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Exploring Delphi Method Utilization Research Trends on Public-Private Partnership Infrastructure Studies

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ABSTRACT

This study seeks to explore the application of the Delphi method in Public-Private Partnership (PPP) infrastructure research over a ten-year span (2015-2024), with a focus on various characteristics such as the application of the Delphi method across different PPP infrastructure sectors, expert criteria for Delphi panels, the diverse use of consensus, and the execution of Delphi rounds. Employing a Systematic Literature Review (SLR) guided by the PRISMA framework, the study utilizes thematic categories alongside co-occurrence and co-authorship analyses to identify trends in the application of the Delphi method in PPP infrastructure studies. The review concentrates on literature indexed in two leading academic databases: Web of Science (WoS) and Scopus. The findings indicate that the use of the Delphi method has grown significantly in the past ten years within infrastructure PPP schemes, particularly in emerging countries driven by the increasing demand for infrastructure development. Research trends have highlighted a variety of characteristics of the Delphi method, including criteria for selecting experts, the number of expert participants, the number of Delphi rounds, and different approaches for achieving consensus or agreement. These findings offer valuable insights to inform and enhance the methodological rigor of future research utilizing the Delphi method in the context of PPP infrastructure.

Keywords: Delphi Method; Infrastructure; PPP; PRISMA; SLR

ABSTRAK

Kajian ini bertujuan untuk mengulas pemanfaatan metode Delphi dalam penelitian infrastruktur berskema *Public-Private Partnership* (PPP) pada rentang sepuluh tahun terakhir (2015–2024). Fokus kajian adalah pada berbagai karakteristik penggunaan Delphi, seperti penerapan metode Delphi di berbagai sektor infrastruktur PPP, kriteria ahli dalam panel Delphi, variasi penggunaan konsensus, serta pelaksanaan siklus Delphi. Metodologi yang digunakan adalah *Systematic Literature Review* (SLR) dengan pendekatan PRISMA yang mencakup kategori tematik, serta ditopang dengan analisis *co-occurrence* dan *co-authorship* untuk mengidentifikasi tren dalam penerapan metode Delphi. Kajian ini berpijak dua basis data utama, yaitu kepustakaan yang terindeks pada Web of Science (WoS) dan Scopus. Hasil analisis menunjukkan bahwa penggunaan metode Delphi dalam kajian infrastruktur berskema PPP mengalami peningkatan yang signifikan dalam sepuluh tahun terakhir, terutama di negara-negara berkembang, seiring dengan meningkatnya permintaan akan pembangunan infrastruktur. Tren penelitian mengungkap berbagai karakteristik metode Delphi, termasuk kriteria pemilihan ahli, jumlah peserta ahli, jumlah siklus/putaran Delphi, serta pendekatan yang berbeda dalam mencapai konsensus. Temuan ini dapat memberi panduan bagi penelitian di masa depan dalam bidang kajian infrastruktur PPP yang menggunakan metode Delphi.

Kata Kunci: Infrastruktur; Metode Delphi; PPP; PRISMA; SLR

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INTRODUCTION

As a framework for infrastructure investment involving long-term contractual arrangements, Public-Private Partnerships (PPPs) engage the private sector to address funding constraints in infrastructure development. This scheme has been widely implemented across various countries over the past decade (De Paula et al., 2023; Yescombe & Farquharson, 2018). Research on infrastructure PPP schemes has attracted scholarly attention due to the advantages that these schemes offer, such as achieving value for money (Almarri, 2023), bridging infrastructure gaps (Malik & Kaur, 2020), enhancing road safety (Albalate & Bel-Piñana, 2019), supporting financial sustainability (Mansilla & Vassallo, 2020), improving socio-economic conditions (AlKheder et al., 2022), promoting low-carbon economic transitions (Guo et al., 2022), strengthening governance (Tian et al., 2023), ensuring environmental security (Kaletnik & Lutkovska, 2021), increasing efficiency (Cheng et al., 2023), and enabling the integration of environmental, social, and governance ratings (Kharlamov, 2023).

Conversely, numerous researchers worldwide have applied the Delphi method in various studies. This approach is used to obtain a trustworthy agreement among a panel of specialists through a structured sequence of detailed surveys and monitored responses (Eyiah-Botwe et al., 2020). It is particularly useful when the subject matter can gain from group-based, panelist evaluations or judgments, especially in situations where effective communication within a group is impeded (Ramiani et al., 2024). Although participants do not interact directly, the Delphi method serves as a group decision-making approach (Kuru & Artan, 2024). The Delphi survey is characterized by several key features, including an expert panel, multiple iterative rounds with managed feedback, statistical overviews of group responses, anonymity, and the encouragement of consensus formation (Arijeloye et al., 2024).

