

Adoption of Public-Private Partnership (PPP) in smart infrastructure development projects in developing nations: An explorative structural equation modelling analysis

Abstract

The needs for smart infrastructure (SI) are increasingly evident, given the expanding imperatives of rapid-urbanisation, environmental difficulties, and worldwide pandemics. To pool diverse resources, Public-Private Partnerships (PPPs) are identified as a suitable procurement and delivery vehicle. However, there has not been much research on the factors affecting PPP procured SI developments in developing nations, particularly utilising quantitative methods. Hence, the purpose of this article is to evaluate the key-elements that contribute to PPP success in SI projects in developing nations, where satisfaction of the public-sector (S1), private-sector (S2) and end-users (S3) define the success of the project holistically. A literature review, expert interviews, a questionnaire survey and a case study were synergised to develop and validate the models illustrating the causal relationship between the affecting factors to S1, S2 and S3. The results indicate that S1 is greatly affected by technical and social factors, while political and legal factors mostly influence S2, and technical barriers affect S3. These insightful and detailed findings could serve as a good foundation for promulgating relevant government policies, informed decisions, and investigating the viability of PPP in developing nations in order to profit from and avoid potential difficulties associated with successful SI projects through PPP.

Keywords: Smart infrastructure (SI), developing regions/nations, “benefits & enablers” (B&E), “barriers” (BA), Public-Private Partnership (PPP), “recommended strategies & enhancing factors” (RS&EF)

Abbreviations: SI – smart infrastructure; PPP- Public-Private Partnership; B&E - “benefits & enablers”; BA - “barriers”; RS&EF - “recommended strategies & enhancing factors” PLBE – Political & legal B&E; TBE - Technical B&E; FEBE – Financial & economic B&E; SBE - Social B&E; SB – Social BA; FB – Financial & economic BA; TB – Technical BA; LSPB – Legal & socio-political BA; LREF – Legal & socio-political related RS&EF; TREF – Technical related RS&EF; SRF – Social related RS&EF; SREF – Stakeholder related RS&EF; FREF – Financial related RS&EF

1. Introduction

Every individual on this planet relies daily on various infrastructure. Infrastructure supports daily life by facilitating the movement of goods, information, and services in urban and regional areas. With the increased number of challenges associated with rapid urbanisation, both urban and rural environments are pressured to provide innovative and technology-driven solutions in better infrastructure development (Mattoni et al., 2020). Consequently, over the past decades, aspirations for smart cities and smart infrastructure (SI) have gained importance in academic discourse and international policymaking (Albino et al., 2015). This is due to the diverse and profound potential benefits of SI, including improved public health and safety, more liveable environments, energy savings, easier access, increased service quality and value, and enhanced maintenance management, which the world needs (Jayasena et al., 2021a; Ibrahim et al., 2018; Morimoto, 2010; Milenkovic et al., 2017; Bibri & Krogstie, 2017). As explained by Sharifi et al. (2024), developing SI has an impact on a better economic growth, improving efficiency and strengthening innovation. These benefits indicate that smart cities could catalyse the transition to sustainable development and address climate change challenges as well. Developing SI is therefore becoming increasingly necessary in order to drive smart urbanisation, since poorly planned infrastructure developments could also disturb and impair

natural ecosystems (Balmford et al., 2016). As urban densities tend to increase day by day, it is clear that SI development is a fruitful and timely topic for discussion.

