Benefits, enablers and barriers in deploying PPP when developing smart infrastructure in non-urban areas

Abstract

Purpose:

The widespread lockdown restrictions brought by the global COVID-19 epidemic inculcated a culture of "work-from-home". However, most rural areas lack reliable and effective community amenities including transportation, health, and education, thereby impeding healthy living and productive employment. Therefore, the underlying goal of this research is to investigate the development of smart infrastructure (SI) in non-urban areas. However, governments' resource limitations must be addressed to develop SI, which urges the research on the potential for Public-Private Partnerships (PPP) to supplement public sector resources when necessary.

Design/methodology/approach:

This paper examined and evaluated the "benefits & enablers" and "barriers" to deploying PPPs to create SI in non-urban areas, using a thorough literature review, five expert interviews, and AHP-based questionnaire responses. The Analytic Hierarchy Process (AHP) technique and content analysis were used to analyse the results and generate the conclusions.

Findings:

The availability of a favourable investment climate and legal framework were identified as the significant factors among the "benefits & enablers" of adopting PPP in SI developments in non-urban areas, while low community acceptance of the private sector involvement, and community culture and values were identified as the significant factors among the "barriers". These highlight the significance of removing barriers connected to community culture and "values".

Originality/value:

The findings and conclusions of this study provide a strong foundation to support the growth of SI in non-urban settings, facilitating more sustainable development that is more evenly distributed in the post-COVID-19 future.

Keywords: Non-urban areas, Public-Private Partnership (PPP), Smart infrastructure, Smart villages

1. Introduction

The traditional way of dividing a country into urban and rural areas has been based on the idea that urban areas offer a different way of life and usually a better standard of living than rural areas (United Nations Statistics Division, 2023). In conjunction with urban centres, metropolitan areas encompass wide territories characterised by rural attributes. There are numerous methodologies for categorising the term “rural”. The utilisation of maps can effectively highlight the notion that the designation "rural" does not uniformly encompass all non-urban areas (Miller, 2013). Arellano and Roca (2017) identified different types of human settlements, which are namely, ‘rural’, ‘rurban’, ‘periurban’ and ‘urban’ areas. Based on the authors' findings, it can be observed that a significant proportion of the global population resides in various geographical settings. Specifically, 40.26% of individuals live in rural regions, 15.53% in ‘rurban’ spaces, 26.04% in ‘periurban’ localities, and a mere 18.16% in central places. Hence, it can be seen that there is a significant proportion of the population still resides in non-urban areas.

In developing countries, the quality of infrastructure, living standards and styles of life remain significantly different between urban and non-urban areas. Other relevant facts are that disasters have a greater economic impact on rural areas and that they often have worse quality infrastructure and services than urban areas. Due to these common and perceived difficulties, non-urban communities may be drawn to move to urban city centres. Even though, according to the 2017 census, despite a rising global trend toward urbanisation, approximately 45% of people worldwide still live in non-urban areas (United Nations 2018). Moreover, the COVID-19 pandemic caused a "pause" in the previously accelerating movements to metropolitan areas around the world as well. However, non-urban residents should also have the right to the same standard of living as city dwellers. If they do have the same quality infrastructure, they will be less inclined to burden the already crowded cities.

According to Zhang (2016) and Jayasena et al. (2021), fast urbanisation leads to environmental deterioration, criminality, and urban poverty, which increases the risk of disease transmission for inhabitants. Additionally, Gong et al. (2012) asserted that the crowded social and environmental conditions that result from urbanization put residents at risk of developing diseases. Such

escalating issues, made worse by slums and unplanned city growth in emerging nations, serve as "wake-up calls" to substantially curb rural-to-urban migration while implementing measures to enhance the standard of living, safety, and health in non-urban regions. Therefore, developing smart infrastructure (SI) in non-urban areas will also be beneficial in managing these escalating urbanisation challenges.

The global COVID-19 outbreak was another stark warning. People were forced to stay at home and government-imposed measures like masks and social seclusion that fostered a "work from home" mentality. In many nations, education likewise changed to a mainly online format. People continued to work on most of their daily tasks from home using the infrastructure that was available. For example, high speed internet service facilities are required by the citizens to carry out their routine office meetings or to continue attending classes conducted by schools. The researchers also tended to work-from-home culture, which also highlighted the importance of cloud-based storage systems, remote access security and VPN services, and video communication tools. To receive these systems, in order to maintain job continuity, this "new normal" highlighted the necessity of swiftly improving Information and Communication Technology (ICT) systems and services in non-urban areas as well. In addition, the need to monitor and contain the pandemic's spread increased the demand for innovative ideas and technologies that also need operationalisation through SI.