Although alternative approaches such as Artificial Intelligence (AI) and Social Network Analysis (SNA) have gained popularity in PPP infrastructure research, the Delphi method offers distinct advantages—particularly when empirical data is limited, or expert judgment is essential. AI facilitates predictive modeling and data-driven decision-making (Kasaei et al., 2023), while SNA helps mapping complex stakeholder relationships (Wibowo & Alfen, 2015). However, these methods often require extensive datasets or predefined structures, which may not be suitable for early-stage or exploratory research. In contrast, the Delphi method is well-suited for identifying risks, setting priorities, and achieving consensus among experts in complex and context-

dependent PPP projects. Its structured, iterative process allows for the integration of diverse expert insights, making it especially effective in areas where informed judgment and stakeholder alignment are critical. This study focuses on the Delphi method to highlight its methodological strengths and its relevance for expert-driven analysis in PPP infrastructure research.

Scholars across various sectors, including those studying infrastructure PPP schemes, have adopted the Delphi method with its varied characteristics in terms of the selection of expert panels, the size of these panels, the number of iterative rounds, and the process for establishing consensus or agreement. Over the past decade, there has been a notable rise in academic interest in infrastructure PPP schemes. The trend is reflected in the increased attention and recognition of their benefits, as documented in indexed databases of Web of Science (WoS) and Scopus. While some studies have reviewed articles on the application of the Delphi method, many lack comprehensive analysis on its characteristics in PPP infrastructure research contexts. This gap may result in differing views on the practical application of the Delphi method within PPP infrastructure research.

The application of a Systematic Literature Review (SLR) serves as a critical first step in conducting an in-depth analysis of the Delphi method's use in Public-Private Partnership (PPP) infrastructure research. The objective of the SLR is to achieve a structured examination of relevant literature on a particular topic, guided by established protocols such as PRISMA (Hijriyah et al., 2023; Kumar, 2023). As noted by Gough et al. (2017), SLRs are particularly effective in obtaining high-quality, detailed insights and resolving ambiguities in existing data.

This study compiles research articles on the application of the Delphi method in PPP infrastructure studies published between 2015 and 2024. The data is drawn from two major global academic databases—Web of Science (WoS) and Scopus—to ensure the reliability of the findings. The SLR also seeks to identify research gaps and differing perspectives regarding the characteristics and implementation of the Delphi method in PPP-related studies.

The subsequent section presents the theoretical framework, outlines the article selection process, and summarizes the selected studies based on predefined criteria. The results and discussion section will then present findings related to the use of the Delphi method across PPP infrastructure sectors, research methodologies, geographic scopes, expert panel selection criteria, consensus measurement approaches, and the structure of Delphi rounds. The findings are expected to provide valuable insights for future research utilizing the Delphi method.

THEORETICAL FRAMEWORK

The Delphi Method is a structured technique that relies on a panel of experts to achieve consensus on a specific issue. This method is guided by several key principles, including participant anonymity, an iterative process, controlled feedback, and response aggregation (Alqahtani et al., 2024; Zarghani et al., 2024). Participant anonymity ensures that expert opinions remain uninfluenced by external factors, minimizing the risk of dominance by certain individuals (Fathi & Shrestha, 2023a; Ramiani et al., 2024). The iterative process enables the refinement of responses over multiple rounds which lead to a more comprehensive evaluation (Gharaee et al., 2023; Ojiako et al., 2023). Controlled feedback provides participants with summaries of previous responses that allow

them to reconsider and refine their perspectives (Tamošaitienė et al., 2021). Finally, response aggregation synthesizes diverse expert opinions into a collective consensus, making the Delphi Method a valuable tool for decision-making and policy development (Rarasati et al., 2014).

A PPP is a collaborative arrangement between the public and private sectors for the provision of public services (The World Bank Group, 2016). This framework is based on three core aspects: risk allocation, financing and investment, and institutional mechanisms involving key stakeholders (Yescombe & Farquharson, 2018). Effective risk allocation ensures that risks are optimally distributed among the parties involved to enhance efficiency and minimize costs (Kouton et al., 2023; Kristiana & Sunandar, 2020; Sunandar et al., 2024). Financing and investment mechanisms in PPPs facilitate the mobilization of private capital, thereby reducing the government's fiscal burden (Jafari Ramiani et al., 2024; Kukah et al., 2023; Sunandar & Indiyati, 2023). Moreover, institutional mechanisms play a crucial role in coordinating various stakeholders to align project objectives with public interests and the private sector's capacities (Fathi & Shrestha, 2023b; Jayasuriya et al., 2024). These aspects collectively contribute to the PPP project's sustainability and effectiveness.

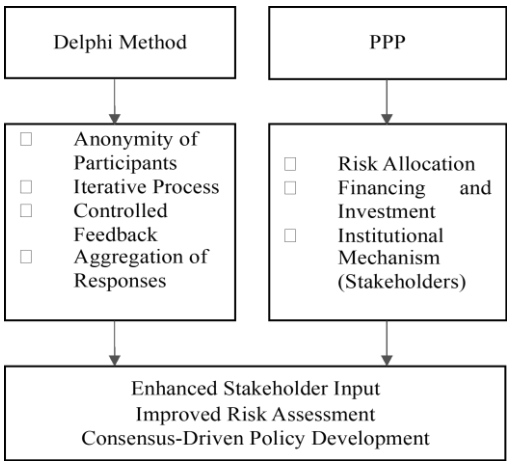

Figure 1. Theoretical Framework

The utilization of the Delphi Method in PPP research enhances stakeholder participation by incorporating expert opinions into the decision-making process (see Figure 1). Given the complexity and long-term nature of PPP projects, structured expert consultation helps identify potential challenges and opportunities early on (Alqahtani et al., 2024; Jafari Ramiani et al., 2024). The Delphi Method provides a systematic approach to gathering insights from various stakeholders, including policymakers, industry experts, and financial institutions. This ensures that PPP initiatives benefit from a comprehensive perspective leading to more well-informed and robust policy decisions (Chan et al., 2024).