Even though SI developments provide better benefits through their ‘smart’ enhancements, the development of SI encounters various challenges. Inadequate funding is the most significant barrier to the development of SI (Rana et al., 2019; Hojer & Wangel, 2015). Further, the variability in stakeholders, low involvement of citizens, limited knowledge and expertise and political vagueness constitute some other critical barriers (Veselitskaya et al., 2019; Vilajosana et al., 2013; Scuotto et al., 2016; Jayasena et al., 2021b). In the research of Spicer et al. (2019), the technology used for SI is prohibitively expensive and out of reach of the vast majority of smaller municipalities, which confront particular financial constraints in SI development. Tan and Taeihagh (2020) explained that although there is a growing demand for SI in developing nations, high development and maintenance costs, the scale and impacts of the informal economy, and a number of governance issues pose many obstacles. To overcome these challenges, involving public-private partnership (PPP) in SI projects have been identified as a viable solution in some previous works (Selim et al., 2018 and Jayasena et al., 2021a). PPP is considered as a strategy, which reduces risk and enhance public infrastructure, services, and project financing capacity (Luo et al., 2021; Ke et al., 2010; Tan and Zhao, 2019).

Indeed, PPP has been used as a strategy for developing conventional/ ‘normal’ infrastructure over the past decades. However, there are drastic differences between normal infrastructure development when comparing to SI development. SI development requires more technological resources and financial resources and also involves innovations, hence encounters more risk than conventional infrastructure developments (Rice & Martin, 2020; Jayasena et al., 2023). By communicating across various components of physical infrastructure, SI can manage data, make sense of it, and make smart decisions (Birgisson, 2020). Considering these differences

between SI and normal infrastructure developments, the application strategies and the project success might differ significantly from PPP involved normal infrastructure developments. Therefore, these differences inspired this study to research into the application and success factors affecting PPP in SI development projects. Moreover, research focusing on PPP-procured SI projects in developing countries were also limited. Tan and Taeihagh (2020) have conducted a literature review based for developing countries, which is on governing smart cities. Milenković et al. (2017) investigated the application of PPP for developing smart cities in Croatia, while Anwar et al. (2017) conducted a study, in the South-Asian region, on the application of PPP in sustainable urbanisation. These clearly indicate that more focus should be placed on research into the development of SI in developing countries. Therefore, this inadequacy of research studies, which have applied quantitative research using empirical data in this research area, especially in developing nations, motivated this study as well. Curating a foundation based on which the PPP success in SI in developing nations could be investigated was deemed a precursor and a viable need. Hence, investigating how different factors affect the success of PPP-procured SI developments was a fruitful area, which should help bridge the above-mentioned research gaps. Consequently, the aim of this study was to assess the influencing factors of PPP success in SI projects in developing nations. In this study, the categorisation provided in United Nations Human Development (UNDP) Report 2020 was used to identify developing nations. The UNDP's country classification system is based on the Human Development Index (HDI), while the developed countries are countries in the top quartile of the HDI distribution and those in the other quartiles are considered as developing countries.

The research question of the study reported in this paper, was formulated as:

What are the principal factors underpinning success in SI developments in developing nations and how are they affecting success?

“Benefits & enablers” (B&E), barriers (BA), and “recommended strategies & enhancing factors” (RS&EF) were identified as the most frequently used factors in evaluating the success of a project as far as research in construction management is concerned (e.g. Jayasena et al., 2022; Darko et al., 2018), so the same framework was adopted to assess PPP success in SI developments in developing nations. Next, developing a criterion for measuring PPP success in SI projects was carried out. For a PPP project to succeed, stakeholder satisfaction is non-negotiable. This was corroborated by Liu et al. (2015a) who averred that stakeholder satisfaction is a crucial performance measurement factor for PPP projects’ success. In the same vein, multiple researchers stressed the importance of stakeholders’ satisfaction in evaluating PPP project success (Yuan et al., 2009; Mladenovic et al., 2013 and Liu et al., 2015b). It is thus widely acknowledged that the satisfaction levels of stakeholders in the public sector, private sector and end-users are of utmost importance for the successful adoption and implementation of a PPP initiative. These criteria were therefore used to evaluate the progress of PPP arrangements in executing SI initiatives. The study primarily examined the factors that influence the successful execution of SI projects using PPP arrangements in developing countries. For this, the study focused on three constructs for measuring success: the public, private and end-users’ satisfaction being S1, S2 and S3 respectively.