SI is unquestionably more crucial in pandemic conditions as seen in the above-mentioned other advantages. However, governments are significantly more resource constrained as a result of tackling hitherto unheard-of economic and health crises concurrently. As a result, Park and Chung (2021) discussed the significance of government and business sector cooperation in the fight against the virus. Steyer and Gilbert (2013) also emphasized the necessity of public and private sector cooperation in addressing such unique threats. Additionally, according to Ogie et al. (2017), the initial costs of SI developments are higher than those of traditional infrastructure developments, whereas non-urban areas are less willing to adopt ICT and other digital advancements (Ranade et al. 2015). Therefore, Public-Private Partnership (PPP) seems an acceptable procurement approach for creating SI during and after this global pandemic in order to solve these problems in funding, capacity building, risk management, and deploying new technologies. For effective and successful results, Viswanadham and Vedula (2010) also

recommended constructing smart villages, small towns, and townships near large cities through PPP. PPP is defined as “a strategy that is utilized to provide quality infrastructure facilities and services with high efficiency, based on a long-term contractual arrangement between public and private parties, through the synergetic cooperation between the public and private partners” (Zhang et al. 2015, p. 498), which also justifies this present study.

Even though there are many perceived advantages of applying PPP, failures of PPP in SI development projects could also arise at different stages. Traditional, contract-based PPP models may not be appropriate for the development of SI, according to Liu et al. (2020), primarily due to the differences between conventional infrastructure and SI as well as the distinctions between cities and non-urban areas. Therefore, the use of PPP in non-urban SI development projects should only be undertaken after a thorough analysis of the social, economic, political, and environmental barriers in those non-urban areas. Therefore, the aim of this study was developed as to investigate and assess the potential for PPP-based SI development projects in non-urban areas. Two study goals were consequently established:

(1) To investigate the current state and applicability of PPP in SI projects in non-urban areas.

(2) To identify and assess the "benefits & enablers" and “barriers” affecting the adoption and effectiveness of PPP in SI projects in non-urban areas.

In this study, the categorization of "benefits & enablers" was consolidated into a single category. An enabler provides assistance and allows the implementation of PPP in SI developments, while the benefits enhance the adoption of PPP in SI developments in non-urban areas.

2. Literature Review

2.1 Importance of smart infrastructure for non-urban areas

The United Nations (UN) made a commitment to 17 interconnected goals and 169 targets as part of the UN Sustainable Development Goals (SDGs), which were adopted in 2015. The SDGs' aims also encompass revitalising rural areas and their connections to urban centres (International Telecommunication Union, 2020). Moreover, according to the report by the International Telecommunication Union, traditional methods have failed to solve the complex issues of ongoing inequality in the way of living. It has become crucially important to investigate the possibility for using the digital revolution to spark social and economic change in rural villages. Development

of SI is the ideal solution to achieve this goal (Jayasena et al., 2023). In this study, SI is referred to as "a system that can measure, monitor, analyse, communicate, and take action based on information gathered by sensors" being based on the description by Nexus Integra (2020). In this study, smart village is defined as “a bundle of services which are delivered to its residents and businesses in an effective and efficient manner” (Somwanshi et al., 2016, p.365).

By enabling the accessibility of SI and ensuring the availability of appropriate digital solutions to individuals, households and public administration, a significant acceleration in the achievement of the SDGs can be observed, These goals encompass several sectors such as health, trade, education, and agriculture. The key attribute that underlies most of these components is the interconnection and generation of data that can be used logically to ensure optimal resource allocation (Babin et al., 2021). In order to effectively address the SDGs in isolated and underprivileged communities, a smart village is a comprehensive and all-inclusive strategy. Prior to the pandemic, only selected urban regions recognized and addressed the need for automated building management and maintenance. Nevertheless, in non-urban areas, these factors weren't frequently taken into account in the planning and development of public infrastructure. However, Anabestani and Javanshiri (2017) demonstrated how problems with rural lands and gardens, high development costs for infrastructure and services, environmental fragmentation and degradation, loss of regional biodiversity, and other issues also affect rural regions. Such concerns highlight the necessity of SI to enhance community quality of life, health and safety, and effective management of infrastructure in non-urban areas as well. Sustainability constitutes an additional crucial element within the context of developing SI.

The global COVID-19 epidemic raised questions on several fundamental concepts that form the basis of modern cities and urban planning. These include the benefits of enormous city size, high density, mass transportation, unrestricted individual movement in cities, and free use of public space (Kakderi et al., 2021). The COVID-19 pandemic outbreak necessitates the acknowledgement and effective handling of several dimensions by leaders in academia, government, and industry, going beyond health (Lambert et al. 2020). Therefore, it is imperative to reassess urban planning with regard to public infrastructure and non-residential building designs. During the epidemic itself, citizen-centric approaches, social participation, user-centred architecture, and general well-being have arisen as important concerns (Michael et al. 2021). Equal

access to quality living circumstances should be extended to people in non-urban areas just as it is provided to those living in urban areas. Additionally, the COVID-19 epidemic made it more urgent to upgrade the infrastructure and services in non-urban areas. The significance of SI for enabling a "pandemic-proof" future smart community was noted by Gupta et al. in 2021. It is clear that "smarter" infrastructure and service connectivity through SI could aid crucial COVID-19 track and trace exercises and social distance maintenance. However, the need for higher financial capacities in developing SI, PPP could be identified as a potential solution (Dolla and Laishram, 2020; Jayasena et al., 2021).

2.2 PPP for smart infrastructure development in non-urban areas

Multi-stakeholder collaboration and partnerships are key to integrate digitalisation and develop SI in non-urban areas (International Telecommunication Union, 2020). PPP agreements have been praised for their capacity to address the capital shortfall in the public sector and bring in private sector knowledge and experience to develop and manage infrastructure assets (Akintoye et al. 2016). According to Dolla and Laishram (2020), the application of PPP has the potential to significantly improve the provision of infrastructure services. PPPs have emerged as a valuable mechanism for governments to effectively leverage private capital and expertise in order to facilitate the provision of public services (Lam and Yang 2020).