METHODOLOGY

Systematic reviews have a number of advantages, such as providing a comprehensive examination of the topic or field under study, which is expected to yield targeted knowledge and assist in identifying focal points for future research (Page et al., 2021; Smith et al., 2011). A systematic search in this study was conducted to literatures published from 2015 to November 3, 2024,. This SLR was meticulously designed to ensure accuracy and alignment with research objectives, thereby opening opportunities for updates in the field of PPP infrastructure by exploring the use of the Delphi methodology in the future or combining it with other methodologies.

A detailed analysis based on inclusion criteria and defined steps or phases was conducted in using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, including identification, screening with specific criteria, eligibility assessment, and abstraction and synthesis review (Harie et al., 2023; Sahoo et al., 2022). The detailed PRISMA procedure is illustrated in Figure 2.

Identification

The PRISMA protocol in this SLR begins with the initial stage of identification (Hijriyah et al., 2023; Moher et al., 2009). Two globally recognized research index databases were employed to ensure the quality of the research, i.e., Scopus and Web of Science (WoS). The selection for these two databases represents a significant portion of high-quality scientific research worldwide valued by global researchers. A search using the keyword "Delphi Method PPP" was conducted to find articles related to the use of the Delphi Method in PPP schemes, which resulted in the finding of 50 articles indexed in WoS and 49 articles indexed in Scopus.

In conducting the identification stage, this study limited the search fields to the Title (T), Abstract (A), and Keywords (K) to maintain specificity and relevance. However, the chosen search string—"Delphi Method PPP"—introduces a methodological limitation, as it may exclude relevant studies that employed the Delphi method in PPP contexts without explicitly using these exact terms. This limitation highlights the potential underrepresentation of applicable studies and suggests that future reviews could benefit from broader or alternative keyword strategies, as well as supplementary methods such as snowballing or citation tracking to enhance comprehensiveness and reduce the bias of potential omission.

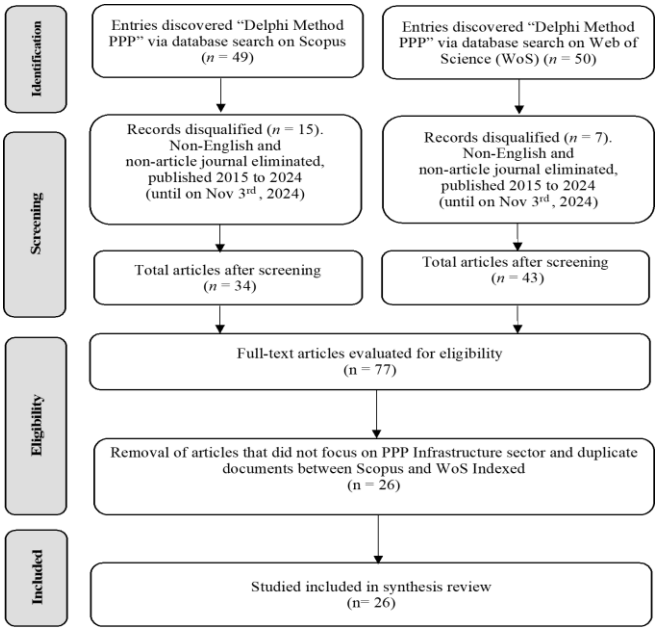

Figure 2. The PRISMA Protocol Adopted in the Research

Screening

From the two databases mentioned in the identification stage, a total of 99 aggregated articles were found, consisting of 50 articles from WoS and 49 articles from Scopus. This process was followed by the second stage, i.e., screening (see Figure 2). In this stage, exclusion criteria for published documents and the determination of criteria for the selected databases were applied (Ismail et al., 2021b). During this phase, several criteria were established to maintain the focus of this systematic review (Ismail et al., 2021a). *First,* regarding the publication period, the main criterion was set to a decade range from 2015 to November 3, 2024, as it was considered sufficient to represent the exploration of the Delphi method in PPP Infrastructure research. *Second,* only peer-

reviewed journal articles were retained, while other types of documents—such as conference proceedings, book reviews, and book chapters—were excluded. This step ensured consistency and academic rigor across the selected literature. *Third,* articles not published in English were excluded to minimize potential misinterpretations due to translation variability.

After applying these filters, 77 articles met the inclusion criteria, consisting of 43 articles from WoS and 34 from Scopus.

Eligibility

The next stage involved assessing the suitability of each article based on predefined inclusion criteria to ensure alignment with the research objectives. A manual assessment was conducted (Hijriyah et al., 2023; Ismail et al., 2021a) by focusing on studies that explicitly applied the Delphi method within the context of PPP infrastructure development. This evaluation considered the criteria established during the screening phase—namely relevance to PPP schemes, methodological rigor, and focus on Delphi-based research. As a result of this rigorous assessment, 26 articles were considered eligible for inclusion in the final analysis due to their direct relevance to the objectives of this systematic review.

