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UTILIZATION OF PUBLIC-PRIVATE PARTNERSHIPS (PPP) IN THE DEVELOPMENT OF SMART INFRASTRUCTURE IN DEVELOPING NATIONS: EMPIRICAL FINDINGS FROM SRI LANKA

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Abstract. Managing cities has become more complex recently with rapid urbanization triggering serious concerns in areas including quality of life, environment, safety, health and access to reliable infrastructure and high-quality services. Smart infrastructure (SI) development helps to address such concerns and meet societal aspirations. However, increasing development costs and risks in developing SI, have prompted a wider adoption of public-private partnerships (PPPs). Thus, this research study aims to determine and assess the major barriers to implementing PPPs for SI developments in Sri Lanka (SL), a developing country in South Asia, and to provide effective strategies for mitigating those barriers. Ten expert-interviews and an empirical questionnaire survey followed a systematic and extensive literature review to achieve this aim. Lack of expertise and certain public-related barriers such as citizens' reluctance to accept private sector participation and unawareness on the perceived advantages from PPP were identified as major barriers in SL. Among the mitigation strategies, creating awareness and capacity-building of stakeholders was discerned as a significant strategy. Quantifying each barrier's influence, interdependence and providing effective strategies for overcoming the barriers are described herein, leading to the findings that construction industry practitioners and policymakers could adopt to develop SI in SL more smoothly and efficiently.

Keywords: Public-Private Partnerships (PPPs), smart infrastructure, barriers, developing nations, Sri Lanka.

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1. Introduction

Infrastructure developments should be properly planned and managed so that rapid urbanisation can prioritise sustainability, safety, and quality of life. According to Jayasena et al. (2021a), developing and integrating smart infrastructure (SI) to enhance the integrated management of infrastructure systems, could boost efficiency, sustainability, productivity and safety, compared to normal infrastructure development. In this study, normal infrastructure is taken to cover basic infrastructure systems and services, which do not include recent technological applications associated with artificial intelligence such as intelligent tracking and decision-making. Developing SI may be recognised as a prerequisite, to achieving smart urbanism (Abu-Rayash & Dincer, 2021; Luque-Ayala & Marvin, 2015). In this research study, SI is defined as "an interconnected network of facilities and services, based on integrated value-adding applications of modern technologies that may include for example: automation and robotics and cyber-physical advances based on information & communication technology, big data, artificial intelligence, and sensor-generated feedback to aid 'intelligent' control of facilities and/or services delivery systems".

As explained by Tan and Taeihagh (2020), many cities in developing countries face challenges in meeting demands for infrastructure. SI development helps to address these challenges by delivering smart solutions in terms of both quality (including performance levels) and quantity (scale/size/capacities). Moreover, smart cities with SI developments are identified as an ideal route towards sustainable urban development. In Sri Lanka, like in many countries, the term "smart city" has created much excitement. This is because of potential benefits of smart cities that

can add value to the nation, foster long-term economic growth, and improve quality of life through the prudent use of the country's natural resources with active participation from the government (Zoysa, 2015). Currently, a few cities including Colombo, Kalutara, Gampaha, Polonnaruwa and Kandy have been identified for development as sustainable smart cities in Sri Lanka as the first step (de Silva, 2019; Caldera, 2015). Inadequate access to public resources, uncontrolled developments, inadequate health and safety management systems and inefficient energy and water distribution and management systems are profound barriers faced by Sri Lanka on its road to achieving sustainable urban development. Considering these challenges, SI is seen as a necessity, rather than a luxury in Sri Lanka and many other developing countries.

Despite the emerging imperative for developing SI in developing countries, the exorbitant cost of maintenance, apart from the capital cost of new infrastructure, and the numerous governance challenges, act as barriers to their development (Tan & Taeihagh, 2020). Moreover, inadequate government and foreign investments in infrastructure in Sri Lanka, trigger a crucial upfront need for private finance, in turn providing a strong driver to mobilise private sector participation. PPP can be considered as a potential solution to such challenges; and could also improve the efficiency, productivity, and quality of infrastructure projects in many ways. These include cost-effectiveness through appropriate risk allocation, managerial and technical competence and innovation, lower life-cycle costs, and higher quality service (Marques & Berg, 2011; Ameyaw & Chan, 2015; Jayasena et al., 2022). In this context, PPP provides a significant strategic approach that can be deployed to attract private capital specifically in the Sri Lankan scenario (Finance Commission of Sri Lanka, 2020).

In the specific context of SI, the mutually reinforcing nature of PPPs could arise for example: (a) from both direct public sector contributions and government demand/uptake guarantees on an otherwise financially infeasible long-term development; and (b) from the domain-specific experience, innovations and results-driven efficiencies of the private sector. The public and private partners would 'mutually reinforce' each other, with the strengths of one partner compensating for the weaknesses of another in any given area. For example, if there is a requirement to develop a smart grid to manage energy efficiently and to decrease carbon emissions, the government could finance the project while the private sector could contribute with their experience in advanced technological applications and proposing smart innovations. Furthermore, the private sector may finance the project, if their return on investment in a costly SI development project is perceived to be boosted by increased public confidence and usage. This can arise from public sector backing and promotion of the project, which could enhance uptake, hence returns. Therefore, if suitably designed and properly implemented, PPPs would synergise the strengths of both public and private sectors. Considering that the challenges associated with PPP arrangements depend on the specifics of the project's goals, priorities, and context, it may not be appropriate for all forms of infrastructure initiatives. However, given the critical need for SI in Sri Lanka, it is crucial to examine the possibility and acceptable circumstances for a mutually beneficial PPP in an SI initiative. Unfortunately, it is seen that less attention has been paid to research into the potential of PPP in developing SI. The research gap is further explained in Section 2.1. Accordingly, this study aims to evaluate the barriers associated with mobilizing PPPs to develop SI in Sri Lanka and to provide appropriate and strategic responses to overcome the barriers. The research questions, addressed in this study are:

"What are the barriers affecting the success of PPP in SI developments in Sri Lanka, how do they affect these developments and how to overcome those barriers?"

The findings of this study should benefit decision-makers and policymakers who consider adopting PPP arrangements in SI in Sri Lanka and other similarly positioned developing countries.

2. Literature review

2.1. Previous research studies and existing research gaps

A systematic literature review was conducted to systematically explore the previous research on the potential of PPP in SI developments. The systematic review used the Web of Science search engine with keywords "smart infrastructure", "smart cities" and "Public-Private Partnership". Accordingly, 37 manuscripts were identified and there were no records of 3 publications. Table 1 summarises the articles classified and sequenced by geographical location and the number of citations. Developing countries are listed first followed by developed countries and literature review based papers.

The analysis of the aforementioned manuscripts shows that only a few researchers have focused on PPP in SI development in developing countries with only. 12 out of 34 papers addressing this. Among those 12, only a few had directly discussed the application of PPP in SI developments as a procurement strategy. One study has focused on the South Asian region as a whole and the other two focused on India.

PPP reduces the financing difficulties and the associated risks in developing countries discussed in the Introduction in SI development. There are numerous benefits of implementing PPP in developed nations, such as appropriate project management and the introduction of new technologies. Given the changing nature of the application of PPP based on the financial, political, economic, and social factors, conducting a study for the specific context of Sri Lanka is fruitful for Sri Lanka as well as for similarly positioned developing nations.