PPP projects facilitate the transfer risks associated with funding, designing, constructing, and running public assets and services to the private sector, either partially or entirely (Liu et al. 2015). Additionally, the study conducted by Lam and Yang (2020) highlighted the positive impact of incorporating the private sector expertise on enhancing service quality. The authors also described how many governments throughout the world believe that working with the private sector speeds up the adoption and spread of technology because the latter pushes ICT advances. Another benefit of PPP is that it lowers the burden on a government's capital budget on SI developments, with private sector investment.

Economic, social, and environmental variables all impact on the decision to use PPP for development projects, according to Du et al. (2018). Moreover, Lam and Yang (2020) provided additional evidence to support the notion that possessing ICT expertise within the private sector is another advantage that contributes to the success of PPP in SI development. Although there are numerous benefits associated with the implementation of PPP in the context of SI development in

non-urban regions, it is important to acknowledge the existence of certain obstacles that may hinder the successful use of this approach. According to Cui et al. (2018), the appropriateness of utilizing PPP as the preferable approach is influenced by internal project characteristics, including its economic feasibility, cost-effectiveness, and stakeholder contentment.

3. Research Methodology

The study's goal was to explore and assess the potential, "benefits & enablers," and "barriers" to SI development projects in non-urban regions through PPP. To this end, a mixed method research technique was used in the study. To obtain a broad overview of the existing literature on the need for SI and the role of PPP in delivering SI in non-urban areas, a thorough review was conducted. However, only few published research papers have given attention to the application of PPP in developing SI in non-urban areas. Therefore, only the background search was able to be done through the literature review. The “benefits & enablers” and barriers preventing PPP in SI projects in non-urban areas were then investigated through five expert interviews. The number of interviewees were also limited due to the low number of experts available in this new area of research. Although the number of expert interviews was limited to five, their levels of experience in, and knowledge about PPP and SI developments were very high, abundant and valid. Each semi-structured interview lasted for roughly 60 minutes. Many researchers employ semi-structured interviews because they are effective in eliciting in-depth human opinions. Sekaran (2003) asserted that semi-structured interviews can help clarify key points and elicit further information. The manual content analysis method was used to analyse the qualitative data obtained from the expert interviews. According to Chan et al. (2011) and Chan and Choi (2015), content analysis classifies textual resources, lowers the contents to relevant and manageable portions of data, and then collects knowledge and understanding of topics pertinent to the overarching objectives and particular study questions. This approach can be used to ascertain the general viewpoints of numerous knowledgeable interviewees. In this study, a matrix was utilised to show any similarities and differences for cross-comparisons of the views of the expert interviewees in obtaining the list of ‘benefits & enablers’ and barriers.

A structured AHP-based questionnaire was then used to assess the identified “benefits & enablers” and barriers. The Analytic Hierarchy Process (AHP) technique, one of the most popular multiple criterion decision-making tools (Vaidya and Kumar 2006), was utilized to determine a relative

weight for each obstacle through the usage of this AHP-based questionnaire (Harputlugil et al. 2011). The most obvious grounds for utilizing AHP, according to Darko et al. (2019), were the small sample size, high level of consistency, and simplicity. The AHP tool was used to create a relative weight for each barrier, which was helpful for the project's planning and feasibility study as well as for removing the obstacles. Since AHP is a subjective method, Wong and Li (2008) noted that a high sample size is not necessary. As stated by Tavares et al. (2008) and Abudayyeh et al. (2007), AHP analysis can be completed with the opinions of just one qualified expert. A limited number of experts are available in the areas of developing smart villages and PPP. Hence, AHP technique was selected in this study to reap the maximum benefits from the available sources. As a result, two experts who took part in the expert interviews and have in-depth knowledge of current PPP-based SI advancements were administered the AHP-based questionnaire. Only two experts were selected for the questionnaire survey as it was time consuming and heavily dependent on realistic replies to an AHP-based questionnaire, hence the need for careful selection. The profiles of the experts who participated in the expert interviews and those who answered the AHP-based questionnaire are indicated in Table I.

Table I: Profiles of the expert interviewees and the experts who responded to the AHP-based questionnaire survey

Experts` profile (expert interviews)				
Expert	**Academic / Industry Practitioner**	**Stake with PPP and/or SI projects**	**Country of Practice**	**Experience Level**
I1	Academic	PPP involved SI projects	China	Over 15 years
I2	Industry Practitioner	PPP involved SI projects	Singapore	5-10 years
I3	Industry Practitioner	PPP involved SI projects	Switzerland	Over 15 years
I4	Academic	PPP involved SI projects	Australia	Over 15 years
I5	Industry Practitioner	PPP involved SI projects	Switzerland	10-15 years
Experts` profile (AHP-based questionnaire survey)				
I1	Academic	PPP involved SI projects	China	Over 15 years
I5	Industry Practitioner	PPP involved SI projects	Switzerland	10-15 years

Source: Table by authors

The first step was to develop the AHP hierarchy diagram. Then pairwise comparisons in the AHP-based questionnaire were designed to allow respondents to express their opinions on the importance of each factor. The relative size of importance of one factor over another element in relation to the criterion against which they are evaluated in turn, must be indicated by a scale for such comparisons (Saaty 2008). The ratio scale that Saaty demonstrated is shown in Table II.