Data Abstraction and Inclusion

The final phase consisted of the data abstraction and synthesis process conducted on the 26 eligible articles. A thorough review of each article was carried out to extract key information aligned with the research objectives. This process involved categorizing and thematically coding the content using a structured framework adapted from Thompson (2022). Each study was analyzed to identify relevant categories and subcategories, including sectoral application of the Delphi method, expert panel composition, consensus techniques, and the structure of Delphi rounds.

FINDINGS

SLR Category by Year, Publisher, and Rankings

This study analyzes a total of 26 articles obtained through the PRISMA protocol from reputable journals indexed in WoS and Scopus to ensure the quality of the research findings. The journals were mostly published in the United Kingdom (UK) and the United States of America (USA). The selected articles, which specifically apply the Delphi method to explore various aspects of PPP infrastructure schemes, are summarized in Table 1.

Table 1. SLR Outcomes Categories by Year, Publisher, and Rankings

No	Authors (Year)	Paper Code (P)	Journal's Name	Journal Impact Quartile	Country of the Publisher
1	Glumac et al. (2015)	P1	Land Use Policy	Q1	UK
2	Chan et al. (2015)	P2	Journal of Infrastructure Systems	Q2	USA
3	Ameyaw and Chan (2016)	P3	Journal of Infrastructure Systems	Q2	USA
4	Wu et al. (2018)	P4	Energy	Q1	UK
5	Sihombing et al. (2018)	P5	International Journal of Civil Engineering and Technology	-	India

No	Authors (Year)	Paper Code (P)	Journal's Name	Journal Impact Quartile	Country of the Publisher
6	Ameyaw and Chan (2018)	P6	Fuzzy Hybrid Computing in Construction Engineering and Management: Theory and Applications	-	UK
7	Li and Wang (2018)	P7	Journal of Risk Research	Q1	UK
8	Han et al. (2019)	P8	Land Use Policy	Q1	UK
9	Wang et al. (2019)	P9	Revista Internacional De Contaminacion Ambiental	Q4	Mexico
10	Eyiah-Botwe et al. (2020)	P10	Built Environment Project and Asset Management	Q2	UK
11	Giti et al. (2020)	P11	Journal of Financial Management of Property and Construction	Q3	UK
12	Surachman et al. (2020)	P12	Journal of Asian Finance Economics and Business	Q2	South Korea
13	Zhao et al. (2020)	P13	Advances in Civil Engineering	Q3	UK
14	Tamošaitienė et al. (2021)	P14	Sustainability	Q1	Switzerland
15	Moradi Shahdadi et al. (2023)	P15	Buildings	Q1	Switzerland
16	Zhao et al. (2023)	P16	Kybernetes	Q2	UK
17	Zhang et al. (2023)	P17	Land	Q2	Switzerland
18	Chan et al. (2023)	P18	Sustainability	Q1	Switzerland
19	Adu Gyamfi et al. (2024)	P19	Journal of Engineering, Design, and Technology	Q1	UK
20	Chan et al. (2024)	P20	Journal of Facilities Management	Q3	UK
21	Kukah et al. (2024)	P21	Journal of Financial Management of Property and Construction	Q3	UK
22	Kuru and Artan (2024)	P22	Journal of Design and Built Environment	Q2	Malaysia
23	Arijeloye et al. (2024)	P23	Journal of Engineering Design and Technology	Q1	UK
24	Nahdi et al. (2024)	P24	Buildings	Q1	Switzerland
25	Mahboubi Niazmandi et al. (2024)	P25	Decision Analytics Journal	Q2	USA
26	Ramiani et al. (2024)	P26	International Journal of Construction Management	Q1	UK

SLR Category by Research Approach, Data Collection, and Data Analysis

The analysis of the Delphi method's use in PPP infrastructure studies indicates that this method can be applied across all research approaches—quantitative (42%), mixed methods (31%), and qualitative (27%)—without dominance by any approach (see Figure 3). In terms of data collection, questionnaires are the most frequently employed method (69%) due to their efficiency in obtaining feedback from expert panels, while a combination of interviews

and questionnaires is utilized in 19% of studies, and interviews alone in 12% (Figure 4). Regarding data analysis, both modeling and statistical analysis are employed in 42% of studies, while thematic analysis accounts for 8%, with combinations of thematic analysis and modeling or statistical analysis, each comprising 4% (Figure 5).