The above approach leads to the following contributions to the body of knowledge as presented in subsequent sections of this paper:.

- (1) Proposes a robust and exploratory SEM framework for assessing PPP success in SI developments in developing nations;

- (2) Illustrates the internal relationships of the essential determinants influencing PPP success in SI initiatives; and
- (3) Produces useful insights through the analysis of the B&E, BA and RS&EF affecting PPP success in SI projects, which ultimately broadens the existing practices and knowledge of SI development through PPP in developing nations.

2. Literature Review: Current status of PPP application in smart infrastructure developments

2.1 Importance of smart infrastructure and the differences between smart infrastructure development and normal infrastructure development

People are flocking to cities in search of better living conditions, and technological progress is a key component in creating these high-tech smart cities that can keep up with their residents' constantly evolving wants and needs (Stamopoulos et al., 2024). As Tan and Taeihagh (2020) explain, many cities in developing nations face difficulties in meeting infrastructure demands, but the concept of SI development permits to address these issues by delivering innovative approaches in terms of the two aspects of quality and quantity. Busy lifestyles of the society have increased the needs for infrastructure that can better adapt to changing needs, e.g., by reducing traffic jams by reversing the direction of some traffic lanes. These need automatic monitoring and control, easy operation and maintenance, tracking and networking and such needs have led to the rise of developing SI.

Further, the demand for SI has grown with the current pandemic situation as well to enhance public health and safety through the application of advanced technological applications, rather than relying on conventional infrastructures (Al-Humairi & Kamal, 2021; Costa & Peixoto, 2020). Examples include using smart applications such as COVID-19 real-time monitoring systems with AI applications for tracking and identifying the suspected cases, AI technology

to improve the management of hospital treatments and high-performance infrared thermal cameras in public spaces to monitor the temperatures of people. More importantly, SI could be used for abnormal behaviour monitoring of patients, disease prevention and diagnosis, clinical decision-making, etc. This research focused on physical SI (or more precisely SI for physical infrastructure, like buildings, roads, power plant and water and waste water schemes) and is defined as “a physical system based on integrated value-adding applications of modern technologies that may include, for example, automation and robotics and cyber-physical advances based on ICT, big data, artificial intelligence and sensor-generated feedback to aid ‘intelligent’ control of facilities and/or services delivery systems”.

Before considering the adoption and success of the use of PPP in providing SI in developed countries and developing countries, it is important to analyse the status of PPP adoption in the provision of conventional/ ‘normal infrastructure’. Here, normal infrastructure is defined to be infrastructure that does not use advanced technological applications e.g., artificial intelligence and sensors, and cannot control or make intelligent decisions without outside input. SI requires more expert knowledge and experience in its delivery than what is needed in conventional infrastructure development as, SI is based on advanced technological applications, which can intelligently control the facilities and/or services delivery systems. According to Albino et al. (2015) among others, ICT advances could be applied to enable rapid if not instant feedback and communications, even linked to automated controls e.g., based on embedded sensors and cameras; and processing of vast amounts of real-time data for better decision-making in smart cities, indicating how SI can make life simpler and better. SI projects are complex, politically contentious, and difficult to execute (Berglund et al., 2020; Offenhuber & Schechtner, 2018). Governments make their largest financial commitments in these projects. However, these projects are fraught with more economic uncertainty, public versus private distributional issues, and environmental considerations.

2.2 Application of PPP in smart infrastructure developments

Public-private partnerships (PPPs) have been used over the past 20-30 years by governments in developed countries to finance infrastructure projects to meet public demand for services such as, for example, new road networks. In the last decade, this has been broadened to include capital projects such as schools, water reclamation schemes, hospitals and prisons, infrastructure traditionally managed within government capital budgets.