Table II: Ratio scale demonstrated by Saaty (2008)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one activity over another
5	Strong importance	Experience and judgement strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	A reasonable assumption

Source: Table by Saaty (2008)

The pairwise comparisons were summarized in the next stage. From pairwise comparison, an average of the respondents' ratings was derived, and the sum of each column was computed. In pairwise comparison matrices, the entries were normalized by dividing each entry by the sum of each column. The row sum was subtracted from the total amount to produce the performance score. The consistency computation was then completed. The Consistency Index is a gauge of consistency (CI). According to Goepel (2015), a Consistency Ratio (CR) is produced from this using a Randomized Index (RI) and the average CI for randomly filled matrices. The first items in the pairwise comparison matrix was multiplied by performance score to get the eigenvector, which was then used to calculate the CR. Each row was added to create a new vector. Next, λ_{max} was calculated as per the equation 1, which gives the average value of the column sum (a_1, a_2, etc.).

Equation 1: calculation of λ max

$$\lambda_{max} = \frac{a_1 + a_2 + a_3 + a_4 + a_5}{5}$$

Subsequently, the CI and CR was calculated as per the following equations.

Equation 2: Consistency Index

$$CI = \frac{\lambda_{max} - n}{n-1}$$

Equation 3: Consistency Ratio

$$CR = \frac{CI}{RI}$$

According to Saaty (2008), only judgment matrices with a CR of less than 0.1 are acceptable (Deng et al. 2014). According to Saaty (2008), if the matrix size is 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 the RI is 0, 0, 0.52, 0.89, 1.11, 1.25, 1.35, 1.40, 1.45 and 1.49 consecutively.

The findings and discussion of the study, which were based on the content analysis technique and AHP technique are discussed in the next section.

4. Research findings and discussion

4.1 Deploying PPPs to develop SI in non-urban areas

Delivering SI is important for non-urban areas in both developed and developing countries, as explained in the Introduction and the Literature Review sections. It was identified as essential that the private sector be involved in these projects due to the high cost of development and the need for more cutting-edge technology. This factor was also substantiated in Dolla and Laishram (2020) and Selim et al. (2018). They also identified PPP as a potential strategy in developing SI. Interviewee 3 (I3) claimed that the main distinction between developed and developing nations is that "developing nations have a higher proportion non-urban areas than developed nations". Additionally, all of the experts believed that establishing SI in non-urban areas in a comparable manner to cities was necessary. Insufficient resources are highlighted as the main obstacle here, and private sector collaboration is essential to surmount these shortfalls and related difficulties. According to expert interviewees, India and China are both leading the way in the creation of smart villages and SI in rural areas. It was determined that, similarly to cities, SI are needed for

transportation, water management, waste management, and energy management. The experts emphasized the importance of SI, particularly for the agricultural industry and for village livestock management. To get the highest production, they underlined the necessity for automation in plant management and crop management. This is another advantage of having SI in non-urban areas.

All of the interviewees recommended PPP as the ideal procurement option for delivering SI to non-urban areas. According to Interviewee 5 (I5), "*village and suburban regions lack self-sufficient funding, leaving them with no alternative except to permit the private sector's involvement in the high cost developments.*" However, they also suggested other methods for developing SI projects in non-urban areas due to the lack of conditions that are identical to those in cities. Table III lists the conditions that are different in urban and rural locations and how they affect the adoption and performance of PPP in SI projects.

Table III: Differences of the conditions between cities and non-urban areas affecting the adoption and success of PPP in SI projects

Cities	**Non-urban Areas**
Have more expertise in advanced technology and capacities of the human resources	Have less expertise in advanced technology and capacities of the human resources
Community has higher capacity to use advanced technological applications	Community has lower capacity to use advanced technological applications
Higher interest of the private sector in the participation	Lower interest of the private sector in the participation
Have more experience on private sector involvement and smart initiatives	Have less experience on private sector involvement and smart initiatives
Supportive community livelihood and lifestyle	Less supportive community livelihood and lifestyle
Higher community acceptance on private sector involvement and developing SI	Lower community acceptance on private sector involvement and developing SI

Source: Table by authors

Those who participated in the interviews, identified constraints resulting from the community's distinct cultures, values, and ways of life prevent SI development in cities from occurring as smoothly as it does in non-urban settings. Additionally, it was found that a lack of laws is having an effect on the growth and participation of the private sector. Furthermore, it became clear that most governments have little interest in developing SI in rural regions, despite the fact that this is

a growing need, as described in the introduction and literature review sections. Although there is an increasing need for the private sector to work with governments, it is also acknowledged that the private sector is a party that is not usually engaged in improvements in villages and suburban regions.

Seven key "benefits & enablers" affecting the acceptance and success PPPs in constructing SI in non-urban areas were identified based on the expert interviews. Also, seven major barriers affecting the adoption and success PPPs in developing SI in non-urban areas were identified based on the experts' opinion survey. These "benefits & enablers" and barriers are shown in Table IV.