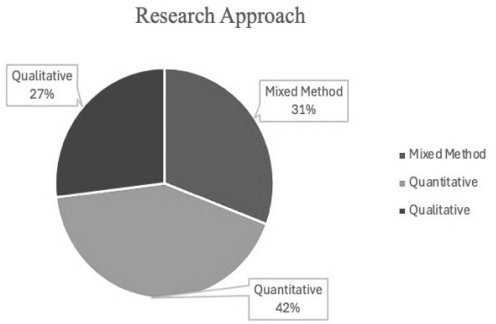

Figure 3. Proportion of the Research Approach in this SLR

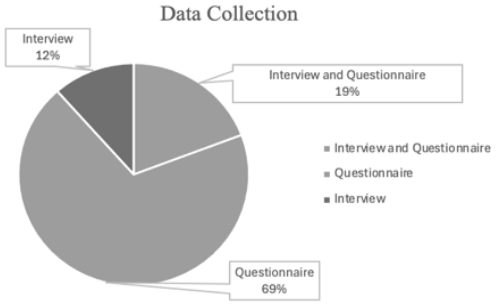

Figure 4. Proportion of Data Collection in this SLR

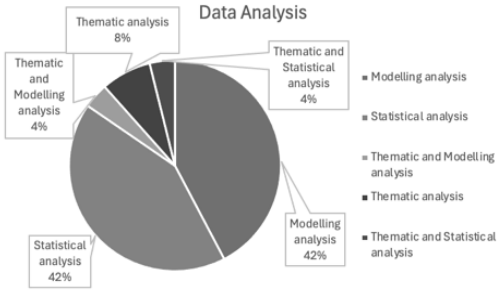

Figure 5. Proportion of Data Analysis in this SLR

SLR Category by Research Locations and Infrastructure Sector

PPP infrastructure schemes aim to promote sustainable development by involving the private sector amid budget constraints, with studies often focusing on emerging markets like China (31%), Iran (23%), Ghana (19%), and Indonesia (12%) (Figure 6).

Besides, the Delphi method is used across various countries, covering expert opinions for validation and consensus. In terms of sectors, it is applied to general infrastructure (35%), water and wastewater (23%), roads (15%), housing (8%), and other areas like power and smart cities (4% each). The data demonstrates the adaptability of PPP schemes to both broad and specific infrastructure categories (see Figure 7).

Figure 6. Mapping of Research Location Using Delphi Method in This Study

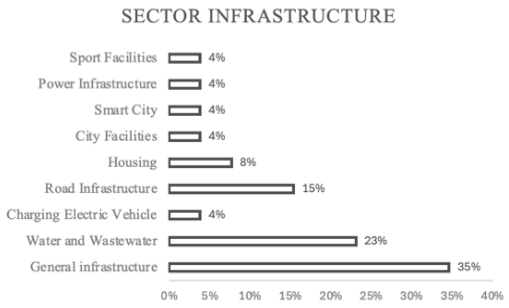

Figure 7: Mapping of Infrastructure Sector Using Delphi Method in This Study

SLR Category by Co-occurrence and Co-authorship Analysis

The co-occurrence analysis using VOSviewer highlights the evolving focus of PPP infrastructure studies employing the Delphi method, with themes shifting from privatization and risk management (2015–2020) to infrastructure projects (2020–2022) and risk factors, barriers, and project delivery (2022–2024) (see Figure 8).

The Co-authorship analysis reveals expanding researchers, from Tamosaitiene and Cristofaro (2015–2022) to broader networks involving Chan, Moradi, Lotfata, and others (2022–2024), reflecting growing academic engagement in this field (see Figure 9).

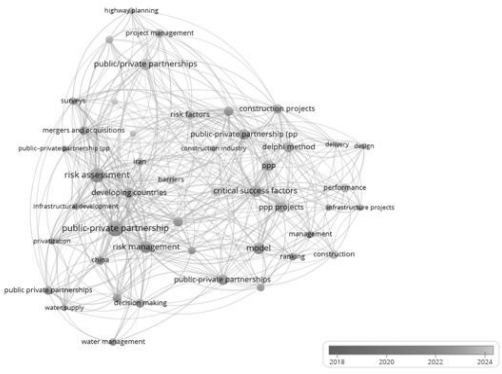

Figure 8: Mapping of the Co-occurrence

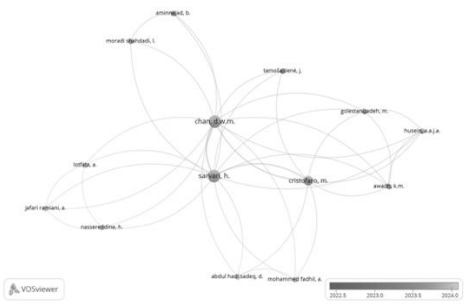

Figure 9. Mapping of the Co-authorship

SLR Category by Delphi Method (Round, Participant, Criteria)

Achieving consensus in the Delphi method typically requires multiple rounds, with most PPP infrastructure studies using three rounds (54%), while 27% use a single modified round, 15% require two rounds, and 4% extend to four rounds (see Figure 10). The number of rounds depends on research objectives, approach, expert homogeneity, and consensus criteria (see Table 2).

