journal of project management (IJPM) with new countries that started showing interest in this research domain including Indonesia, Spain, Australia, and Greece, whereas China, the United Kingdom, and Singapore continued to work in this period. Other countries that jumped in during the next 5 years (2011–2015) period include Iran, the United States, Thailand, Italy, Malaysia, Ireland, and Taiwan. IJPM continued to publish the largest number of studies in this period. Ghana, Vietnam, Turkey, Portugal, the UAE, Colombia, and Egypt appeared as new contenders in the next 5 years period (2016–2020). The journal of construction engineering and management (JCEM) and the sustainability (Switzerland) journal published the largest number of studies in this period. Nepal was the only new country that saw a relevant paper coming out in the year 2023. Engineering, Construction, and Architectural Management (ECAM) journal published the largest number of studies in this period. It is understandable that as time goes on, governments across the world are finding interest in this mode of procurement and therefore the increase in interest to study the critical issue of RAS is also understandable.

3.2 Publication journal title

The reviewed papers were extracted from 20 journals in total. As evident from the information in Table 1, the six journals that published 62% of all the papers reviewed include the JCEM, IJPM, Construction Management and Economics (CME), ECAM, Sustainability (Switzerland), and the International Journal of Strategic Property Management. This result is also partially supported by the findings of previous more general reviews on PPPs (Tang et al., 2010; Cui et al., 2018).

3.3 Publications distributed by lead country or region

The United Kingdom and Australia are considered to be the leaders when it comes to promotion of the PPP mode of

infrastructure procurement (Table 2). However, China contributed the most by accounting for 26% of total reviewed studies in this research, followed by Australia and the United Kingdom. It should also be noted that the statistics shown in Table 2 were developed by considering the country of institutional affiliation of the first author only. This assumption is based on the logic that the position of the author in a publication is a direct indicator of the level of research contribution, thus justifying the country of association of the lead author to be the country of origin of research. Co-authors may contribute in various ways in any research and could be multinational thus their countries of association were not considered in the research origin analysis. On the contrary, cases were observed where the lead author in a paper is affiliated with one country whereas the paper reports data on PPP RAS by covering the case of another country. Examples include the research by Mazher et al. (2019) and Almarri et al. (2019), where the lead authors show their institutional affiliations with Hong Kong and the UAE while presenting data and analysis on PPP projects in Pakistan and Saudi Arabia, respectively. Table 2 also shows how so many other countries where PPP projects are implemented remain under-represented in research in PPP RAS.

3.4 Publications distributed by project type

It is common in research on RAS to focus on a particular infrastructure sector context (either economic or social infrastructure). This is essentially true because considerations for RAS vary significantly from one infrastructure sector to another (e.g., transport and power sectors), from one subsector to another (e.g., power plants and transmission grid) and from one technology to another (e.g., hydropower plant and solar power plant) (Mazher et al., 2019). In the review sample, 29 research papers did not specify any specific infrastructure sector whereas all the rest focused on one particular sector (Table 3). The transport sector seems to be the focus of most research, followed by the water and power sectors. This trend is clearly visible from the research coming out of China and Australia where more papers deal with transport infrastructure than water infrastructure projects. Other infrastructure sectors saw a low interest in RAS research in PPPs. According to the private participation in infrastructure (PPI) database by the World Bank, investment statistics up to the year 2018 show that the power and transport infrastructure sectors account for the largest share of global private investment in public infrastructure in low- and middle-income countries (Mazher et al., 2018). A troubling finding here is that the social infrastructure sector which includes prisons, hospitals, student hostels, etc. are largely ignored by the extant research. Moreover, even in the domain of economic infrastructure, which includes highways, water supply systems, power plants etc., many sectors and subsectors are under-represented by the existing research. Energy infrastructure for natural gas systems, waste collection and management systems for municipal solid waste, solar power systems, are a few examples of the infrastructure sectors and subsectors that need attention in RAS research.