Advantages of PPP in developing SI include sharing tasks, risks, responsibilities and resources in an efficient manner to cater the technologically advanced applications, which provide better standards of living (Siokas et al., 2022). PPP enables harnessing of hitherto untapped synergies from particular strengths of private and public sectors that can compensate for the weaknesses of the other in certain aspects. Furthermore, SI projects involve many stakeholders as a result of complex technological applications associated in the development rather than normal infrastructure development. According to Grossi and Trunova (2021), a wide variety of stakeholders are involved in smart city projects, although the specific responsibilities of these stakeholders as well as the level and type of their involvement can differ. These illustrate the importance of partnerships to pool the resources of private and public parties in developing SI.

Smart city initiatives have been researched and developed extensively in developed countries while, in most developing countries, smart initiatives are yet to be developed (Vu & Hartley, 2018). This is mainly because of the financial barrier. However, there are successful examples of the development of smart city initiatives in developing nations like China, India, Vietnam and Croatia, that have benefitted from PPP. Dolla and Laishram (2018) discussed factors affecting the PPP involved SI developments in India. Nguyen and HaDuong (2009) also discussed the application of PPP in the context of Vietnam. Milenkovic et al. (2017) showed PPP to be a high potential solution for developing SI in Croatia.

The original primary driver for PPP, as identified by the previous research work is the promising mechanism for attracting private capital and resources, while having more efficient project and risk management. PPPs allow governments to build infrastructure without raising taxes or borrowing money right away (Khmel, & Zhao 2016). In addition, the usage of PPP is a strategy for boosting the economic value of infrastructure outputs that may be applied to a diverse spectrum of public-sector infrastructure (Cui et al., 2018). Moreover, there are advantages of PPP in infrastructure development projects in boosting public sector efficiency, resulting in better value for money; transferring certain risks to the private sector; leveraging or mobilising private sector expertise and managing capacities; and allowing the public sector to concentrate on strategy rather than operational management (Cruz & Sarmiento, 2017).

Different factors affecting the use of PPP in providing normal infrastructure were also identified through the literature review other than the factors affecting SI developments that involved PPPs. For example, Kwak et al. (2009) identified the importance of legal and regulatory background, favourable investment climate and importance of policies for PPP in normal infrastructure developments. Zhang (2005) also identified the effect of tax benefits and risk sharing for the success of PPP. Ibrahim et al. (2006) discussed stakeholder complexities, unethical practices and challenges in management, which affect the adoption and success of PPP in infrastructure developments. These factors, which were identified from the literature review, were also considered in finalising the factors affecting the success of SI developments involving PPPs, in addition to the findings of the expert interviews and the questionnaire survey.

3. Development of the Research Framework and Hypotheses

3.1 Research Framework

A research framework provides a foundation or model that guides the collective research efforts (Agherdien, 2007; Simon & Goes, 2011), which can be founded on theory and/or logic and is essential for producing new knowledge. The research framework for this study is grounded in both theory and logic. The models were developed using PLS-SEM modelling, which consisted of two phases: first, a measurement model that quantifies the connections between the variables that are latent and their observed variables; and second, a structural model that indicates the connections between the latent variables.

The hypothesised research framework is shown in Figure 1. PPP success in SI development initiatives in developing nations was measured using 3 criteria, which are the satisfaction of public, private and end-users' represented by S1, S2 and S3 respectively.

[Figure 1: Hypothesised research framework for the study]

3.2 Research Hypotheses

This study focuses on three broad factors, which are 'B&E', 'BA' and 'RS&EF' and explores their implications on PPP adoption and success in SI. A three-step procedure was followed to identify the criteria for measurement for these three broad factors. During the first phase of the project, through a literature review and 20 expert interviews, the final set of factors affecting were identified and they were grouped as per the opinions of the experts. The factors which were identified through the literature review were validated through the afore-mentioned expert interviews. Four categories were derived from the identified 23 B&E: 'Technical,' 'Social,' 'Political & Legal,' and 'Financial & Economic'. 36 BA factors were categorized into four distinct groups: 'Financial & Economic,' 'Legal & Socio-Political,' 'Social,' and 'Technical,'. Similarly, 25 RS&EF were classified into; "Legal & Socio-Political," "Stakeholder," "Social," "Technical," and "Financial." To examine the effects of these constructs and measurement items on the PPP arrangements success in executing SI in

developing nations, the 13 constructs mentioned above for B&E, 'BA', and 'RS&EF' are depicted in Figure 2 below.