Table 1. Summary of the manuscripts identified and examined in the literature review

No.	Core theme of the paper	Citation of authors	Name of Journal/Conference	Research focused regions	No. of citations
1.	The focus of this study was on the governance of smart cities in underdeveloped nations.	Tan and Taeihagh (2020)	Sustainability	Developing countries (Literature Review)	229
2.	Presented the opportunities for the implementation of sponge city and urban heat island mitigation strategies.	He et al. (2019)	Land Use Policy	China	204
3.	Presented how PPP can support sustainable urbanization and development goals.	Anwar et al. (2017)	Sustainability	South-Asian region	41
4.	Explored the implementation of PPP models in smart cities.	Milenković et al. (2017)	40th International Convention on Information and Communication Technology, Electronics and Microelectronics	Croatia	42
5.	Discussed on sustainable cities.	Rai (2012)	Procedia – Social and Behavioral Sciences	India	34
6.	The utilization of sophisticated communication technologies in the context of telemedicine and telecare to facilitate collaborative learning was discussed.	Chand et al. (2019)	2019 9th International Conference on Cloud Computing, Data Science & Engineering (Confluence)	India	19
7.	Explored the application of multiple criteria decision analysis to evaluate public investment options in streetlighting renewal projects.	Juričić et al. (2020)	Economic Research – Ekonomska Istraživanja	Croatia	15
8.	Studied what inspires public stakeholders to undertake PPP initiative.	Luo et al. (2022)	International Journal of Environmental Research and Public Health	China	8
9.	Conducted a study on the impact of option-games on infrastructure investment in Vietnam.	Ha and Fujiwara (2014)	Proceedings of PICMET'14 Conference: Portland International Center for Management of Engineering and Technology; Infrastructure and Service Integration	Vietnam	6
10.	Used quadruple innovation to examine tools and technologies that promote sustainable territorial development.	Parygin et al. (2022)	Sustainability	Russia	11
11.	Discussed the concept, coordination challenges and funding mechanisms to smart cities.	Goryainova (2020)	Revista Turismo Estudos e Práticas – RTEP/UERN	Russia	3
12.	The potential for the digitalization of cities through the utilisation of PPP was explored.	Saldaeva et al. (2019)	European Proceedings of Social and Behavioural Sciences	Russia	–
13.	Explored the barriers to using urban infill development aiming smart growth.	Farris (2001)	Housing Policy Debate	United States	212
14.	Established a model for assessing the effectiveness of PPPs in achieving sustainable development targets.	Berrone et al. (2019)	Sustainability	Brazil	119
15.	Discussed on the improvisational perspective on the governance of smart infrastructure.	Offenhuber and Schechtner (2018)	Cities	Italy	24
16.	Considered smart city as a hub for nourishing PPPs.	Siokas et al. (2022)	Sustainable Cities and Society	Greece	16
17.	Exploration of the suitability of PPPs in the development of smart infrastructure.	Jayasena et al. (2023)	International Journal of Construction Management	Hong Kong	12
18.	Examined the advantages, drawbacks, and suggested approaches to PPP implementation in smart infrastructure.	Jayasena et al. (2022)	Sustainability	Developed Countries	7
19.	This study examined the aspects pertaining to value for money and their interrelationships in the context of PPP initiatives in smart cities.	Almarri (2023)	Construction Innovation	United Arab Emirates and United Kingdom	6

End of Table 1

No.	Core theme of the paper	Citation of authors	Name of Journal/Conference	Research focused regions	No. of citations
20.	Explored on enhancing the efficacy of the PPP system to enhance the quality of life for the population in the region.	Belikova et al. (2019)	1st International Scientific Conference "Modern Management Trends and the Digital Economy: from Regional Development to Global Economic Growth"	Russia and The European region	6
21.	The identification of critical success factors for the effective implementation of public-private partnerships (PPPs) in smart city infrastructure projects.	Almarri and Boussabaine (2025)	Construction Innovation	Internation-ally	5
22.	Discussed on a case study to apply PPP.	Viglianisi et al. (2019)	New metropolitan perspectives (ISHT 2018). Smart innovation, systems and technologies	Italy (Villa San Giovanni)	3
23.	Investigated the optimization of public value through the implementation of PPPs in municipal Wi-Fi networks.	McShane (2019)	Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance	Australia	3
24.	Explored the significance of stakeholder information processing in urban innovation programs aimed at facilitating sustainable environmental transformation.	Kroh and Schultz (2023)	International Journal of Project Management	Germany	3
25.	Conducted an assessment of collaborative Public-Private Partnerships.	Nelischer (2024)	Journal of the American Planning Association	Canada (Toronto)	2
26.	Provided illustrations of exemplary approaches in the governance of smart cities.	Vrabie (2020)	Strategica	Romania (Bucharest, Iași), Neth-erlands (Amster-dam), United Kingdom (Birmingham City), Chica-go, Dubai,	1
27.	Presented an efficient decision-making framework for PPPs.	Rayi et al. (2019)	2019 International Conference on Unmanned Aircraft Systems (ICUAS)	United States (Syracuse)	1
28.	An assessment of digital strategy in the field of education has been conducted with the perceptions of students in the fields of social sciences and humanities.	Voda et al. (2022)	Transformations in Business & Economics	Romania	–
29.	The role of engaged citizens in the development of intelligent urban environments was presented.	Bull and Azennoud (2016)	Proceedings of the Institution of Civil Engineers - Energy	Literature Review	47
30.	Explored the emerging themes related to the application of PPPs in the context of establishing smart city projects and developed a conceptual framework was developed to provide a comprehensive understanding of the key factors and considerations.	Liu et al. (2021)	Built Environment Project and Asset Management	Literature review	46
31.	This study conducted a comprehensive and methodical examination of existing literature in order to analyse and design PPP models that can effectively facilitate the delivery of smart infrastructure.	Jayasena et al. (2021b)	Built Environment Project and Asset Management	Literature review	40
32.	Discussed the deployment of smart infrastructure through public-private partnerships (PPPs) aiming at attaining sustainable development.	Selim et al. (2018)	International Journal of Critical Infrastructures	Literature review	34
33.	Investigated the application of PPP model in developing smart cities.	Yang and You (2019)	IOP Conference Series: Earth and Environmental Science	Literature review	10
34.	The utilisation of platform-based business models in the context of public transport development has been elaborated.	Kreidenko and Sharkova (2020)	In International Scientific and Practical Conference: Digital Finance	Comparison of published reports	1

A summary of the research gaps identified from the previous studies is presented below in point form.

- A comprehensive list of the factors affecting and the extent/ levels to which they affect the success of PPP procured SI developments have yet to be fully developed for Sri Lanka and other developing countries.
- Strategies to drive the success of PPP-procured SI developments still need to be proposed and refined for Sri Lanka and other developing countries.

After the identification of the research gaps by reviewing the inclusions of the identified articles from the systematic search, a comprehensive literature review was conducted to identify the importance of SI development and the barriers and other factors affecting PPP-procured SI development projects.

The findings presented under the importance of SI development and the affecting barriers were not limited to the findings of the identified articles from the systematic search. The factors affecting PPP-procured SI development projects were initially identified from the articles indicated in Table 1 and then presented alongside the factors affecting PPP-procured normal (non-SI-enhanced) infrastructure developments and non-PPP procured SI developments.

2.2. Importance of smart infrastructure development and barriers affecting the development of smart infrastructure

Making the infrastructure, 'smart' help to 'get more with less' (Jebaraj et al., 2023; Milenković et al., 2017). Given specific challenges in urban development such as climate change and social and economic pressures, the establishment of SI was crucial to strengthening the community's resilience (Lugaric et al., 2010). Kumar and Dahiya (2017) and Kumar et al. (2020) assert that the process of transitioning a city into a smart city necessitates a methodical examination to facilitate strategic and cohesive planning to devise smart city services. The authors emphasize the significance of SI development as a basic step in achieving this endeavour.

Research conducted by Jayasena et al. (2021a) identified that the urban environment, its inhabitants, cognitive abilities, inventive practices, intelligent systems, physical infrastructure, and technological advancements play a vital role in smart city development. Marsal-Llacuna et al. (2015) claim that several smart city initiatives aim to augment urban functionality by leveraging data, information, and information technologies to monitor and enhance existing infrastructure improving the quality of life for citizens. According to Musa et al. (2019), SI development is important in developing countries because of the emerging complex environmental, social and economic challenges, arising from concentrated activities in urban centres.

Adequate SI development is identified as one of the major determinants or measures of good urban settlement (Otegbulu, 2011; Jayasena et al., 2023). Improving competitiveness, innovation potential, environmental performance, governance and delivery of services to the citizens can be significantly improved through SI. Moreover, SI development is crucial in increasing value capture for investors, thereby supporting public and private investment (Bouch et al., 2018). Furthermore, Bouch et al. (2018) explained that it is imperative to broaden the scope of the infrastructure concept beyond its traditional focus on transportation, water, waste management, electricity, and information and communication technology (ICT). Along with those traditional focuses, the extended 'new normal' infrastructure concept should encompass many forms of social infrastructure, such as healthcare, education, and cultural facilities.