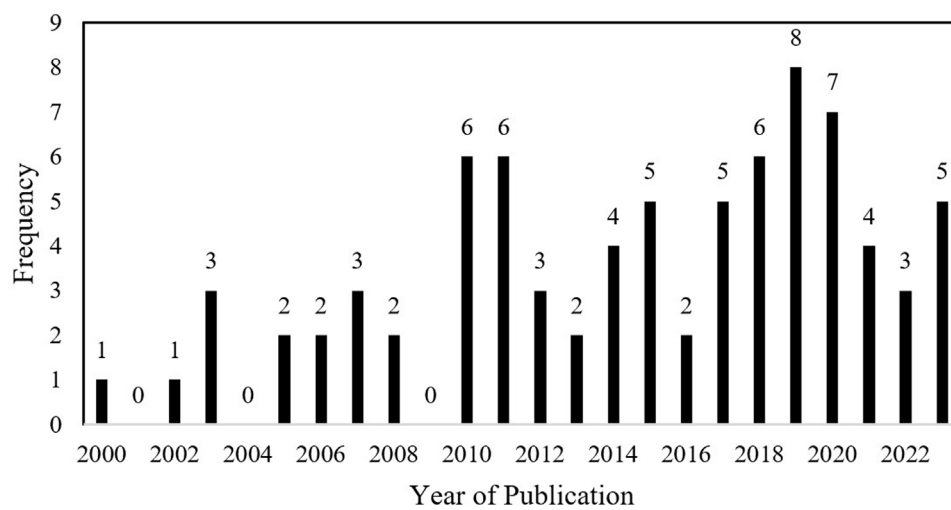


FIGURE 3
Number of publications annually from the year 2000–2023.

3.5 Research methods and data type adopted by researchers

Most of the research reviewed adopted mixed methods for research whereby several data collection and analysis techniques were employed in a single research study. More research methods are better to cross validate the research findings, which makes the study more rigorous and convincing (Zhang et al., 2016). Through content analysis method, the research methods of each paper are identified and counted, as shown in Table 4. Case study method appeared to be the most popular method of all the methods adopted. Out of the 80 reviewed papers, 42 papers adopted this method to either discuss RAS schemes on projects or to use the case study data for testing and validation of a proposed model. Case study method is the best method to explore the intricacies of proportioning risks between the public and the private sector. Interviews with project experts and review of project documents are some of the data collection methods used in case studies that lead to discovery of specific details on a project. Literature reviews (28), questionnaire survey (24), and interviews (12) are other popular data collection methods that were adopted by researchers. Literature reviews are mostly adopted to position research in the existing knowledge landscape. Questionnaire surveys are more popular than interviews as they serve as a versatile medium to obtain large amounts of data in a short amount of time and with limited resources. Monte Carlo Simulation (MCS) simulation and NPV modeling techniques have also been popularly adopted to understand the influence of various risk allocation and sharing scenarios and the effect of risk mitigation strategies on project revenues and VfM. Various MCDM techniques have been used in research to propose RAS models that provide a structured decision-making methodology which avoids weaknesses of human qualitative judgement.

It was also found from the review exercise that most of the research (37.5%) used primary data for modeling and analysis whereas only 7.5% of the reviewed articles adopted secondary

data (Table 5). For example, Kukah et al. (2024) used Delphi surveys to propose a fuzzy quantitative risk allocation model for Ghanaian PPP power projects (a typical case where primary data was used) whereas Xu et al. (2014) collected 10 PPP project cases from journal papers, doctoral/master thesis, and news reports from official media, in identifying how government guarantees influence the success of PPP projects (a typical case where secondary data was employed). 15% of the papers reviewed used both primary and secondary data whereas the remaining 40% of the papers did not mention the type of data collected.

3.6 Classification of research themes

Table 6 shows the sub-themes of risk allocation and sharing that were established to conduct a detailed systematic review of research in RAS in PPPs. To better understand the basis of this proposed categorical framework for this review, a general RAS decision framework is proposed in Figure 4. It can be clearly seen that risks are to be proportioned based on the capabilities of the public and the private sector to shoulder the risk individually or together in a shared mode, while always ensuring that the arrangement leads to a commercially feasible and a bankable project that also ensures VfM for the public. This exercise of determining and assessing the capability of a party (public and private sectors) is complex as it is based on stakeholder characteristics, project characteristics, and a project's environmental characteristics, all of which could be uncertain and hard to estimate. Therefore, a lot of research efforts have been exerted to determine how risks should be ideally proportioned. This led researchers to study RAS preferences of PPP stakeholders. In other cases, the researchers adopted a different approach whereby they leaned on various modeling approaches such as artificial intelligence (AI), MCDM, Game theory, Real options, MCS, NPV, etc., to quantify the capability of the stakeholders and to analyze project characteristics to properly apportion risks. While transferring certain risks to the private sector, and in an effort to

TABLE 1 Number of publications distributed by journal.