[Figure 2: Proposed constructs and their associated measurement items]

Expert interviews and the literature review revealed that BA could have an adverse impact on the S1, S2, and S3 satisfaction. The advent execution of SI via PPP arrangements are encouraged by B&E and RS&EF, which has a positive effect on S1, S2, and S3. These observations led to the following research hypothesis presented in Figure 3.

[Figure 3: A series of research hypotheses established for the study]

Figure 4 illustrates the hypothetical model. The study's hypotheses will be tested, and the outcomes of the research will aid scholars gain a deeper appreciation for the ways in which S1, S2, and S3 can influence the PPP arrangements in the execution of SI projects. Even though the hypothetical model of the research study is presented in one figure (Figure 4), three (3) separate models were developed to focus on each of the three (3) categories, B&A, BA and RS&EF to minimise any apparent complexity in examining only one model.

[Figure 4: Hypothetical model of the research study]

4. Research Methodology

4.1 Research Approach

As stated by Sandelowski (2000), mixed-method research is described as a “dynamic option for expanding the scope and improving the analytic power of studies” (p.254). To compensate for the shortcomings of each approach and to provide a detailed understanding of the research problem, mixed research approach was adopted in this study.

4.2 Data collection

Initially, a literature review was conducted, this being followed by a set of expert interviews. A pilot survey was then conducted. Next, a questionnaire survey of relevant participants from developing countries was conducted. Finally, a case study was carried out in order to validate the developed models. Subsequently, a global questionnaire survey was conducted among experts in PPP and/or SI developments in developing nations.

4.2.1 Literature review

According to Grant and Booth (2009), an examination of recent or current published literature will be carried out in a literature review to cover a wide range of papers at various levels of completeness and comprehensiveness. Hence, a literature review was initially carried out to explore the concepts of a SI, PPP and the role of PPPs in SI development in developing regions/nations. Suitable case examples were also explored. Further, the factors affecting the success of PPP involved SI developments were explored through literature.

4.2.2 Expert interviews

In research related to construction management it is a common technique to use interviews to gather qualitative data on practitioner opinions, attitudes, skills, and best practices (Hansen, 2021). As explained by Adams (2015) and Adeoye-Olatunde and Olenik (2021), semi-structured interviews are appropriate if the researchers need (a) to conduct some in-depth exploration before designing large-scale surveys; (b) to configure focus group agendas; (c) to construct overall research strategies; or (d) to explore unclear situations or findings that emerge (or remain) after the analysis of the survey data or focus group findings. Therefore, after the literature review, a set of semi-structured interviews were carried out among relevant experts in Sri Lanka (a developing nation) to investigate the parameters influencing the project success of SI development with PPP involvement programmes in developing nations before moving on to the international questionnaire survey.

In this study, the expert interviewees were selected utilising the snowball sampling technique under non-probability sampling technique. Data saturation occurred after the ten interviews, given the limited number of projects in this SI and PPP domain in Sri Lanka. The interview process was thus successfully concluded in this domain with the ten interviews as further interviews with less knowledgeable persons and/or on less relevant projects would not have added value to the findings. Data saturation has emerged as a crucial concern in the context of interview techniques, as it directly impacts the quality of the resulting data (Hansen, 2021). The term “saturation” is described as the stage where no additional pertinent information is obtained, even with further interviews (Galvin, 2015). Data saturation is a frequently used reason to justify the number of interviews (Hansen, 2021). Hence, the number of interviews conducted can be justified in this study domain. Further, the extensive and in-depth experience of the interviewees was also taken into account to validate the quality of the interviewees. The selected ten expert interviewees had more than 9 years’ experience in the areas of PPP and SI developments in Sri Lanka. Among the selected interviewees, 5 had experience in the relevant areas for more than 20 years. Table 1 presents the profile of the expert interviewees.