Through the above-mentioned factors, it can be confirmed that the development of SI is a necessity in the modern world including developing countries. However, many barriers to developing SI were identified as follows.

Among the articles presented in Table 1, Tan and Taeihagh (2020), who conducted a literature review focusing on developing nations, identified some barriers affecting the development of SI or smart cities. Those barriers are financial limitations and challenges related to funding, inadequate preparedness of technology-related infrastructure, dispersed or divided authority, lack of governance policies and legal frameworks for smart cities, lack of suitable human resources, special environmental concerns, inadequate engagement of the citizens and inadequate technical know-how among the citizens. According to Cruz and Sarmento (2017), shortfalls in financial resources, technology, policies and regulations, skilled human capital, and citizen participation, pose as challenges in SI development. As explained by Tan and Taeihagh (2020), these barriers impact developing countries on a larger scale as these countries have lower financial and technical resources. According to Khan et al. (2020), budgetary constraints, lack of resources, strategic approaches, institutional capacities, and social acceptability of the projects are challenges in smart city development projects. Moreover, a wide range of stakeholders are identified as substantial contributors to developing SI (Myeong et al., 2018). This is due to the fact that smart cities are the result of a strategic alliance of numerous centralized (and mostly direct), as well as decentralized (and mostly indirect) stakeholders. To overcome these above-mentioned barriers in developing SI, PPP is a potential solution. PPP could be used as a procurement strategy to effectively align diverse infrastructure project stakeholders, starting with the public and private sectors (Zou et al., 2014).

2.3. Public-Private Partnerships in smart infrastructure development

Before discussing the barriers specific to PPP-procured SI developments, a brief discussion of PPP and the barriers, which could arise in PPP projects in general are discussed initially in this section. Next, the barriers affecting PPP procured SI developments, which were identified through the systematic review are explained.

PPPs have existed since the Roman Empire and become popular as a governing model for the efficient delivery of public goods and services (Forrer et al., 2010). As explained by Zhao and Ying (2019), interest in PPPs was already accelerating recently, because of the growing need for collaborative procurement methods to handle many uncertainties. These uncertainties have increased with COVID-19. According to Engel et al. (2013), the main difference between a PPP, compared with conventional procurement, is that PPP bundles investment and service provision in a single long-term contract. A commonly agreed definition for PPP cannot be identified as the context of PPP differs with the economic, social and political background of a country. Table 2 presents various definitions of PPP as identified from the literature and conveys an understanding of the basics of PPP.

In the absence of a clear definition, Ministry of Finance in Sri Lanka (2019) defined PPP as "a special contractual arrangement between a Government of Sri Lanka Entity and a private entity for providing a public infrastructure asset or service, in which there is an appropriate transfer of risk to the private investor and where the private party bears investment and management responsibility on a long-term basis."

In the present context, many governments are facing difficulties in fulfilling complex financial obligations. Municipalities must encourage the development of SI, and collaborations must be funded and supported through subsidies (van Winden & van den Buuse, 2017). According to Scuotto et al. (2016), to successfully launch smart cities, barriers to knowledge development and connection building with external stakeholders must be alleviated or even eradicated. With these factors in mind, the importance of PPP has therefore increased further, especially in developing countries like Sri Lanka.

According to Grimsey (2004), PPP provides a clear direction in cost management and in overcoming delays in traditional procurement methods for infrastructure development. Given the lower budget power, smaller municipalities may not be able to afford the high costs associated with developing SI (Spicer et al., 2021). After the recent advancements in SI, Nguyen and Garvin (2019) showed how PPP may utilise big data for commercial usage by developing software and hardware for acquiring and processing big data. As Cruz and Sarmento (2017) noted, PPP is widely used in the creation of SI across the globe given its mutually beneficial outcomes to all stakeholders involved.

Complex decision-making, ineffective risk management, a lack of transparency, and an absence of competition are only some of the potential obstacles to PPP implementation (Kwak et al., 2009). Zhang (2005) also identified, a variety of problems in the execution of PPP projects. Osei-Kyei and Chan (2018) also explained that there are highly successful PPPs as well as unsuccessful PPPs, in infrastructure development. The implementation of PPP in underdeveloped countries has been hindered by a perceived deficiency of information and knowledge within the business sector (Sharma & Bindal, 2014). In addition, finding the right stakeholders in smart city initiatives is a major challenge (Sandulli et al., 2017). This area of study was driven by a desire to investigate the origins of such obvious issues and evaluate the prospect of using PPP to procure SI initiatives in the context of developing nations – the case of Sri Lanka is a suitable example, given its ongoing endeavours to mobilise successful PPPs.

According to the analysis of the articles based in developing countries in Table 1 only Anwar et al. (2017) and Milenković et al. (2017) identified barriers affecting PPP-procured SI and smart city developments in developing countries. Those barriers are lack of implementation frameworks, dishonest/unethical practices and corruption, lack of knowledge, competence and skills, unavailability/lack of relevant policies, the citizens' hesitancy to embrace private sector engagement and challenges that arise in the governance of smart cities. Taking these factors as the basis, expert interviews were conducted to investigate

Table 2. Definitions of PPP as identified from desktop literature review

Source	Definition
Zhao and Ying (2019)	PPPs are cooperative business models that involve a long-term contract between a public agency and a private entity, with shared risks and profits and the goal of achieving a win-win situation.
Regan et al. (2011)	The objective of public-private partnerships (PPPs) in infrastructure initiatives is to ensure the financing, construction/renovation, and operation of a public infrastructure service.
Ministry of Finance and Economic Planning (2011)	A contractual agreement between a public entity and a private sector party with explicit agreement on shared goals for the provision of public infrastructure and services traditionally provided by the public sector.
Forrer et al. (2010)	"Public-private partnerships are ongoing agreements between government and private sector organizations in which the private organization participates in the decision-making and production of a public good or service that has traditionally been provided by the public sector and in which the private sector shares the risk of that production." (p. 476)
Daube et al. (2008)	A long-term contractual arrangement between the public and the private sector to realise public infrastructure and services more cost effectively and efficiently than under conventional procurement.
Infrastructure Australia (2008)	"A procurement method [in] which projects are part of a broader spectrum of contractual relationships between the public and private sectors to produce an asset and/or deliver a service. They are distinct from early contractor involvement, alliancing, management contracting, traditional procurement (design and construct) and other procurement methods."

the barriers affecting the development of SI in Sri Lanka. The adopted data collection techniques and analysis techniques are further described in the Research Methodology section.

3. Research methodology

This study employed a mixed method research strategy to examine the potential of PPPs in executing SI initiatives in Sri Lanka. The research methods used under this mixed method approach included qualitative analysis of the expert interviews and quantitative analysis of the data captured through the questionnaire survey. Sandelowski (2000) explained mixed-method research as a dynamic approach that allows for the broadening of study scope and enhancement of analytical capabilities within investigations (Sandelowski, 2000). Undertaking mixed method approach gives a detailed understanding of the research problem (Creswell, 2014) and improves the validity and reliability of the resulting data (Abowitz & Toole, 2010). The stages of data collection in this study are explained below.

Stage 1: Initially, a systematic literature review was conducted to establish the research gap and next, to comprehend the advent of PPP for SI execution, a comprehensive literature review was conducted.

Stage 2: Subsequent to the literature review, 10 comprehensive face-to-face interviews were conducted with professionals who possess expertise in the domains of SI and/or PPPs in Sri Lanka. The sample size was constrained due to the limited availability of specialists, as the implementation of public-private partnerships in the context of SI initiatives in Sri Lanka is an emerging trend. Only one smart city development project is available in Sri Lanka and that project is located in Colombo, Sri Lanka. Therefore, the interviewees were also from Colombo in Sri Lanka. They have, nevertheless, garnered an incredible amount of information and practical expertise in PPP and SI investments. Hence, valid information and insightful ideas covering Sri Lanka were obtained through the interviews. Due to the novelty of the research area in Sri Lanka, the snowball-sampling technique was used to identify the experts based on direct abundant hands-on experience in the fields of PPP and/or SI. Several previous research studies (e.g., Creswell, 1998; Chan et al., 2011; Chan & Choi, 2015; Al Nahyan et al., 2019) adopted the same research technique, with less than or equal to ten interviewees who were perceived to sufficiently represent the respective populations under study.