Journal title	Number	Journal title	Number
Journal of Construction Engineering and Management	13	Transport	2
International Journal of Project Management	12	Canadian Journal of Civil Engineering	2
Construction Management and Economics	11	Engineering Economist	2
Engineering, Construction and Architectural Management	6	Transportation Research Part A: Policy and Practice	2
Sustainability (Switzerland)	6	International Journal of Construction Management	2
International Journal of Strategic Property Management	5	Review of Financial Economics	1
Journal of Infrastructure Systems	4	Transport Reviews	1
Utilities Policy	3	Critical Perspectives on Accounting	1
Journal of Financial Management of Property and Construction	3	Sustainability (United States)	1
Journal of Cleaner Production	2	International Journal of Critical Infrastructures	1

attract private investment, the governments provide various types of support including guarantees which are essentially a risk allocation and sharing exercise. In some instances, during a PPP project's operational lifecycle phase, uncertainties may lead to situations where the project stakeholders are forced to renegotiate the project's original risk allocation and structuring leading to undetermined effects on VfM. Therefore, the sub-themes proposed in Table 6 condenses all similar research and summarizes developments in five proposed sub-themes.

4 Discussion

4.1 RAS preferences, practices, and models

A large number of researchers with interest in the subject of RAS in PPPs/PFIs have sought to explore perceptions of experts on fair and equitable allocation of risks using surveys. It is imperative to

TABLE 2 Research origin of studies by country.

Country	Number	Country	Number
China	21	United States	2
Australia	13	Iran	1
United Kingdom	4	Vietnam	1
Indonesia	4	Ireland	1
India	4	Nepal	1
Singapore	4	Portugal	1
Spain	3	Turkey	1
Italy	3	Thailand	1
Greece	3	UAE	1
Malaysia	3	Colombia	1
Hong Kong	3	Egypt	1
Ghana	2	Taiwan	1

TABLE 3 Number of publications by project type.

Project types	Number	Project types	Number
Transport (Road/Highway/Motorway/Railway/Tunnel/Bridge/Port/Airport)	30	Combined cooling heating and power project	1
Water (Supply/Waste disposal/Wastewater treatment/Seawater desalination)	9	Funeral service center	1
Power (Plant, Transmission line, Geothermal, Energy from waste)	5	Sustainable characteristic town development	1
River management	1	Archeological site	1
Construction waste recycling	1	Rental retirement villages	1

understand that risks and their allocation are heavily influenced by the context in which a particular project is executed. Preferences for allocation and sharing of risks vary by geographical location of a project, the infrastructure sector, technology involved in the project, and local economic, financial, and political factors, among others (Mazher et al., 2019). The most common research methods adopted to capture PPP experts' judgements include questionnaire surveys and interviews. These approaches are well-recognized and widely used in social science, general management and project management research (Thomas et al., 2003; Wibowo and Mohamed,

TABLE 4 Research methods adopted by researchers.

Research methods	Number	Research methods	Number
Case study	42	Multiple Linear Regression modeling	3
Literature review	28	Variance model	2
Questionnaire survey	24	Principal agent model	2
Monte Carlo Simulation	21	AI modeling	2
Net Present Value (NPV) modeling	16	Optimization modeling	2
Interviews	12	Shapley value modeling	2
Multi-Criteria Decision Making (MCDM) modeling (FSE, AHP, ANP, and others)	10	Numerical simulation	1
Sensitivity analysis	8	Cost/Benefit analysis	1
Game theory modeling	8	Internal Rate of Return (IRR) modeling	1
Real options modeling	7	Scenario analysis	1
Delphi survey	7	Genetic Algorithm modeling	1
Fuzzy set theory	3	Workshop	1

TABLE 5 Types of data used by researchers.