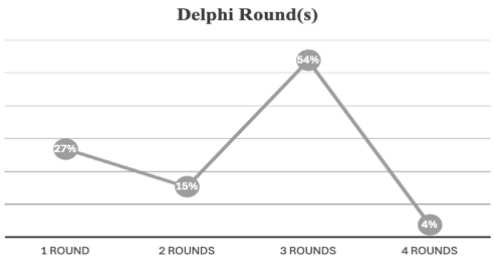

Figure 10. Delphi Round(s) used in this SLR

Table 2. SLR Outcomes Categories by Delphi Panel and Criteria

Paper Code (P)	Participants	Delphi Panel Criteria
P1	43	• Independent developers, contractors, asset creators, development agencies, and municipalities as experts
P2	105 and 93	• Involved in PPP projects in China, having extensive experience • Directly engaged in risk management for PPP projects in China, having recent or current involvement • Possessing a solid understanding and knowledge of PPP risk concepts, having gained through experience
P3	37, 37, and 10	• Water Company in Ghana, Public Utilities Regulatory Commission, Urban Water in Ghana, PPP Advisory Unit, Public Procurement Authority, along with private water developers and consulting firms, are all involved in the sector

Paper Code (P)	Participants	Delphi Panel Criteria
P4	5	• Government, private sector, and contractors
P5	16	• With 17 to 50 years of experience in the field, the respondents included academics, project management specialists, government officials, toll road investment experts, and infrastructure financing professionals
P6	37, 37, and 10	• Public and private organizations directly involved in PPP projects
P7	110	• In-depth expertise in the F-AHP risk assessment model • Author of books and reviewer of papers on the subject • Has participated in related projects
P8	16	• Officers (two), consultants (four), scholars (six), and managers (four) with relevant experience in the topic were invited to participate
P9	5	• Five experts in the field of water conservancy PPP project
P10	10	• Expertise and experience related to the issue under investigation • Ability and willingness to participate • Adequate time availability for participation in the Delphi process • Strong practical communication skills
P11	88	• Developing housing products from a policy perspective (housing practitioners/policymakers) with experience • Housing financing perspective (housing financiers) with experience • Housing development and the challenges associated with such strategies (housing developers) with experience
P12	Not mentioned	• Government contracting agencies (GCA) • Special Purpose Vehicle (SPV) • Ministries related to PPP in Indonesia • Other stakeholders: Multilateral agencies, IIGF, Lenders, and PPP consultants
P13	10	• Managers with extensive practical experience should be considered experts • Substantial theoretical knowledge of sponge city PPP projects should be possessed by experts • A minimum of 5 years of practical experience in sponge city PPP projects is required for experts
P14	60	• Involved in public-private partnership projects: experts, company managers, project managers, organizations, employers, and contractors
P15	14	• Academic staff in construction management or civil engineering • Professionals in construction or engineering management for water or sewage systems
P16	10	• Linear academic background with topic • Experts from different fields and industries
P17	9	• University professors (three) • Representatives from land reserve agencies (two) • Officials from land consolidation agencies (two) • Managers from land remediation companies (two)
P18	35	• Have knowledge and experience related to topic • Have time to participate and effective communication skills
P19	12	• Experts with between 5 and 30 years of experience in PPPs and risk management within construction industry in Ghana possess significant expertise.

Paper Code (P)	Participants	Delphi Panel Criteria
P20	103, 103, and 10	• A minimum of 20 years of professional experience in PPPs related to road transportation infrastructure in Iran
P21	48	• Have participated in at least one PPP power project • Possess work experience in the power sector and a solid understanding of its risks • Possess comprehensive and profound expertise in risk management within PPP procurement
P22	12	• Legal consultants is having experience and knowledge in project contract management and risk management processes
P23	11	• Knowledge and experience with the issues under investigation • Capacity and willingness to participate • Sufficient time to participate in the Delphi • Effective communication skills
P24	12	• Practitioners from contractors with a minimum of ten years of experience in PPP • Experts with an understanding of construction management in government projects • Experts knowledgeable about partnering and collaboration in government projects
P25	42	• Academic experts • Managers from contracting firms • Consulting service providers
P26	10	• Possess work experience in at least five distinct sports projects • Have participated in the implementation of PPP projects within the past one or two years

SLR Category by Delphi Method Consensus Utilization

The Delphi technique is used in PPP infrastructure studies for validation through expert judgment, with consensus achieved through repeated rounds. Criteria for consensus vary across research approaches, data analysis methods, and objectives, influencing the process. Table 3 outlines these criteria, offering a framework to guide future research and improve the quality of findings in PPP infrastructure studies.

Table 3: SLR Outcomes Categories by Delphi Consensus and Criteria

Paper Code (P)	Consensus in Round	Consensus or Agreement Criteria
P1	2	Collective opinions were gathered using the fuzzy Delphi method, offering a statistically valid experimental framework.
P2	2	In Round 2 of the Delphi process, risk factors with normalized values of 0.50 or higher were identified as Critical Risk Factors after the experts reviewed the overall responses. This threshold helped ensure that the most significant and pertinent risk factors were prioritized for further analysis in subsequent rounds.
P3	3	In Round 3, the risk factors used for modeling the risk-allocation decision-making were selected based on mean scores exceeding 5.05. This threshold was applied to ensure that only the most relevant and highly rated factors were considered. Besides, Kendall's coefficient of concordance (W) was employed to assess the level of consensus among the respondents.