An expert interview is considered as a useful technique to establish face validity in research (Yang et al., 2018). In this study to ensure the reliability and quality of interviews, the selection of interviewees was carried out based on their professional expertise and experience. The profile of the interviewees is presented in Table 3. The tabulated profile indicates that six experts out of the ten had gained more than 20 years of working experience in the fields of PPP and SI development. Therefore, 60% of the interviewees had acquired more than 20 years of in-depth knowledge and experience in the area of research. The other experts (40%) had more than 9 years of working experience in the relevant fields. Therefore, the collected data for this research paper reflects a broad as well as an in-depth view of the topic even though the sample is small due to the novelty of this domain in a developing country like Sri Lanka. The interview results and feedback were deemed to be representative and reliable, as they effectively encompassed the entirety of the population being studied.

Each interview was conducted as a semi-structured interview and lasted for approximately 60 minutes. Semi-structured interviews help to extract in-depth human opinions and are used by many researchers. According to Sekaran (2003), important opinions can be clarified, and further details can be obtained through semi-structured interviews. The interview guidelines for the expert interviews were prepared to capture the experts' ideas and opinions regarding how PPP adoption may facilitate the provision of SI, and the main enablers, challenges, and methods for improving it.

The data obtained from the expert interviews was subjected to analysis using the manual content analysis method, which involved the use of a matrix to facilitate the identification of similarities and differences for the purpose of cross-comparisons. The process of content analysis involves the classification of textual resources, condensing the content into pertinent and manageable units

Table 3. Profile of the expert interviewees

Interviewee	Designation	Work experience (years)	Work sector	Work organisation
I1	Lawyer and President's Counsel	Above 20	Private	Private Developer
I2	President, Chamber of Construction Industry Sri Lanka	Above 20	Private	Contractor
I3	Town Planner	9	Public	Government
I4	Chief Financial Officer	Above 20	Private	Private Developer
I5	Director/CEO	Above 20	Private	Private Developer
I6	Project Consultant	18	Private	Consultant
I7	Senior Lecturer	Above 20	Public	Government
I8	Senior Lecturer	16	Public	Government
I9	Deputy CEO (Finance)	Above 20	Private	Private Developer
I10	Town Planner	12	Public	Government

of data (Weber, 1990). This method subsequently gathers information and comprehension pertaining to topics that align with the overall objectives and specific inquiries of a research endeavour (Chan et al., 2011). Manual content analysis or phrase-based content analysis is a method, which divides a text into phrases and is then classified by human raters based on an explicit set of classification rules (Rosenberg et al., 1990). This methodology can facilitate the assessment of the aggregated perspectives of many seasoned interview participants regarding which directions PPP enable or impede the execution of SI in developing nations such as Sri Lanka.

Stage 3: After results were obtained through manual content analysis, the identified enablers and barriers were subjected to quantitative analysis through a questionnaire survey. The sample of the questionnaire survey was 10 experts in PPP and/or SI developments based in Sri Lanka. The professional and experience-related representation profile of the 10 experts is illustrated in Table 4.

The results of the questionnaire survey were analysed using the MICMAC and Interpretive Structural Modelling (ISM) techniques. As used by Warfield (1974), the ISM technique is helpful to investigate a complicated system by breaking it down into numerous subsystems. According to Saka et al. (2020), the process entails breaking down an intricate system into multiple subsystems based on the expertise and knowledge of professionals. Using this approach, a multi-level structural model may be built to precisely depict the interconnected parts. Previous studies (Saka et al., 2020; Ravi & Shankar, 2005; Shen et al., 2016) have noted that the ISM survey differs from traditional surveys in that it does not necessitate a substantial number of respondents. The reason is that the ISM approach emphasises the significance of insightful responses above the quantity of the sample. As explained by Ravi and Shankar (2005), a small team of competent and experienced experts, even 2 experts, is sufficient for such a survey. Given that PPPs for SI initiatives are still relatively novel in Sri Lanka, this approach was deemed to be an appropriate way to accomplish the research goal. Due to its efficacy, the technique has been widely embraced by researchers in the area of construction management and built environment. For example, Sun et al. (2020) classified the risk factors affecting the application of BIM technology in the construction industry using the ISM technique and Saka et al. (2020) used the ISM technique to analyse the barriers in the application of BIM in the construction industry. Li et al. (2022) also used the ISM technique to evaluate and formulate the critical factors affecting the choice of prefabricated concrete buildings. Considering these factors, it is the most appropriate for this study environment because of the limited number of specialists. Also, it would not be viable to gather enough reliable replies using a survey approach. The ISM approach enables the examination of interrelationships within a complex system, thus, providing valuable insights into the direct and indirect connections among the variables within the system. The Matrice d'Impacts croises-multipication applique a classement (MICMAC) method was conceived and developed by Duperrin and Godet (1973). It entails categorising factors according to their degree of dependence and driving force. Hence, used for the further analysis of the findings of this study.

According to Saka et al. (2020), the steps used in the analysis using the ISM technique is as follows.

- Step 1: Identification of the variables affecting the system under consideration;
- Step 2: Establishment of the contextual relationship between the identified variables in Step 1;
- Step 3: Development of the Structural Self-Interaction Matrix (SSIM) for the variables, which indicate the pairwise relationships among them;
- Step 4: Development of the reachability matrix from the SSIM and checking the matrix for transitivity;
- Step 5: Partitioning the reachability matrix into different levels;
- Step 6: Development of a diagraph based on the reachability matrix and hierarchy structure;
- Step 7: Checking for the conceptual inconsistency in the developed ISM model.

Section 4 discusses the findings of the study on the applicability of PPP in the development of SI in Sri Lanka. Section 4.3 presents effective recommendations and suggestions for overcoming the barriers and the discussion on the comparison of the perceived benefits vs. potential barriers.

Table 4. Professional and experience-related representation of the 10 expert respondents to the questionnaire survey

Demographics	Category	Number of responses	Percentage
Profession	Engineer	2	20%
	Surveyor	1	10%
	Town Planner	3	30%
	Researcher	4	40%
Sector type	Public Sector	5	50%
	Private Sector	5	50%
Years of professional experience	Above 15 years	1	10%
	10–15 years	2	20%
	5–10 years	5	50%
	Less than 5 years	2	20%

4. Research findings

The interview findings of the expert interviews are presented in the following sub-sections.

4.1. Barriers to PPP in smart infrastructure development in Sri Lanka: Findings from expert interviews

The conducted literature review and the expert interviews based in Sri Lanka revealed 10 barriers affecting the success of PPP-procured SI developments. Those barriers are presented in Table 5. The ticks in Table 5 illustrate the number of times, where the different barriers were mentioned by the expert interviewees. Each barrier is discussed afterwards to explain the effect of those barriers in PPP-procured SI developments in Sri Lanka.

Lack of requisite knowledge, competence and skills

The findings of the expert interviews indicated that lack of knowledge, competence and required skills is a major challenge for a developing country like Sri Lanka. According to the experts, competencies, skills and knowledge are essential in the management and execution of PPP projects. However, it was mentioned that these factors play a significant role especially in SI developments involving PPP as there are many technological-related applications associated with SI developments.

'The citizens' hesitancy to embrace private sector engagement' and 'Public unawareness of PPP's perceived benefits and importance'

According to the findings from the expert interviews, the unawareness of the public considering the perceived benefits and significance of PPP-procured SI projects is a paramount obstacle for the government in project implementations. It was identified as important to educate the public on the potential benefits of deploying PPP in SI development in a developing country. The experts revealed that the mindset of the community regarding the participation of the private sector along with the public sector affects the application of PPP in SI development. Further, it was identified that the public is suspicious of corruption distorting some PPP deals in developing countries due to bribing associated with the processes.

Unavailability/lack of relevant policies

The experts revealed that a favourable legal framework and the availability of the required enabling policies were another necessary condition for enticing private entities to invest in SI. When there are relevant policies, the private parties will be more willing to participate in SI developments as they have a clear framework to work and to compensate for any future problems that might occur in the procurement process.