Data type	Number
Primary	30
Secondary	6
Mixed	12
Not specified	32

2010; Mazher et al., 2018). The main research question is to seek a consensus-based opinion on whether a particular risk should be allocated to the public sector or to the private sector or shared. A risk shall be transferred to the private sector if they have a superior ability or comparative advantage to manage it. Alternatively, it should be retained by the public sector. Where none of the parties show adequate capability in managing a risk, then it should be shared (Asian Development Bank, 2000; Irwin, 2007). General risk allocation preferences have been explored in

TABLE 6 Number of publications distributed by themes of risk allocation and sharing.

Sr	Sub-themes	Number	Percentage
1	RAS preferences, practices, and models	39	49%
2	RAS via government support and guarantees	22	28%
3	RAS via concession period and tariff design	8	10%
4	Determinants of RAS	6	7%
5	Influence of RAS on VfM and governance	5	6%

previous research in the United Kingdom (Bing et al., 2005), Nigeria (Ibrahim et al., 2006), China (Ke et al., 2010b) Greece (Rouboutsos and Anagnostopoulos, 2008), Singapore (Hwang et al., 2013), Saudi Arabia (Almarri et al., 2019), in a comparative study of China and HK (Ke et al., 2010a), and in a cross-country comparison between Taiwan, Singapore, China, the United Kingdom, and Indonesia (Chou and Pramudawardhani, 2015). Some researchers have focused on expert's risks allocation preferences in particular infrastructure sectors. Thomas et al. (2003) conducted one of the first studies that explored experts' perceptions on risk allocation for BOT road projects in India. Kate and Patil (2020) explored risk allocation preferences for power transmission line projects in India. Shrestha et al. (2018) indicated risk allocation inefficiencies in Chinese PPP water projects whereas, Nur et al. (2023) investigated risk allocation perceptions in Indonesian geothermal projects. Other infrastructure sectors surveyed from the perspective of RAS include: Egypt's domestic wastewater treatment and seawater desalination PPP projects (Rafaat et al., 2020), Indonesian water supply projects (Wibowo and Mohamed, 2010), and energy from waste technologies in Indian PPP waste treatment projects (Dolla and Laishram, 2021).

A particular stream of research effort has been directed at developing models to assist in risk allocation decision making. Researchers have adopted MCDM, game theory, genetic algorithms, and AI techniques to model and optimize the risk allocation decision making process. The risk allocation decision process can be likened to a MCDM problem where a utility function can be employed in evaluating multiple risks (Mazher et al., 2019). Wang et al. (2023) adopted the Best-worst multi-criteria decision-making method and comprehensive fuzzy evaluation method to develop a practical and effective risk sharing model for PPP construction waste recycling projects. Based on a set of established risk-allocation criteria, Ameyaw and Chan (2015) and Ameyaw and Chan (2016) developed fuzzy synthetic evaluation-based models to assist in risk allocation in water supply infrastructure projects in Ghana. Valipour et al. (2016), Mazher et al. (2019) and Kukah et al. (2024) also developed different fuzzy MCDM quantitative risk allocation models to guide decision-making on risk allocation in PPP projects. Valipour et al. (2019) presented a hybrid SWARA-COPRAS approach to examine risk allocation, particularly for PPP water supply and sewerage