Table IV: 'Benefits & enablers' and 'barriers' affecting the adoption and success of PPPs in developing smart infrastructure in non-urban areas

Code	**Benefits & enablers' affecting the adoption and success of PPPs in developing SI in non-urban areas**	**I1**	**I2**	**I3**	**I4**	**I5**
E1	Supportive legal framework	✓	✓		✓	
E2	Supportive national and regional policies			✓		✓
E3	Favourable investment climate		✓		✓	
E4	High cost of smart infrastructure development	✓		✓	✓	
E5	Need for advanced technological applications		✓	✓		✓
E6	Public/ community support	✓		✓	✓	
E7	Tax benefits		✓	✓	✓	
Code	**Barriers affecting the adoption and success of PPPs in developing SI in non-urban areas**	**I1**	**I2**	**I3**	**I4**	**I5**
B1	Low acceptance of the private sector involvement by the community		✓	✓	✓	
B2	Return on investment perspective of the private sector	✓			✓	✓
B3	Culture and values of the community		✓	✓	✓	
B4	Insufficient regulations	✓		✓	✓	✓
B5	Low interest of the government because of the other priorities of the government		✓		✓	✓
B6	Confidence of the government and political influences		✓		✓	
B7	Low interest of the private sector	✓		✓		✓

Source: Table by authors

Based on the steps described in the Research Methodology section, first, the AHP hierarchy diagram for the questionnaire was developed, as illustrated in Figure 1.

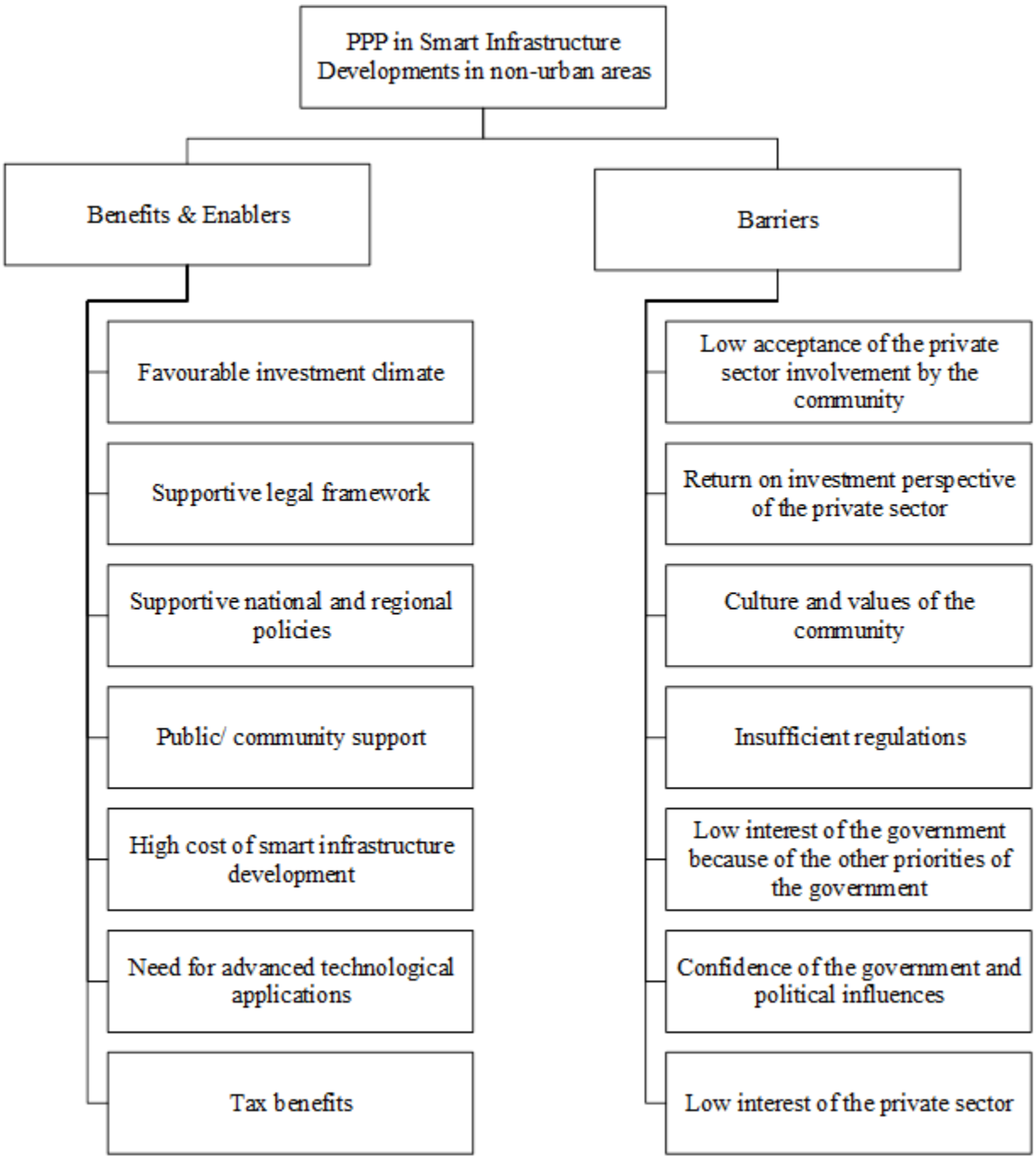

Figure 1: AHP hierarchy diagram for the questionnaire
Source: Figure by authors

4.2 'Benefits & enablers' for the success of PPPs to develop smart infrastructure in non-urban areas