Complex or restrictive financial infrastructure

The expert interviewees also highlighted that restrictive and/or complex financial infrastructure could pose critical barriers to mobilising PPPs. An expert in SI development stated that suitable investors and financial investors could be engaged only after developing conducive policies and viable legal and financial infrastructure. This may offer a solution to overcome the difficulties of enlisting private investors in SI initiatives. Many experts agree that the present tax regimes need to be changed if the private sector were to be enticed to adopt PPP initiatives. It was concluded that unfavourable financial infrastructure is a major barrier to the implementation of PPP.

Political instability/political influence

The findings from experts revealed that political instability creates uncertainty in continuing development projects by themselves. This raises augmented barriers in the paths of PPP in the SI development projects since the private sector is more vulnerable to political instability. According to the experts, a developing country like Sri Lanka

Table 5. Barriers to applying PPP in SI development in Sri Lanka

Barriers to applying PPP in SI development	interviewee										Total number of 'hits' for each barrier mentioned
	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	
■ Lack of knowledge, competence and skills	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
■ The citizens' hesitancy to embrace private sector engagement	✓	✓		✓	✓			✓	✓		6
■ Unavailability/ lack of relevant policies	✓	✓	✓	✓	✓	✓		✓	✓	✓	9
■ Complex or restrictive financial infrastructure	✓	✓		✓	✓	✓		✓		✓	7
■ Political instability/ political influence	✓	✓				✓			✓		4
■ Public unawareness of PPP's perceived benefits and importance	✓				✓	✓	✓	✓	✓	✓	7
■ Lack of local and foreign investors		✓	✓		✓		✓		✓		5
■ Dishonest/ unethical practices and corruption	✓			✓	✓	✓		✓		✓	6
■ Inconsistency in the interests between citizens and private investors		✓		✓		✓	✓			✓	5
■ Multi-stakeholder coordination complexities	✓		✓	✓	✓			✓	✓	✓	7
■ Total number of barriers mentioned by each interviewee	8	7	4	7	8	7	4	7	7	7	66

faces substantial barriers due to political instability, as the implementation of SI development would vary with changes in political leadership. As building effective partnerships with the private sector depends a lot on the principal participants from the public sector, frequent changes in such key public participants and other political uncertainties demoralise the private sector participants and erode the efficiency of project operations, hence the value of the outcomes.

Lack of local and foreign investors

In the Sri Lankan context, the expert interviewees have identified deficiencies in attracting local and foreign investors. When it comes to PPP usage in SI projects, a lack of investors is a major impediment to adoption. The unstable financial condition/fluctuation of the currency rates was identified as the major reason behind this barrier. Nurturing a favourable investment climate in Sri Lanka would attract local private sector investors for developing SI in the country, while foreign investors may also be attracted by further incentives relating to SI.

Dishonest/unethical practices and corruption

Dishonest/unethical practices and corruption pose barriers, as mentioned by the experts because these raise in uncertainties in the minds of the citizens regarding the development projects. Moreover, genuine competent private sector participants will be reluctant to participate in development projects if subject to unethical practices, also considering the extra costs and risks involved. This barrier should be overcome to energize the private sector to participate in the SI projects and to overcome public apprehensions and doubts about the development of SI.

Inconsistency in the interests between citizens and private investors

According to the experts, public demands must guide SI development initiatives. However, some SI development projects may not ensure adequate returns on private sector investments e.g. if the payback period is too long or the demand levels are uncertain. If so, the private sector will not be interested in developing such SI, although needed by the citizens and/or promoted by the Government. SI developments often face difficulties with PPP arrangements due to the inherent tension between the interests of residents and private investors.

Multi-stakeholder coordination complexities

SI development projects require multiple stakeholder participation, while the involvement of the private sector in the development will also increase the number of stakeholders in the projects. However, as explained by the interviewees, coordination of all the stakeholders is a major challenge. These coordination issues could significantly impact the application of PPP in the development of SI. The interviewees recommended that all stakeholders in the projects should be handled equitably by pre-agreed protocols.

The next section provides the findings gained from the analysis of the responses to the questionnaire survey using the ISM and MICMAC techniques.

4.2. Barriers to PPP in smart infrastructure development in Sri Lanka: Findings from the empirical survey

4.2.1. Structural Self-Interaction Matrix (SSIM)

The participants of the survey were able to identify the contextual links that exist between the hurdles to implementing PPP in the development of SI in Sri Lanka using: V = Barrier B_i will help to achieve/alleviate barrier B_j; A = Barrier B_j will help to achieve/alleviate barrier B_i; X = Barriers B_i and B_j will help to achieve/alleviate each other; O = Barriers B_i and B_j are unrelated.

Table 6 presents the structural self-interaction matrix (SSIM), which displays the compiled data from the 10 questionnaire replies. In order to mitigate subjectivity, the process of aggregation is conducted based on the principle of 'Minority yielding to the majority', as proposed by Saka et al. (2020), Jayasena et al. (2023) and Mathiyazhagan et al. (2013).

4.2.2. Initial reachability matrix

The next step involved transforming the SSIM into a basic reachability matrix based on these guidelines. If the cell entry is: (a) V in SSIM, cell *i, j* will be 1 and cell *j, i* will be

Table 6. Structural self-interaction matrix (SSIM) as consolidated from the survey responses

ID	Barriers	B_{10}	B_9	B_8	B_7	B_6	B_5	B_4	B_3	B_2	B_1
B_1	Lack of requisite knowledge, competence and skills	O	V	O	A	O	O	O	A	V	
B_2	The citizens' hesitancy to embrace private sector engagement	V	X	A	A	A	A	O	A		
B_3	Unavailability/ lack of relevant policies	V	O	V	V	O	A	A			
B_4	Complex or restrictive financial infrastructure	O	O	O	V	O	A				
B_5	Political instability/ political influence	O	V	V	V	O					
B_6	Public unawareness of PPP's perceived benefits and importance	V	X	O	O						
B_7	Lack of local and foreign investors	O	A	A							
B_8	Dishonest/ unethical practices and corruption	O	O								
B_9	Inconsistency in the interests between citizens and private investors	X									
B_{10}	Multi-stakeholder coordination complexities										

0; (b) A in SSIM, cell *i*, *j* will be 0 and cell *j*, *i* will be 1; (c) X in SSIM, cell *i*, *j* will be 1 and cell *j*, *i* will be 1; (d) O in SSIM, cell *i*, *j* will be 0 and cell *j*, *i* will be 0.

The SSIM's initial reachability matrix for barriers to PPP adoption in SI projects is shown in Table 7.

4.2.3. Final reachability matrix

The initial reachability matrix was examined for transitivity using the processes outlined in the ISM technique. Transitivity is a core principle in using the ISM technique, positing that if A is equivalent to B and B is equivalent to C, then A will also be equivalent to C (Saka et al., 2020; Jayasena et al., 2023). The transitivity was examined by the below Python function (Figure 1) in order to generate the final reachability matrix, which is presented in Table 8.

```
def transitivity( matrix):
    result = ""
    length = len(matrix)
    for i in range(0, length):
        for row in range(0, length):
            for col in range(0, length):
                matrix[row][col] = matrix[row][col] or (matrix[row][i] and matrix[i][col])
        result += (" n\n W" + str(i) + " is: \n\n" + str(matrix).replace("],", "]") + "\n\n")
result += ("\n\n Final Reachability Matrix is \n\n" + str(matrix).replace("],", "]\n\n"))
print(result)
return result
```

Figure 1. Python function used in the study

4.2.4. Hierarchical structure of barriers to PPP in smart infrastructure development projects in Sri Lanka

Each barrier's distinct level is established by calculating its reachability set, antecedent set, and intersection set from the final reachability matrix. A barrier's reachability set consists of that barrier and any other barrier in the corresponding row with a value of 1. The antecedent set includes the barrier and any other drivers that similarly have a value of 1 in the appropriate column. The components that are present in both the reachability set and the antecedent set constitute the intersection set. Table 8 illustrates the final reachability matrix, which is used to display the reachability set, antecedent set, and intersections for every barrier.

The classification of barriers as having the same level was based on whether or not their reachability sets and intersection sets were identical. According to Table 9, Level 1 includes B_1, B_2, B_6, B_7, B_8, B_9, and B_{10}. This is because the reachability set '1, 2, 6, 7, 8, 9, 10' is the same as the intersection set '1, 2, 6, 7, 8, 9, 10'.