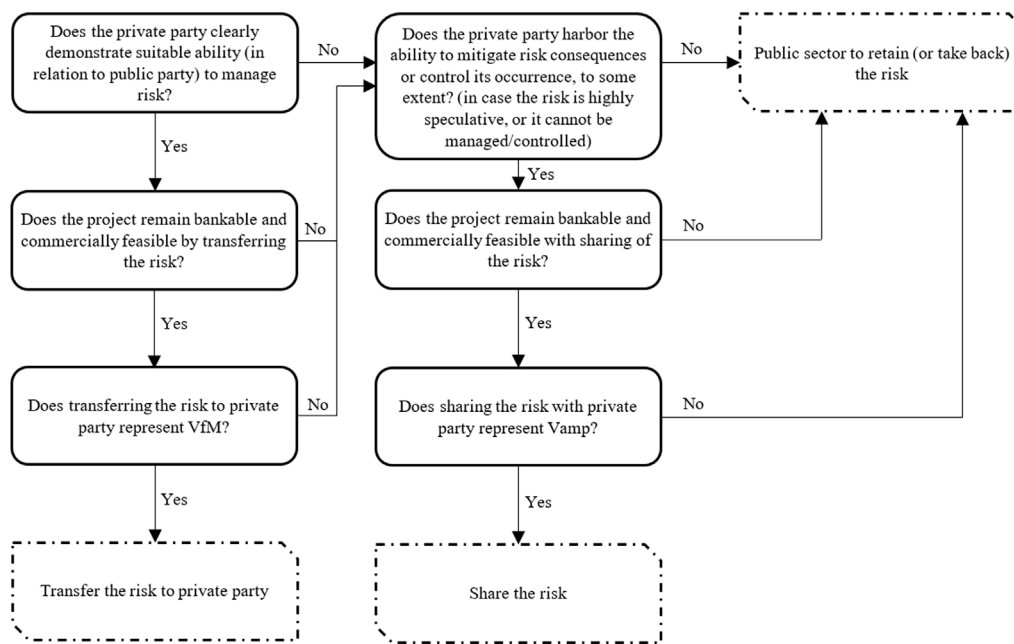


FIGURE 4
Risk allocation and sharing general decision framework.

projects in the context of Malaysia. [Li et al. \(2017\)](#) contended that the risk allocation can be analyzed as a game to more fully reflect the risk allocation bargaining process among the parties i.e., the public and private sectors involved in PPP projects. [Lai \(2018\)](#) explored optimal risk-sharing scheme between the public sector and the private sector for six main kinds of risks in the development of PPP based sustainable characteristic town through use of a game model. A different approach was adopted by [Alireza et al. \(2014\)](#) to develop a Genetic Algorithm based optimization model to enhance risk allocation process in PPP projects. [Jin and Zhang \(2011\)](#) and [Jin \(2011\)](#) proposed and validated methodologies for modelling risk allocation decision-making process in PPP projects based on artificial neural network and neuro-fuzzy techniques, respectively.

For complex social science and real-life events, the case study method enables systematic observation of a phenomenon in its natural context. This method can provide a deeper understanding of the phenomenon under consideration. In case study research, both qualitative and quantitative data can be collected using other methods ([Eisenhardt, 1989](#)). Data are usually collected using interviews, primary and secondary documentary analysis which may include contract documentation, government and private sector reports, journal articles, conference presentations, and newspaper articles, among other sources ([Ng and Loosemore, 2007](#); [Heravi and Hajihosseini, 2012](#)). [Ng and Loosemore \(2007\)](#) discussed difficulties in distributing risk appropriately while presenting a case study of the troubled New Southern Railway project in Sydney, Australia. [Nguyen et al. \(2018\)](#) conducted very interesting research by evaluating 21 PPP project contracts in the U.S. highway market and baselined risk allocation and provisioning among contemporary contracts. Similarly, other notable research reviewed that adopted

case studies as the primary research method include a case study of the Tehran–Chalus Toll Road project in Iran ([Heravi and Hajihosseini, 2012](#)), risk allocation in Chilean highway PPPs ([Castelblanco et al., 2020](#)), risk allocation in water sector projects in China ([Xu et al., 2011](#)), and risk allocation in the context of a river management Design-Build-Finance-Operate-Transfer project ([Liu and Xue, 2019](#)). Such research provides in-depth insights on a project's contextual aspects and why certain risks are apportioned in a particular way with some authors providing suggestions to improve risk allocation practices for future projects.

A small number of papers in the reviewed sample adopted a unique approach to their investigations pertaining to risk allocation by focusing on particular risks including revenue risk allocation for transport infrastructure PPP projects ([Roumboutsos and Pantelias, 2015](#)), demand risk in Irish PPP toll road projects ([Burke and Demirag, 2015](#)) and forex risk-allocation ([Kuikel et al., 2023](#)). [Roumboutsos et al. \(2020\)](#), in one of the first efforts, introduced two composite indicators as tools to guide contracting parties in efficient demand risk allocation.