In order to successfully use PPP in SI projects in non-urban areas, it is critical to evaluate these "benefits & enablers" and create a relative weight for each benefit/enabler. The results that were obtained using the AHP approach are shown below. The "benefits & enablers" influencing the acceptance and success PPPs in developing SI in non-urban areas are presented in Table V as a paired comparison matrix, normalized comparison matrix, and consistency calculation matrix. Each benefit and enabler was given a proportionate weight in the normalized comparison matrix. The consistency of the acquired data was determined using the consistency calculation matrix and the equations 1, 2, and 3 described in the Research Methodology section.

Table V: Pairwise comparison matrix, normalised comparison matrix and the consistency calculation matrix of the 'benefits & enablers'

Pairwise comparison matrix							
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**
E1	1.00	1.00	0.33	1.67	4.00	4.00	6.00
E2	1.00	1.00	0.67	3.00	1.67	3.00	4.00
E3	3.03	1.50	1.00	4.00	3.00	3.00	4.00
E4	0.60	0.33	0.25	1.00	1.00	0.33	6.00
E5	0.25	0.60	0.33	1.00	1.00	1.00	2.00
E6	0.25	0.33	0.33	3.00	1.00	1.00	6.00
E7	0.17	0.25	0.25	0.17	0.50	0.17	1.00
Sum	6.30	5.02	3.16	13.83	12.17	12.50	29.00

Normalised comparison matrix									
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**Sum**	**Performance score**
E1	0.16	0.20	0.10	0.12	0.33	0.32	0.21	1.44	0.21
E2	0.16	0.20	0.21	0.22	0.14	0.24	0.14	1.30	0.19
E3	0.48	0.30	0.32	0.29	0.25	0.24	0.14	2.01	0.29
E4	0.10	0.07	0.08	0.07	0.08	0.03	0.21	0.63	0.09
E5	0.04	0.12	0.11	0.07	0.08	0.08	0.07	0.57	0.08
E6	0.04	0.07	0.11	0.22	0.08	0.08	0.21	0.80	0.11
E7	0.03	0.05	0.08	0.01	0.04	0.01	0.03	0.26	0.04
								7.00	

Consistency calculation matrix									
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**Sum**	**Sum/ performance score**
E1	0.21	0.19	0.09	0.15	0.32	0.46	0.22	1.64	7.96
E2	0.21	0.19	0.19	0.27	0.14	0.34	0.15	1.48	7.94
E3	0.62	0.56	0.29	0.36	0.24	0.34	0.15	2.56	8.93
E4	0.12	0.11	0.07	0.09	0.08	0.04	0.22	0.74	8.19
E5	0.05	0.05	0.10	0.09	0.08	0.11	0.07	0.55	6.80
E6	0.05	0.05	0.10	0.27	0.08	0.11	0.22	0.88	7.71
E7	0.03	0.03	0.07	0.01	0.04	0.02	0.04	0.25	6.78

Source: Table by authors

Accordingly, the CI = 0.1261 and the CR = 0.0934. As per Saaty (2008)'s rule of thumb, judgment matrices with CR< 0.1 can only be accepted. Hence, the derived CR is less than 0.1, the collected data passes the requirement of consistency. Utilising the performance score, the percentage of relative significance was calculated and accordingly, a rank was given to each benefit/enabler. These ranks of the 'benefits & enablers' are presented in Table VI.

Table VI: Relative importance-based ranks of the 'benefits & enablers'

'Benefits & enablers'	**Percentage**	**Rank**
Favourable investment climate	29%	1
Supportive legal framework	21%	2
Supportive national and regional policies	19%	3
Public/ community support	11%	4
High cost of smart infrastructure development	9%	5
Need for advanced technological applications	8%	6
Tax benefits	4%	7

Source: Table by authors

The relative importance of each identified benefit and enabler is shown in Table VI as a percentage of the performance score. Based on the resulting 29% relative weight, "having a favourable investment climate" was determined to be the most important benefit/enabler determining the adoption and effectiveness of PPP in SI investments in non-urban areas. The importance of a favourable investment climate was previously identified by Zhang (2005) for PPP in normal (non-

SI) infrastructure projects and by Jayasena et al. (2021) for SI developments in smart cities. Hence, it can be seen that it is significantly important for the SI developments in non-urban areas as well. The second-highest weight (21%) was given to the benefit/enabler of "supporting legal framework". Supportive national and regional policies had the third-highest relative weight (19%). These show the criticality of 'favourable conditions in the host nation' are for the development of SI', whether it be in urban, rural, or non-urban areas. Before entering into a PPP contract, the investors, according to I3, "*search for the available financial and legal situations and relevant policies of the host country*." It is clear that more investors will be encouraged to build SI in non-urban areas if financial and legal conditions are stable in the host nation. Selim et al. (2018) identified the importance of a legal framework in developing SI in general and the importance of having favourable policies was determined by Jayasena et al. (2021) for the context of PPP in SI developments in smart cities. However, these findings are novel for the context of the application of PPP in SI developments in non-urban areas as well.