4.2.3 Pilot Survey

Combining the findings of the literature review and expert interviews, a list of factors was identified and categorised, which affect the project success of SI developments involving PPP. These factors were validated using a pilot survey before the main questionnaire survey, which comprised of a set of five expert interviews in Sri Lanka (being a developing country).

4.2.4 Questionnaire Survey

The next step was conducting the questionnaire survey. The sample of respondents included experts in PPP and/or SI developments in developing nations. The questionnaire was divided into six separate sections. The objectives of the study were explained in the first section of the

questionnaire, and respondents' background information, were gathered in the second section. Respondents were asked to rate the relevance of S1, S2, and S3 as well as the measurement items of B&E, BA, and RS&EF. The measurement items were evaluated by the respondents using a five-point Likert scale. A five-point Likert scale was used because despite the advantages of a seven-point or nine-point Likert scale in certain scenarios where greater differentiation is warranted; in scenarios like the present, where broader overviews are more useful, the expanded range of choices could potentially lead to survey fatigue, as participants may perceive it as a time-consuming and cognitively demanding task to navigate through several possibilities. Therefore, by using seven-point or nine-point scales may lead to low quality results and less responses. A five-point Likert scale was a very commonly used scale in the research related to construction management and PPP (e.g. Owusu-Manu et.al., 2021; Malek & Bhatt, 2023; Chileshe et al., 2022). Research, which used SEM for developing models, used the five-point Likert scale commonly as well, as in Jayasena et al. (2022), Darko et al. (2018), Ekanayake et al. (2021), Tripathi and Jha (2018) and Siokas et al. (2021). Hence, the five-point Likert scale was used in this study.

Academics and industry players with some considerable level of experience and knowledge in PPP and/or SI in developing nations were included in the survey population. Convenience and snowball sampling strategies were utilised in this survey under non-probability sampling to obtain a representative sample size, as in earlier construction management studies by Ahmadabadi and Heravi (2019), Darko et al. (2018), Zhang et al., (2011), and Mao et al., (2015).

Accordingly, 250 questionnaires were distributed. Eventually, 104 completed questionnaires were returned. Hence, the response rate was 41.6%. However, only 100 questionnaires were used in the analysis as there were 4 incomplete questionnaires. Table 1 displays the respondent

profiles of the expert interviewees and the survey respondents. The analysis of the profile of the respondents of the survey reflected in Table 1 below highlights that only experienced professionals responded to the questionnaire, which provides validity to the set of collected data. An equal number of respondents from both the public and private sector were also recorded. These respondents represented 7 developing nations (Sri Lanka, India, Pakistan, Nigeria, Ghana, Iran and Malaysia). The respondents were from these 7 developing nations because, the sampling methods adopted in this study were convenience sampling and snowball sampling. This may be considered a limitation of this study, which was due to time and budget constraints. However, these 7 developing nations are very prominent in the application of PPP in SI and provided sufficient and representative findings for this study. According to Dykes and Jones (2016) and Osei-Kyei and Chan (2016), PPPs are timely for the governments in the Sub-Saharan countries like Nigeria and Ghana where there are more potentially useful applications of PPP for infrastructure developments at this time. A similar view was presented by Sharma (2023) for Asia Pacific countries like Sri Lanka, India, Pakistan, and Malaysia. Hence, it is confirmed that the countries from which data was collected, do apply PPP on a large scale for developing infrastructure and the respondents have sufficient experience in the application of PPP in SI and normal infrastructure developments as confirmed in Table 1 too.