4.2 RAS via government support and guarantees

PPP projects usually exhibit a significant exposure to high impact risks which necessitate support provided by the governments to attract private sector interest. Risks related to political, legal, and economic stability mainly influence the confidence of investors. Other risks of concern for private investors include those that can potentially negatively influence cash flows due to uncertainty in

demand, variation in toll/tariff, different project revenue and debt denominations, and force majeure, among other risks. Government support often required includes revenue guarantee, foreign exchange risk guarantee, debt repayment security, price adjustment, restrictive competition guarantee, and the compensation for force majeure events (Ye and Tiong, 2000; Wang and Liu, 2015). Such government intervention protects the project stakeholders by shielding them from the full financial costs of risks (Iyer and Sagheer, 2011). In PPP projects, provision of guarantees by the government to the investors is an important risk-sharing scheme. Another concern is that information asymmetry between the government and the private investors leads to speculation since the government does not have the same information as the private investors (Wang et al., 2019). Provision of guarantees by the government may potentially open doors for opportunistic behavior by the private sector where either this provision may weaken the capacity of the private sector to reduce risks or such a provision may be abused by the private sector and they may qualify for government guarantees by purposefully limiting revenues and keeping them lower than the expected threshold thereby reducing cost commitments (Medda, 2007; Wang et al., 2018; Wang et al., 2019).

The extant literature recognizes the difficulty in assessing the real impact of these supports on project's performance and the stakeholders. Firstly, these supports cause the government to assume all contingent liabilities thus potentially leading to a situation where the government has to face significant future budgetary impacts and it may also become penalizing for the public sector (Pellegrino, 2021). Secondly, the arrangements under these supports must ensure an even risk distribution between the public and the private sector, while also balancing the distribution of benefits that result from the application of such supports and avoiding windfall gains to one party at the expense of the other (Carbonara et al., 2014b; Wang and Liu, 2015; Zhang et al., 2021). Guarantees are expensive and too many guarantees can induce government credit risk whereas inadequate guarantees provided may make the project uneconomical (Sobhiyah et al., 2009). Xu et al. (2014) argued that many PPP projects have been heavily criticized in China because the government provided the private sector with too many guarantees and suggested that both the public and the private sectors need to enhance their understanding of risk sharing to obtain a reasonable guarantee structure. A similar observation was shared by Bel et al. (2017) where the authors summarized three PPP failure case studies from Spain. The authors showed that the local taxpayers and users absorbed losses as the state's financial liability activated and resulted in the government assuming heavy financial obligations. Alonso-Conde et al. (2007) presented the case study of the Melbourne CityLink Project and used the real options approach to model the financial incentives/guarantee provided by the government. They analyzed the consequential partial risk transfer back from the private to the public sector and how these options affect the incentive to invest and further estimated the value the public sector may be transferring to the private sector through government guarantees. Liu et al. (2017) and Pellegrino (2021) proposed quantitative models to guide governments' decisions when choosing among the support mechanisms when the financial viability of a project is uncertain. The authors contended that there is a real risk of surplus fiscal support ex ante or unexpected liabilities ex post in case of a government's inability to evaluate various alternatives.

A plethora of research exists that has modeled and explored fair traffic and revenue risk allocation and the influence of traffic guarantees, and government minimum revenue guarantee and traffic revenue cap (Medda, 2007; Vassallo, 2010; Iyer and Sagheer, 2011; Ashuri et al., 2012; Kokkaew and Chiara, 2013; Carbonara et al., 2014b; Wang and Liu, 2015; Buyukyoran and Gundes, 2018; Wang et al., 2018; Wang et al., 2019; Du et al., 2019; Zhang et al., 2021; Wu et al., 2022; Jin et al., 2023). Liu et al. (2019) adopted the real option theory and explored non-competitive guarantee in PPP rental retirement villages and developed a model to evaluate government compensation and guarantee costs in consideration of benefit redistribution if the governments are unable to keep the promise on guarantee provision.