After categorising Level 1 of the hierarchical structure, Table 9 showed that the '1, 2, 6, 7, 8, 9, 10' were deleted entirely from the subsequent iteration. The same procedure, which was used in categorising Level 1 of the barriers in the hierarchical structure, was followed in categorising Levels, 2, 3, and 4 as illustrated in Tables 10, 11, 12.

Table 8. The final reachability matrix of barriers to PPP arrangement in SI procurement

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
B_1	1	1	0	0	0	1	1	1	1	1
B_2	1	1	0	0	0	1	1	1	1	1
B_3	1	1	1	0	0	1	1	1	1	1
B_4	1	1	1	1	0	1	1	1	1	1
B_5	1	1	1	1	1	1	1	1	1	1
B_6	1	1	0	0	0	1	1	1	1	1
B_7	1	1	0	0	0	1	1	1	1	1
B_8	1	1	0	0	0	1	1	1	1	1
B_9	1	1	0	0	0	1	1	1	1	1
B_{10}	1	1	0	0	0	1	1	1	1	1

Table 7. Initial reachability matrix of the barriers to adopting PPP in SI development projects derived from the SSIM

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
B_1	1	1	0	0	0	0	0	0	1	0
B_2	0	1	0	0	0	0	0	0	1	1
B_3	1	1	1	0	0	0	1	1	0	1
B_4	0	0	1	1	0	0	1	0	0	0
B_5	0	1	1	1	1	0	1	1	1	0
B_6	0	1	0	0	0	1	1	1	0	0
B_7	1	1	0	0	0	0	1	0	0	0
B_8	0	1	0	0	0	0	1	1	0	0
B_9	0	1	0	0	0	1	1	0	1	1
B_{10}	0	0	0	0	0	0	0	0	1	1

Table 9. Level 1 of the hierarchical structure of the barriers using the final reachability matrix

Barrier	Reachability set	Antecedent set	Intersection	Level
B_1	1, 2, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 6, 7, 8, 9, 10	1
B_2	1, 2, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 6, 7, 8, 9, 10	1
B_3	1, 2, 3, 6, 7, 8, 9, 10	3, 4, 5	3	
B_4	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	4, 5	4, 5	
B_5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	5	5	
B_6	1, 2, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 6, 7, 8, 9, 10	1
B_7	1, 2, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 6, 7, 8, 9, 10	1
B_8	1, 2, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 6, 7, 8, 9, 10	1
B_9	1, 2, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 6, 7, 8, 9, 10	1
B_{10}	1, 2, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 2, 6, 7, 8, 9, 10	1

Table 10. Level 2 of the hierarchy of the barriers via the final reachability matrix

Barrier	Reachability set	Antecedent set	Intersection	Level
B_3	3	3 ,4, 5	3	2
B_4	3, 5	4, 5	5	
B_5	3, 4, 5	5	5	

Table 11. Level 3 of the hierarchy of the barriers based on the final reachability matrix

Barrier	Reachability set	Antecedent set	Intersection	Level
B_4	5	4, 5	5	3
B_5	4, 5	5	5	

Table 12. Level 4 of the hierarchical structure of the barriers using the final reachability matrix

Barrier	Reachability set	Antecedent set	Intersection	Level
B_5	5	5	5	4

As a result, the hierarchical structure of the barriers associated with PPP adoption in SI development projects in Sri Lanka is shown in Figure 2.

The findings revealed the following barriers to PPP arrangements in SI initiatives in Sri Lanka. Seven (7) barriers, which include 'Lack of knowledge, competence and skills', 'Reluctance of the citizens to accept private sector involvement', 'Unawareness of the general public on perceived advantages and importance of PPP', 'Lack of local and foreign investors', 'Dishonest/ unethical practices and corruption', 'Inconsistency in the interests between citizens and private investors' and 'Multi-stakeholder coordination complexities' were identified as 'Level 1' barriers, which influences PPP implementation in SI projects in Sri Lanka. Four (4) out of the seven (7) 'Level 1' barriers include the difficulties that arise from the general public. This interprets the significance of citizens as a stakeholder.

The development of SI should be based on the needs and wants of the public as they are the end users of the developed SI. Their approval of private sector participation is crucial as it is revealed because the private sector will focus on the return on investment while the benefit for the end-users must be user-friendly conditions with improved quality of life. Given that SI typically involves a large number of stakeholders, the complexities, which arise in managing the stakeholders is also identified as a significant barrier. Also, the lack of investors for SI development projects is seen as a major barrier to the adoption of PPP in such projects in Sri Lanka. Unethical corrupt practices are recognized as a significant hurdle, classified as a Level 1 obstacle, that decision-makers consider while implementing SI initiatives under PPP arrangements in Sri Lanka. Unavailability/ lack of relevant policies was identified as a Level 2 barrier, while Restrictive and/or complex financial infrastructure and Political instability/ political influence are considered as barriers, which do not significantly impact on undertaking SI initiatives using PPP arrangements in Sri Lanka.

4.2.5. Findings of the MICMAC Analysis

Table 13 displays the levels of dependent power and the corresponding driving force for each barrier. For a given barrier, the dependency power is the sum of all the values in a specific row of the final reachability matrix table. Contrary to this, driving power is the total of all values within a column of the final reachability matrix table that are all related to the same barrier.

The barriers were plotted as in Figure 3 using the dependence and driving power.

Using the identified barriers' degrees of autonomy, dependency, and connectivity as well as the links, a MICMAC analysis was conducted.

(a) *Autonomous category*: This category refers to the barriers with minimal driving and dependent power. The results revealed no barriers under the autonomous classification.

(b) *Dependent category*: The barriers in this category have a high reliance power but a low driving force. 'Unavailability/lack of relevant policies', 'Restrictive and/ or complex financial infrastructure' and 'Political instability/political influence' were identified barriers under this category, which are with strong dependence power and weak driving power. This illustrates that all these barriers are depending on each other. This is likely due to the influence of the government or political parties in formulating pertinent policies and overseeing the nation's financial infrastructure.

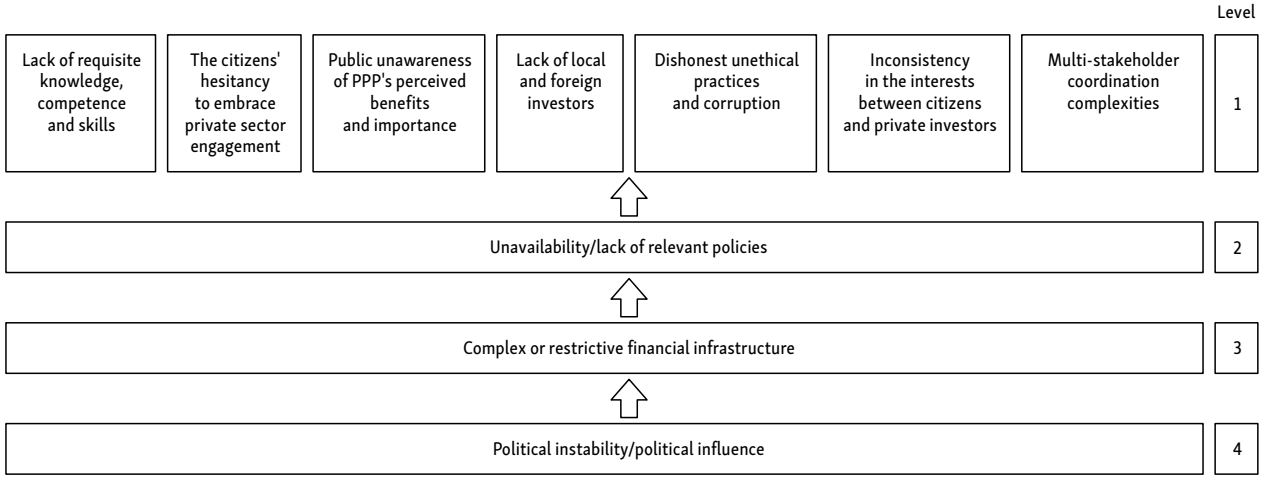

Figure 2. Hierarchical structure for the barriers to using PPP in creating SI initiatives in Sri Lanka

Table 13. Dependence and driving power of the barriers to adopting PPP in SI development projects derived from the SSIM