Public and community support is the fourth important benefit or facilitator. Thus, it is clear that public support is essential for the success of PPP in the construction of SI in non-urban areas as well. Stratigea et al. (2015) and Cardullo and Kitchin (2019) echoed this as important for developing SI in general through the application of PPP as well. The need for cutting-edge technology applications and the high expense of developing SI were ranked fifth and sixth, respectively. The relative weights of these two "benefits & enablers" did not differ much. Interviewee 1 (I1) stated that "*increasing development costs and the necessity for cutting-edge technology are the key reasons for the governments to seek resource pooling with the private sector*." Selim and ElGohary (2020) advocated this as an important consideration in developing SI. The final rank was assigned to 'tax benefits'. This illustrates the relative importance of the other factors explained above, as against tax benefits, for the success of PPP in SI developments in non-urban areas. This suggests that it may be interesting to separately investigate later, whether 'tax benefits' may possibly be considered more important in urban settings as the private organisations who may prefer to operate in their traditional comfort zones there, may be paying higher taxes, hence value tax benefits more. This factor was not previously recognized in the literature for PPP in SI projects. Zhang (2005) discerned this as important for the context in developing normal infrastructure through PPP. However, it is seen that these "benefits & enablers" are applicable to the context of PPP in SI developments in non-urban areas as well.

4.3 Barriers to the success of PPPs to develop smart infrastructure in non-urban areas

Planning how to overcome these barriers is crucial to the success of PPP in SI projects in non-urban areas. This evaluation of the barriers and the assignment of a relative weight for each barrier are critical steps. The results from using the AHP approach are shown below. Table VII lists the barriers preventing PPPs from being adopted and being successful in creating SI in non-urban areas, as well as the pairwise comparison matrix, normalized comparison matrix, and consistency calculation matrix.

Table VII: Pairwise comparison matrix, normalised comparison matrix and the consistency calculation matrix of the barriers

Pairwise comparison matrix

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
B1	1.00	6.00	2.00	3.00	4.00	3.00	3.00
B2	1.00	1.00	0.24	1.57	0.20	0.17	1.00
B3	0.50	4.20	1.00	4.00	5.00	3.00	2.00
B4	0.33	0.64	0.25	1.00	4.00	0.33	2.00
B5	0.25	5.00	0.20	0.25	1.00	0.60	6.00
B6	0.33	5.83	0.33	3.00	1.67	1.00	3.00
B7	0.33	1.00	0.50	0.50	0.17	0.33	1.00
Sum	3.75	23.67	4.52	13.32	16.03	8.44	18.00

Normalised comparison matrix

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**Sum**	**Performance score**
B1	0.27	0.25	0.44	0.23	0.25	0.36	0.17	1.96	0.28
B2	0.27	0.04	0.05	0.12	0.01	0.02	0.06	0.57	0.08
B3	0.13	0.18	0.22	0.30	0.31	0.36	0.11	1.61	0.23
B4	0.09	0.03	0.06	0.08	0.25	0.04	0.11	0.65	0.09
B5	0.07	0.21	0.04	0.02	0.06	0.07	0.33	0.81	0.12
B6	0.09	0.25	0.07	0.23	0.10	0.12	0.17	1.02	0.15
B7	0.09	0.04	0.11	0.04	0.01	0.04	0.06	0.38	0.05
								7.00	

Consistency calculation matrix

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**Sum**	**Sum/ performance score**
B1	0.28	0.08	0.46	0.28	0.46	0.44	0.16	2.16	7.73

B2	0.28	0.08	0.05	0.15	0.02	0.03	0.05	0.66	8.18
B3	0.14	0.04	0.23	0.37	0.58	0.44	0.11	1.91	8.28
B4	0.09	0.03	0.06	0.09	0.46	0.05	0.11	0.89	9.64
B5	0.07	0.02	0.05	0.02	0.12	0.09	0.33	0.69	6.00
B6	0.09	0.03	0.08	0.28	0.19	0.15	0.16	0.98	6.69
B7	0.09	0.03	0.12	0.05	0.02	0.05	0.05	0.40	7.36

Source: Table by authors

Accordingly, the CI = 0.1162 and the CR = 0.0861. As per the Saaty (2008)'s rule of thumb, judgment matrices with CR< 0.1 can only be accepted. Hence, the derived CR is less than 0.1, the collected data passes the requirement of consistency. Utilising the performance score, the percentage of relative significance was calculated and accordingly, a rank was assigned to each barrier, as presented in Table VIII.