4.3 RAS via concession period and pricing/tariff

In BOT projects, concession period represents the span of time within which the private sector must construct the project and then operate it to recover the investment and to generate a return on investment (Carbonara et al., 2014a). The risk burden shifts to the government if the concession period is too long and it shifts to the private sector if it is too short. The stakeholders need a reasonable length of concession period to ensure that the private sector makes a favorable profit, and the public sector gets VfM (Shen et al., 2002; Guo et al., 2021). The design of concession period involves the design of period structure, the determination of period length and incentive schemes. Each concession has its duration, which may be fixed or variable where the choice is influenced by various risk factors such as completion time, product prices and market demand (Ye and Tiong, 2003b). Shen et al. (2002) developed an NPV based approach for determining the concession period that incorporates both the investor's and the government's interests. Ye and Tiong (2003b) systematically explored the types of concession structures for BOT projects and evaluated the effectiveness of different concession period structures on financial return and completion risk management through mathematical analyses and computer simulations. Carbonara et al. (2014a) developed a model for calculating the concession period as the best instant of time that creates a "win-win" solution for both the concessionaire and the government and allows for a fair risk sharing between the two parties, while taking into account the uncertainty that affects the PPP projects using the MCS. Ma et al. (2018), Lomoro et al. (2020), and Guo et al. (2021) proposed more advanced and robust approaches for the determination of the optimal concession period.

A related issue is with regard to concession pricing or tariff determination and adjustment. A similar concern exists here in the determination of the concession price where the private sector wishes to ensure a reasonable return on investment and the public sector wishes to achieve VfM (Zhang, 2009). It is one of the most important issues during the PPP contract negotiations and it embodies risk sharing between the government and the private sector (Xu et al., 2012). Xu et al. (2012) developed a general concession pricing model from the perspective of the private sector. Ye and Tiong (2003a) utilized simulation analysis to systematically explore tariff adjustment frameworks for PFI projects, given project risk exposure and incentives, and evaluated the effect

of adjustment frameworks on the tariff charged to customers and the rate of return earned by the project company.

4.4 Determinants of RAS

In PPP, the greatest VfM driver is risk transfer. It means that higher value can be achieved in terms of cheap and high-quality services when compared to conventional procurement methods, if risks are appropriately transferred to the private sector based on its capability (Clayton, 2006). However, in practice, the greatest risk management capability is difficult to be clearly determined (Lam et al., 2007). Xu et al. (2010) identified the critical criteria for equitable risk allocation and established a quantitative model for equitable RAS. Jin and Dolo (2008) contended that risk allocation mechanism lacked theoretical support and that the claim of allocating risks based on capability is often “violated” by current industrial practice. The authors proposed and validated a theoretical framework for understanding risk allocation practice in PPP projects. Jin and Zuo (2011) studied the risk management environmental uncertainty factors to achieve efficient risk allocation and minimize risk management-related costs in a long-term view. Shrestha et al. (2017) studied three critical parameters in the principal agent relationship in PPP wastewater treatment projects, i.e., (i) competition, (ii) monitoring and (iii) incentives, and demonstrated how risks can be efficiently transferred to the private sector using these parameters. Shrestha et al. (2019) proposed a theoretical framework composed of a thirteen-step process for the allocation of risk in PPP projects using the principal agent theory and risk allocation capability of stakeholders.

4.5 Influence of RAS on VfM and governance

Optimal allocation of risk between the public and private sector is instrumental to the enhancement of VfM for PPP infrastructure projects (Wibowo and Sundermeier, 2020). If risks are not appropriately transferred to the private sector, enhanced risk premiums and inefficient management of risks may make the project more expensive than what could be procured using traditional procurement methods. Dikmen et al. (2011) described the mechanism of PFI used by the United Kingdom Government and evaluated three case studies in achieving the essential characteristics of adequate risk transfer and VfM to the taxpayer. Wibowo and Sundermeier (2020) offered a novel approach to evaluate VfM of a PPP infrastructure project that considers the risk mitigation capability of the public and private sector stakeholders and enables early project-based decision-making for the public sector before the tendering begins.