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
Dp power (y)	10	10	3	2	1	10	10	10	10	10
Dr power (x)	7	7	8	9	10	7	7	7	7	7

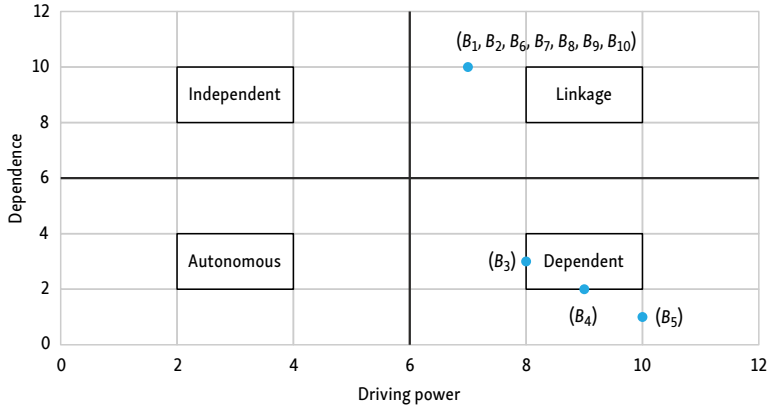

Figure 3. MICMAC analysis of SSIM-derived PPP barriers for SI projects

(c) *Independent category*: The barriers in this category have a strong driving force but weak dependence power. In this study, there were no barriers identified under the independent category.

(d) *Linkage category*: There is a strong dependency and driving force behind these barriers. 'Lack of knowledge, competence and skills', 'Reluctance of the citizens to accept private sector involvement', 'Unawareness of the general public on perceived advantages and importance of PPP', 'Lack of local and foreign investors', 'Dishonest/unethical practices and corruption', 'Inconsistency in the interests between citizens and private investors' and 'multi-stakeholder coordination complexities' were identified as linkage barriers in the study. This confirms the importance of managing the stakeholders efficiently and effectively. Moreover, it is much more significant to consider citizens as an important stakeholder as many barriers are rising and depending on the factors related to the citizens.

4.3. Strategies for enhancing PPPs in delivering smart infrastructure projects

The interviews with industry experts also revealed the rising significance of applying PPP in SI projects after overcoming the critical barriers identified in this study. The interviews were also used to understand the potential of PPPs in developing nations while providing SI. Strategies to improve the use of PPPs in the implementation of SI projects in Sri Lanka are shown in Figure 4, while Table 14 presents the analysis of the strategies, as consolidated from what interviewees collectively conveyed during the interviews.

Enhancing public awareness on the project

The expert interviewees also highlighted that providing necessary awareness of the perceived advantages of the projects should help to minimise the disruptions to the project execution due to any public protests.

Table 14. Strategies for enhancing PPPs for SI delivery

Strategies for enhancing PPPs in developing SI projects	Interviewee										Total number of 'hits' for each strategy mentioned
	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	
Well-designed organisational structures and well-focused management procedures of PPP projects											
▪ Providing the minimum specifications and functions as basic parameters, in the call for the proposals for PPP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
▪ Deciding on the best timeframe for delivering PPP projects	✓	✓	✓	✓	✓	✓	✓		✓	✓	9
▪ Maintaining high transparency in the operational procedures of PPP projects	✓	✓	✓		✓	✓	✓	✓	✓	✓	9
Enhancing public awareness on the project											
▪ Effective communications of the project stakeholders with the general public through various media	✓	✓	✓	✓	✓	✓	✓	✓		✓	9
▪ Providing further detail on examples of PPP projects that have been completed successfully	✓	✓	✓	✓	✓	✓		✓	✓	✓	9
▪ Excellent management of both internal and external stakeholders	✓	✓	✓	✓	✓		✓	✓	✓	✓	9
Close monitoring and control of the project											
▪ Having regular meetings for project inspections and reviews	✓	✓	✓		✓	✓	✓	✓	✓	✓	9
▪ Using penalties and rewards as incentives to improve corrective measures	✓	✓	✓	✓		✓	✓	✓	✓	✓	9
▪ Providing methods for the government to regulate the project delivery procedure	✓		✓	✓	✓		✓	✓		✓	7
▪ Total number of strategies mentioned by each interviewee	9	8	9	7	8	7	8	8	7	9	80

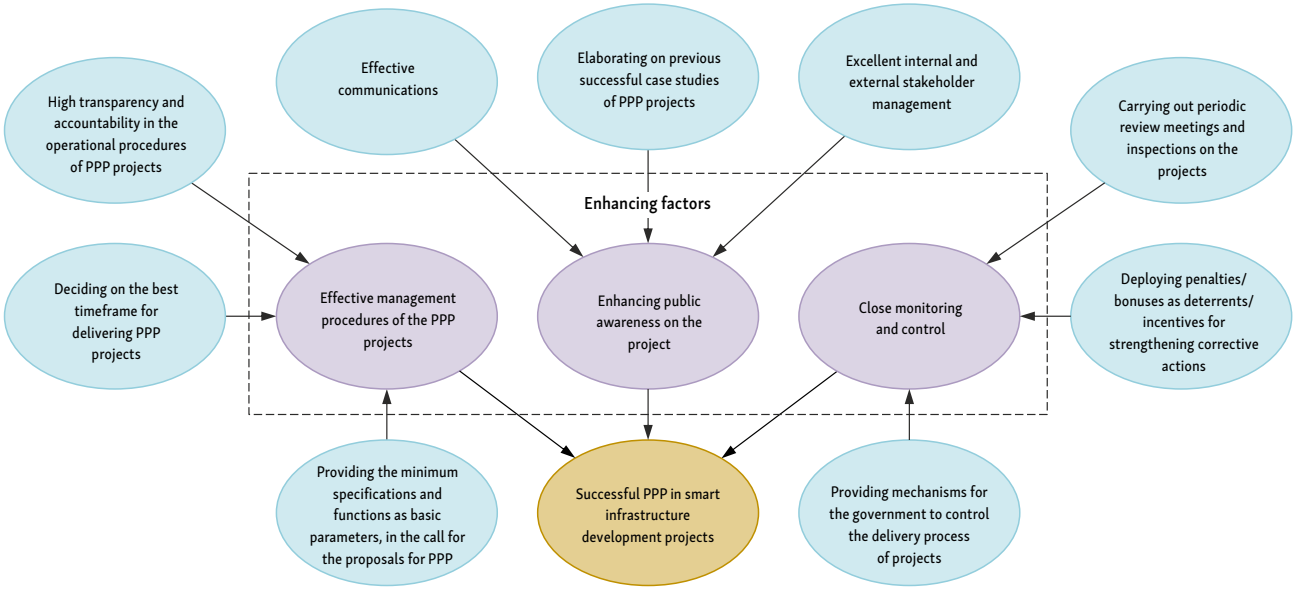

Figure 4. Strategies for enhancing PPPs in delivering SI projects in Sri Lanka

The experts identified effective communication with the project stakeholders through media as crucial for overcoming the unawareness of the public. Public protests and acts against the participation of the private sector in SI development could be overcome by disseminating previous successful case studies in countries close to Sri Lanka.

Well-designed organisational structures and well-focused management procedures of PPP projects

According to the expert interviewees, the structures and management procedures of the PPP should be very carefully designed in order to pre-empt or swiftly overcome the problems that may arise in the execution of the envisaged SI development. Initially, project proposals for PPP projects in Sri Lanka spanned a wide range and hence, could not be easily compared. Nevertheless, identifying critical specifics, starting with the call for the proposals for PPP, the experts recommend clear unambiguous articulation of the minimum functions, specifications, and basic parameters. This is crucial for SI development as high technology is required; but needs to be managed well. Therefore, deciding on these minimum functions and base spec-

ifications is critical in PPP-involved SI development. Once these minimum functions and specifications are set, competing proposals may be evaluated against these, while the functions can be improved further but must be managed well. Consequently, the best timeframe should be decided, to receive the required services on time and efficiently. High levels of transparency are required in designing organisational structures, communication channels and management mechanisms, for maximising effectively and minimising opportunities for corruption in PPP projects by both the private sector and public sector.