Paper Code (P)	Consensus in Round	Consensus or Agreement Criteria
P4	Not reported	The significance of each index within the ANP system was determined based on experts' qualitative opinions.
P5	3	The Mean Score (MS) and Standard Deviation (SD) of the Critical Success Factor were calculated using relative importance indices.
P6	3	The risk allocation for a critical risk event related to PPP water supply projects was validated in Round 3 of the Delphi survey.
P7	Not reported	Experts' qualitative insights on risk levels and the likelihood of risk occurrence were gathered to obtain the necessary information.
P8	3	After 3 iterations of the questionnaire, with no further revisions from the experts, a consensus was reached, and the process was repeated until that point.
P9	Not reported	The expertise of a Delphi panel (qualitative) was used to establish a risk evaluation index system for water conservancy PPP projects.
P10	3	The Delphi technique was employed to identify the key factors and variables based on expert opinions, after which a field survey questionnaire was administered in Round 3.
P11	3	The mean and standard deviation were calculated to determine the level of consensus, after which Round 3 was conducted based on the responses from Round 2.
P12	Not reported	Delphi technique was used to get the importance levels of the factors from experts opinion (qualitative).
P13	Not reported	A risk evaluation index system for sponge city PPP projects was established based on qualitative expert opinions, using the Delphi method.
P14	3	Descriptive statistics were used to validate the indications, and the Kolmogorov–Smirnov test was applied to assess the normality of the data distribution and determine whether they are parametric or nonparametric.
P15	4	After determining the significance of the items, the degree of agreement among the participants was assessed using Kendall's coefficient of concordance. Items with an importance rating of ≥3.4 were selected based on the consensus achieved. This method ensured that only the most relevant items, as determined by expert judgment, were included in the final list.
P16	Not reported	Risk indicators were screened and identified based on qualitative expert opinions using the Delphi method.
P17	3	A consensus was reached in round 3 (qualitative), and in the round 4, the experts did not provide any additional significant changes.
P18	3	Consensus among participants on a particular topic indicates agreement. Additionally, the agreement among experts was assessed using Kendall's coefficient of concordance in each round of the Delphi process.
P19	3	It used questionnaire to obtain consensus or validate from experts qualitative opinion.
P20	3	In round 3, face validity was determined using Lawshe's equation to assess the validity of each factor.
P21	2	Consensus or validity was measured by using mean score ranking.
P22	3	The consensus criteria were defined as follows: Items were added to the final list if they met the following conditions: "IQR ≤ 1", "% of agree ratings (Ratings 4 and 5) ≥ 50%", "Median ≥ 4", and "Mode ≥ 4". Items were excluded if they did not meet these thresholds, such as when "% of agree ratings (Ratings 4 and 5) < 50%", or if the "Median < 4" or "Mode < 4". These criteria ensured that only those items with strong expert agreement were retained.

Paper Code (P)	Consensus in Round	Consensus or Agreement Criteria
P23	2	The level of agreement among the Delphi experts was assessed using Kendall's coefficient of concordance, which was found to be statistically significant at the 0.01 (1%) level. This result confirmed a high level of consensus among the experts, providing confidence in the reliability and validity of the findings.
P24	Not reported	It applied Focus Group Discussion (FGD) with Delphi panel to reach consensus among participants.
P25	3	The probability of occurrence, effect intensity, and detectability were measured using expert opinions (qualitative) through the Delphi method.
P26	3	The face validity of the questionnaire was assessed based on expert opinions, ensuring that the content was relevant and appropriate for the research objectives. A confirmatory analysis using SPSS was conducted, with Cronbach's Alpha values of 0.7 or higher supporting the retention of items. This analysis confirmed the content validity of the instrument, ensuring that the selected items accurately represented the intended constructs.

DISCUSSION

In general, the United Kingdom (UK) accounts for the majority of publications related to PPP infrastructure studies employing the Delphi method, representing 54% of the total, followed by Switzerland at 19%, and the United States at 12%. In terms of journal impact quartile, 42% of the selected articles are published in Q1 journals, followed by 31% in Q2, 15% in Q3, and only 4% in Q4. This distribution indicates that the application of the Delphi method in PPP infrastructure research is largely published in high-quality, Q1 and Q2 journals.

Various data collection techniques are employed in the reviewed studies. This variation demonstrates the versatility of the Delphi method in PPP infrastructure research. The techniques include questionnaires, interviews, or a combination of both. Quantitative and mixed-method studies often utilize modelling and statistical analyses to achieve consensus, while qualitative studies tend to rely on thematic analysis. In some qualitative studies, consensus is determined using simple statistical measures such as the mode, mean, or Inter-Quartile Range (IQR).

The use of the Delphi method in PPP infrastructure studies has been adopted in various countries, often involving local expert opinions. This ensures that the resulting insights are both practical and context-specific. While many studies focus on general infrastructure (macro-level), the Delphi method is also applied to sector-specific issues, depending on the research objectives.

A keyword co-occurrence analysis reveals significant trends. From 2015 to 2018, research centered around themes such as water supply, China, privatization, and decision-making. Between 2018 and 2020, the focus shifted to models, PPP, risk management, surveys, and mergers and acquisitions. From 2020 to 2022, emphasis was placed on PPP projects, infrastructure development, ranking, and construction projects, with a notable increase in studies based in Iran. Finally, from 2022 to 2024, the dominant themes included the Delphi method, construction, PPP, risk factors, barriers, delivery mechanisms, and design. These trends highlight a significant growth in the use of the Delphi method in PPP infrastructure studies, particularly from 2021 onward, as reflected in both the WoS and Scopus databases.