Abednego and Ogunlana (2006) discovered the perception of proper risk allocation of each party involved and utilized the findings as the foundation to develop the concept of good project governance. One of the downsides of adopting long-term PPP contracts is the possibility of renegotiations. In long-lasting cooperation, contractual elements of risks and benefits distribution and project implementation between government and private sector are subject to change (Chen et al., 2023). Variation in identified

risks and emergence of unidentified risks are the main reasons for the renegotiation phenomenon during the concession period of PPP projects, where the purpose of these renegotiations is risk re-sharing on new terms to “save the deal” in a bilateral, asymmetric, and noncompetitive environment (Fernandes et al., 2019; Wang and Yu, 2020). Factors contributing to these renegotiations could include poor estimations and forecast, weak project documentation, and inadequate technical and economic evaluations, and unilateral changes by the government that involves a change in risk-sharing structure of the contract, among a range of other factors (Fernandes et al., 2019). Guasch et al. (2014) reported that more than 50% Latin American transport concession contracts and contracts in the water sector were renegotiated. Similarly, more than half of Portuguese concessions studied in different sectors were renegotiated (Cruz and Marques, 2013).

5 Conclusion and recommendations

PPPs are becoming more prevalent in the global infrastructure landscape as governments around the world feel the pressure to enhance public infrastructure and services. However, the mantra of VfM, that is used as a policy in some cases and as a foundation to justify the adoption of this route for infrastructure and services procurement, is highly uncertain. Efficient RAS lies at the core of this mantra and therefore this subject has received extensive attention in the past. This research was undertaken to systematically analyze the growing body of knowledge in the domain of RAS in PPPs and to synthesize a summarize the developments since the start of the 21st century. A total of 80 journal articles were carefully selected and reviewed and classified into five categories to provide a structure to the existing body of knowledge in the RAS domain. It is clear that the researchers have approached the non-trivial subject of RAS from various perspectives including exploration of PPP expert perceptions and modeling of stakeholders’ risk management capability to suggest the optimal scheme of RAS. Additionally, researchers have modeled and evaluated how government support in the form of guarantees to the private sector stakeholders can influence the RAS on projects with the suggestions that the government should be extremely careful in extending such support to avoid being excessively burdened by the inherent contingent liabilities and to avoid being taken an advantage of in certain circumstances. Other researchers have investigated how the design of concession period and concession pricing and tariff structures can be used to favorably apportion risks between the stakeholders. Some have endeavored to explore the determinants of effective RAS to provide a theoretical understanding of the subject. Yet some researchers are investing resources in critically analyzing the influence of RAS on a PPP project’s VfM and governance.

Consequently, many research gaps exist that need further attention to address various unexplored issues in RAS. Many infrastructure sectors remain unattended as most of the focus is on road, water, and power infrastructure sectors. Energy, ports, mining, airports, telecommunication, social infrastructure and other sectors and subsectors of infrastructure remain underrepresented in the extant literature. RAS is a highly contextual subject and therefore exploring each contextual domain is critical to develop a comprehensive understanding of what drives efficient RAS in

individual contexts. Similarly, there is a lot of room to explore in depth the nature of risk management capability possessed by public and private sector stakeholders for each given risk. Establishing the risk management capability is a complex task and it is yet unknown what are the critical success factors, drivers, and barriers for each stakeholder in assuming the management of given risks (such as inflation, forex risks, technical risks, etc.) in a PPP contractual relationship. Moreover, value and risk distribution between the public and private sectors need to be investigated for other types of public support offered as the current literature is largely focusing on only traffic, demand, and revenue guarantees. Also, more research is needed to reflect the influence of risk allocation and sharing on the interest of the taxpayers and the public/users as the current literature tends to address only the concerns of the government and the private sector stakeholders. Evidence suggests that many contracts undergo renegotiations. The review shows that very few studies exist that explore the influence of risk allocation and sharing on VfM ex-ante (i.e., at contract closure) and the remaining VfM ex-post (i.e., upon renegotiations during the contract).

The review exercise presented in this paper has highlighted knowledge gaps of concern and it is expected that the outcomes of this review will enable researchers to direct their research efforts to address these gaps and to enhance the body of research in the RAS domain.

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