Close monitoring and control of the project

The expert interviewees also emphasised the importance of close monitoring by the public and private sectors at the contract development stage, to ensure the efficacy and efficiency of the outcome. When the project is executed by the counterparty, the government must maintain the capacity to rigorously oversee and monitor activities, ensuring that the outputs are accomplished within the stipulated timeline and in compliance with all regulations. The experts recommended scheduling regular inspections and review sessions, as well as using sanctions and rewards to encourage or discourage certain behaviours. The experts also emphasised the significance of the government punishing private sector for non-performance or late performance. These factors, as well as the means for the government to regulate the project's execution, must be factored in before its inception. All the experts concur that public-private partnerships are the best option for infrastructure development in Sri Lanka and could be enhanced through lessons learned from successful cases in both developed and developing countries.

5. Discussion of findings and study implications

The development of a PPP is a multifaceted and ever-evolving process that encompasses several stages throughout the project's life cycle, including project identification, preparation, procurement, execution, transfer, and post-transfer phases (Bao et al., 2018). This study identified the significant barriers affecting the project success of PPP-procured SI developments in Sri Lanka. The barriers were analysed qualitatively and quantitatively. As per the findings, the most significant barriers (Level 1 barriers) are 'lack of knowledge, competence and skills', 'reluctance of the citizens to accept private sector involvement', 'unawareness of the general public on perceived advantages and importance of PPP', 'lack of local and foreign investors', 'dishonest/ unethical practices and corruption', 'inconsistency in the interests between citizens and private investors' and 'multi-stakeholder coordination complexities'.

Nam and Pardo (2011) assert that innovative ideas from creative individuals are essential for launching the sophisticated system applications necessary for the development of smart cities, which are pivotal to sustainable urban development. Veselitskaya et al. (2019) and Allwinkle and Cruickshank (2011) have also conveyed the importance of updating specific knowledge and improving competencies of the project stakeholders as an essential condition for project success. Therefore, the barrier (lack of knowledge, competence and skills) is clearly important as identified in this study. The next citizen-related barriers, which had a higher dependence and a driving power to the above barrier are 'reluctance of the citizens to accept private sector involvement', 'unawareness of the general public on perceived advantages and importance of PPP' and 'inconsistency in the interests between citizens and private investors'. According to Banerjee et al. (2015), public and private sector participants could collude in corrupt deals, unless careful checks and balances are installed. Moreover, Ke et al. (2010) confirmed that some local government officials may demand bribes or unjust rewards in PPP. Considering this, the public may be hesitant to quickly accept private sector engagement in implementing public infrastructure due to the possibility of corruption that plaque government expenditures. These confirm the significant impact of 'dishonest/unethical practices and corruption', which was also identified as a Level 1 barrier. 'Lack of local and foreign investors' and 'multi-stakeholder coordination complexities' are the other significant barriers (Level 1) identified in this study, which are also seen as having the same dependence and driving power as the above-mentioned barriers.

'Unavailability/ lack of relevant policies' is a Level 2 barrier identified in this study while 'restrictive and/or complex financial infrastructure' and 'political instability/ political influence' are the next 2 barriers in terms of the significance and the driving power. As depicted by Kang et al. (2018), lack of confidence in legal and regulatory systems, economic stability and governance institutions may constitute significant impediments in applying PPP. Further, Aijaz and Hoelscher (2015) highlighted the importance of favourable policies to deploy PPP in infrastructure developments. Ng et al. (2012) also highlighted the importance of a favourable social climate and a supportive political and legal framework. Further, Babatunde et al. (2016) mentioned that the success of any PPP project is largely dependent on the country's maturity. As explained in Rana et al. (2019), the significance of the country's political environment in the implementation of PPP in SI development.

To overcome those barriers, Le et al. (2014) and Deng et al. (2003) explained the importance of transparency to deliver the expected PPP outcomes efficiently. Moreover, experience in some other countries (Ji et al., 2021; Osei-Kyei & Chan, 2017; Ng et al., 2012; Dulaimi et al., 2010) has shown that early 'public engagement' of at least the key stakeholders can help pre-empt such challenges. This aligns with the need for excellent stakeholder management in PPPs in general, as also highlighted by Jayasuriya et al. (2020). Therefore, it can be concluded that this study provides useful recommendations (explained in Section 5.3) to overcome the above-mentioned barriers.

5.1. Theoretical implications

The identification of key barriers and strategies to overcome these barriers, hence influencing the effectiveness of PPP arrangements in SI initiatives in Sri Lanka, contributes to the existing theoretical knowledge. Moreover, this methodology and the base frameworks and formats developed and deployed could be used by researchers as a sound platform from which to launch similar studies and formulate country-specific strategies in similarly positioned developing countries or in developed countries.

5.2. Managerial implications

When considering the context of Sri Lanka, the experts mentioned that the application of strategies to overcome the barriers affecting the success of PPP-procured SI developments is at a very dissatisfactory level. All the experts mentioned that there is room to improve the policies, though there are basic definitions provided related to the application of PPP in the context in Sri Lanka. Further, the interviewees explained that more attention should be given to effective management procedures in developing SI, as SI development encounters more barriers, compared to the general adoption of PPP in developing traditional (non-SI-enhanced) infrastructure. Moreover, it was identified that the capacities of the end-users (citizens) should be greatly improved as well. According to the expert interviewees, this is relatively hard for a developing country like Sri Lanka when compared with developed countries.

Therefore, these research findings could be used by the decision-makers, policymakers and construction project management personnel to boost the success rate of PPP in SI developments in Sri Lanka and similarly positioned developing countries/ regions. Boosting the development of SI will contribute to the enhanced quality of life of the citizens of a country and sustainable development worldwide, while also mitigating the potential impacts on the environment.

6. Conclusions

The concepts and execution of SI developments are significant and advantageous for both developed and developing nations. This study identifies several difficulties that disproportionately impact developing countries. The financial barriers and the associated risks are the most crucial barriers identified in this study from the literature review. To address these prevalent difficulties, effective procurement via PPP is a viable method recognized by developing nations to consolidate, synergize, and deploy various cross-sector resources. Therefore, this study provided answers to: "What are the barriers affecting the success of PPP in SI developments in Sri Lanka, how do they affect and how to overcome those barriers?" research questions.

Firstly, this study provided an appropriate definition for SI. Developing SI requires more technological advancements, as well as technical and managerial expertise than developing normal (non-SI) infrastructure. As per the findings, the involved private partner could inject those advanced technologies and expertise in a developing country like Sri Lanka. The identified Level 1 barriers in Sri Lanka with a stronger driving power (using the ISM technique and MICMAC technique) are 'lack of knowledge, competence and skills', 'reluctance of the citizens to accept private sector involvement', 'unawareness of the general public on perceived advantages and importance of PPP', 'lack of local and foreign investors', 'dishonest/unethical practices and corruption', 'inconsistency in the interests between citizens and private investors' and 'multi-stakeholder coordination complexities'. Further, it was identified that these factors depend on each other as well. Therefore, surmounting these obstacles is essential for the success of PPP arrangements in SI projects in Sri Lanka. This study recommends several broad strategies to overcome these hurdles, derived from the collective experiences and profound insights of the expert interviewees. These strategies include 'increasing the awareness of the citizens', 'close monitoring and control of the project' and 'well designing and managing the PPP project'. The findings clearly illustrate that there is more room to apply the recommended strategies in Sri Lanka and to boost SI development in Sri Lanka.

Although this study focused on Sri Lanka, the important precursor international literature review transcends this focus to place it in context, while the research methodology including the questions that could be adapted and applied elsewhere. Expert inputs into research study were limited to only 10 suitably experienced experts due to the novelty of this area in Sri Lanka. However, this limitation was overcome by choosing appropriate and effective methods to analyse and generate the findings. The ISM technique is suitable for similar situations, where there are a smaller number of experts in the area. Moreover, the identified experts were very knowledgeable with expertise and experience in the area. The identified 10 major barriers and the strategies for overcoming those major barriers could further be deconstructed into sub-barriers and strategies. However, the major points are identified and presented in this paper. The study findings have identified potential strategies for reducing the identified barriers in order to enhance PPP procurement in SI development in similarly situated developing nations. Future research could explore the determinants influencing PPP in SI development projects, with a comparative analysis between a developed nation and a developing nation. Also, other similar investigations could be carried out in other developing countries as well, based on the research methodology and formats developed and adopted in this study.

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