Achieving consensus in the Delphi method requires several rounds, or a single round if the consensus or agreement criteria are met. Thus, the decision regarding the number of Delphi rounds is influenced by several factors, including the research objectives, approach, the homogeneity of expert opinions, and the consensus requirements established for the study (Arijeloye et al., 2024; Eyiah-Botwe et al., 2020).

A fundamental aspect of the Delphi method involves determining the appropriate number of panelists or experts, as well as establishing the criteria for their selection. Numerous studies have not identified a direct link between the size of the expert panel and the effectiveness of the data gathered (Giti et al., 2020). In terms of expert criteria, it is crucial to ensure that experts possess both relevant academic qualifications and practical experience in their respective fields that enable them to offer valuable perspectives. Additionally, choosing experts from diverse sectors and industries is crucial to ensure the robustness and credibility of the research outcomes (Zhao et al., 2023). However, the expertise of the panelists is deemed more important than their quantity (Ramiani et al., 2024).

The Delphi technique is selected to validate requirements due to its reliance on expert judgment (Kuru & Artan, 2024). Consensus is defined as the agreement among participants on a particular topic (Chan et al., 2023), and the process is repeated until consensus is reached (Han et al., 2019). The variability in how consensus, agreement, or validation is determined in the application of the Delphi method in PPP infrastructure studies is evident across different research approaches, including mixed methods, qualitative, or quantitative methodologies. Furthermore, the choice of data analysis and the research objectives also influence the process of achieving consensus. This provides valuable insights for future research and offers a framework to determine consensus and present various options and criteria, which can assist researchers and enhance the quality of research findings, particularly in PPP infrastructure schemes.

While the Delphi method offers significant strengths in facilitating expert consensus and incorporating diverse stakeholder perspectives—making it particularly useful for complex and context-specific PPP infrastructure issues—it is not without limitations. A key drawback is the potential for the bandwagon effect, in which participants may align their views with perceived majority opinions and thus potentially compromise the objectivity of the results. Furthermore, the method's inherent emphasis on consensus may favor agreement over the accuracy or diversity of expert insights, which can lead to oversimplified conclusions. The iterative, multi-round nature of the Delphi process is also time-consuming and may result in participant fatigue or dropout, thereby affecting data quality and consistency.

The above challenges highlight the importance of careful panel selection, clear communication of objectives, and a robust design of consensus criteria. Critically addressing these limitations enables researchers—particularly those unfamiliar with the Delphi method—to apply it more effectively and avoid common pitfalls in PPP infrastructure research.

CONCLUSION

This study investigates the trends in the application of the Delphi method in PPP infrastructure scheme research over the past decade (2015–2024) by focusing on several key characteristics of the method, including criteria for selecting expert panels, the

number of experts involved, Delphi rounds, the approaches used to reach consensus or agreement, and additional aspects such as research methodologies, locations, publishers, co-occurrence and co-authors.

The findings reveal that the research mainly concentrates on the differences in opinions and decisions associated with the utilization of the Delphi method in PPP infrastructure research. The Delphi method is applicable to all types of research approaches, including mixed methods, qualitative, and quantitative research. The results show that no single approach is predominant; instead, the method is consistently applied across various research methodologies, depending on the goals of the study. Furthermore, Delphi method has been widely adopted in PPP infrastructure studies across different countries by incorporating the perspectives of local experts. The method can be effectively implemented using a range of data collection techniques, such as surveys, interviews, or a combination of both. Statistical approach is the most widely employed method; however, thematic or modelling techniques, or combinations of these methods, are also evident.

The results of this study offer an academic contribution as they highlight not only the bibliometric trends but also the thematic areas in which the Delphi method is applied within PPP infrastructure research—such as risk assessment, critical success factors, and stakeholder consensus. The study also reveals the method's frequent integration with tools like AHP and ANP in mixed methods approaches, so that it provides insights into why researchers adopt Delphi to address complex, multi-stakeholder issues in PPP studies.

Building upon the findings of this study, future research could explore the application of the Delphi method in relatively under-researched domains within Public-Private Partnership (PPP) infrastructure, such as digital infrastructure and urban resilience initiatives. These sectors present distinct challenges, including rapidly evolving technologies, complex interdependencies, and diverse stakeholder interests, which warrant further methodological innovation. Scholars are also encouraged to integrate the Delphi method with complementary participatory approaches—such as scenario planning or multi-criteria decision-making (MCDM)—to improve the analytical rigor and inclusivity of expert-based consensus-building processes.

Furthermore, comparative studies that investigate how cultural, institutional, or governance contexts influence consensus-building and expert judgment in PPP frameworks could provide valuable insights for both academic inquiry and policy development. Such investigations can help uncover context-specific factors that shape decision-making dynamics and offer both theoretical and practical contributions for policymakers and practitioners. These future research directions not only have the potential to enrich the methodological landscape of Delphi-based inquiry but also enhance its applicability to multidisciplinary challenges in infrastructure development across diverse socio-political environments.

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