Table VIII: Relative importance-based ranks of the barriers

Barrier	Percentage	Rank
Low acceptance of the private sector involvement by the community	28%	1
Culture and values of the community	23%	2
Confidence of the government and political influences	15%	3
Low interest of the government because of the other priorities of the government	12%	4
Insufficient regulations	9%	5
Return on investment perspective of the private sector	8%	6
Low interest of the private sector	5%	7

Source: Table by authors

The relative importance of each identified barrier is shown in Table VIII as a percentage of the performance score. Accordingly, based on its resulting 28% relative weight, "Low acceptance of the private sector involvement by the community" was recognized as the most important barrier impacting the adoption and implementation of PPP in SI developments in non-urban areas. This barrier was not determined in the literature for PPP in SI developments. There was no discernible difference between the first and second ranks, and the barrier related to "Culture and values of the community" received the second highest weight (23%) in the analysis. This barrier was also a

novel factor recognized in this study for the area of PPP in SI developments in non-urban areas. There is a substantial gap between the relative weights of the second and third rated barriers (which was 15%), therefore it can be inferred that the local community is the primary obstacle retarding the growth of SI through PPP. Therefore, citizen-centric decision making would be a major strategy to overcome this obstacle. People are reluctant to embrace the involvement of the private sector, according to Interviewee 4 (I4), because they are concerned about potential instances of dishonesty or unethical behaviour. Banerjee et al. (2015) discussed the reluctance of citizens to accept private sector involvement in developing SI in general.

'Confidence of the government and political influences' and 'Low attention of the government because of the other goals of the government' are the third and fourth important barriers, respectively. That illustrates how crucial the government's efforts are, as a stakeholder. Governments need to be more sensitive to community demands and take measures to get rid of political influences on projects. Interviewee 2 (I2) outlined the significance of government initiatives in creating the necessary rules and regulations to facilitate the smooth implementation of PPP in the provision of SI. Selim and ElGohary (2020) have also pointed out this barrier in developing SI. The fifth place was inadequate rules. Private sector perspectives on return on investment and low interest rates have risen to positions 6 and 7, respectively. These barriers could be especially perceived as essential in developing PPP in non-urban areas.

The three lowest-ranked hurdles are not significantly different from one another, indicating that they have about similar effects on the acceptance and success of PPP in SI projects in non-urban areas. The private sector is typically more drawn to projects that give them a larger return on investment, according to Interviewee 1 (I1). As a result of rural communities' different means of subsistence and income levels from city dwellers, governments cannot ask them to pay for some services (if using a "user-pays" PPP model, even if subsidized by the government), so developing SI in rural and suburban areas will not yield a higher return. Therefore, in order to encourage participation in initiatives like SI, which the government is unable to manage on its own, extra incentives should be provided to the private sector.

The expert interviewees have also shared their opinions on how to overcome or mitigate these significant obstacles. Local job development is one of the most significant strategies listed by I1. In order to demonstrate an increase in income from the projects to the community in villages and

suburban regions, the experts advise developing a short-term strategy. This will make a positive impression on the community's mentality and make them more inclined to accept the private sector's contribution to the creation of the SI they require. I1 claims that this would result in a situation where everyone wins, including the public sector, the private sector, and the community. The expert interviewees noted that explaining the project's impact and how it will improve their quality of life is a crucial tactic. The need for project-centric contractual arrangements was acknowledged by all the experts. The community was also recognised as a crucial stakeholder in these projects and should be treated as such.

5. Conclusions

The COVID-19 epidemic outbreak and the culture of working from home have intensified the demand for enhancing the quality of life of communities in non-urban areas. Also, there are growing worries about the issues caused by fast urbanization and the underlying migration from villages to cities, and safety and health. Additionally, this would be in line with the United Nations' Sustainable Development Goals (SDGs), which recognized developing SI in rural regions as an important course of action. However, the inadequate funding and resources of the governments point to the significance of the private sector's participation in PPP initiatives. On the other hand, PPP acceptance and success in SI projects face challenges outside of urban regions. These obstacles are brought about by the public, corporate, and non-profit sectors. The most significant impediments were determined to be the community's low acceptance of the private sector and the distinct culture and values of those living in non-urban areas. The second important level of hurdles was found as less intense political drivers, activities, and the interests of many governments in developing non-urban areas and enhancing the quality of life of rural residents. The least significant hurdles have been determined to be the private sector's anticipated profit-drivers and their interest in developing non-urban areas.

Thus, it can be stated that SI advancements in non-urban areas can be implemented through PPP by developing the necessary capacity and educating the population living in the non-urban areas. Due to the potential low return on investment for the private parties participating in non-urban developments, incentives like tax benefits may be suggested for the private sector based on project performance, to attract even private organisations with proven good track-records in developing SI in urban areas. Clearly, there is a pressing need for more investigations in developed and

developing countries separately and the creation of assessment models for determining the acceptability and success rates of PPP in SI projects in non-urban locations. Planning for more research could be based on delving deeper into the findings of this study with the generation of any effective strategies for combating the identified barriers during implementation and expanding and strengthening the methodologies adopted herein for deriving better and more reliable results for reference. Due to the novelty of the research topic, the study was only conducted with 5 expert interviews. However, this restriction was alleviated by carefully selecting suitably knowledgeable experts and very appropriate and productive procedures for the analysis and production of what are seen as insightful consolidated results for reference and execution. The findings could be used as a solid basis to start more research in developing SI in non-urban areas, especially in developing countries, hence beneficial for the academics The findings of the study are useful for the industry practitioners as well. Relevant policy makers and decision makers could make good use of these findings to deliver SI in non-urban areas through successful PPP projects, possibly starting with a couple of pilot projects, moving to a few demonstration projects and then to wider deployment in suitable scenarios.

6. References

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