[Table 1: Profile of expert interviewees and survey respondents]

4.2.5 Model validation

The models were validated quantitatively using the parameters presented in section 5.1, while a qualitative validation of the developed models was also carried out in this study. According to Liu et al. (2014), the trend of using case studies to validate research conducted under construction topics has gradually increased. Therefore, a case study, which deployed PPP in delivering SI in a developing country (Colombo, Sri Lanka) was selected to validate the

developed models. A single case study was selected not just because of the limited availability of PPP involved SI developments in developing regions/nations, but as this particular case is a good example that conveys various aspects of the issues that emerge and how they may be dealt with. This case study project pertains to delivering a smart mini-city (a 'port city') using PPP and is a crucial component of China's Belt and Road Initiative (BRI), hence one of the flagship projects in this mega-programme, apart from being of great significance to Sri Lanka. The project is worth USD 1.4 billion and spans 269 hectares of reclaimed land from the sea.

Semi-structured interviews were conducted to gather data from the case study among the experts involved in the PPP-based SI development project. The selected respondents from the case study were interviewed according to a semi-structured interview guideline, which consisted of three (3) sections. In Sections A and B, the background information of the interviewees and the details of the project were captured consecutively. The expert interviewees, who participated in the case study includes a project mechanical, electrical and plumbing (MEP) manager (I1), who has gained experience for 17 years, a project architect (I2) with 12 years' experience and a town planner (I3) who has acquired experience for 11 years. The identified B&A, BA, RS&EF and the developed models were validated, and further improvements required for the model were gathered from Section B. Moreover, the applicability of the developed models and expert views on the applicability of the factors identified for the success of SI development projects involving PPP, were also investigated with reference to the case studies.

4.3 Data Analysis

The data captured through the expert interviews were analysed using the content analysis technique while structural equation modelling (SEM) method was utilised in this study to analyse data gathered through the questionnaire survey. As a prominent multivariate statistical

tool, SEM has gained a lot of prominence (Xiong et al., 2015). Also, as a general linear model, SEM technique is used to examine relationships between dependent and independent variables. SEM analyses the structure of interactions between variables by combining factor analysis, multiple regression analysis, and path analysis (Hair et al., 2019; Ullman, 2006). These variables can include both observed or unobserved variables. Because the benefits of SEM include calculating a large number of interconnected dependencies, there has been a rise in the application of SEM in the context of construction management investigations (Li et al., 2020; Darko et al., 2018; Ekanayake et al., 2021; Hon et al., 2014; Seo et al., 2015; Zahoor et al., 2017; Chen et al., 2012). Therefore, for this particular study, SEM was chosen as the most suitable method to draw inference and appreciate the data. Given its versatility (Sarstedt et al., 2014), PLS-SEM was used in this work to do both exploratory and confirmatory research aimed at making predictions. In addition, Hair et al. (2019) elucidated that PLS-SEM is suggested while working with a small sample size.

The sample size used in this study was satisfactory as the recommended sample size to satisfy the central limit theorem is 30 (Darko et al., 2018; Ott and Longnecker, 2010). Furthermore, because SI advancements have yet to be broadly embraced in developing nations, the number of experienced people in this field is limited, so the ‘population size’ is small. According to Hair et al. (2019), a “PLS-SEM minimum sample size should be equal to the larger of the following: (1) ten times the largest number of formative indicators used to measure one construct or (2) ten times the largest number of structural paths directed at a particular latent construct in the structural model” (p.144). However, this method can produce erroneous estimations of the minimal sample size (Kock and Hadaya, 2018; Goodhue et al., 2012). Hence, the minimal R-squared technique (the coefficient of determination) was adopted in this study to validate the number of samples. Hair et al. (2014) explained that the sample can be validated based on reliability if the R-squared value is more than 0.3. Based on this, the number of

responses selected for this analysis was validated. Several studies have employed a SEM technique with a lower sample size than necessary to confirm their own structures, such as (Ozorhon et al., 2010; Yuan et al., 2011 and Ahmadabadi & Heravi, 2019). As explained by Kock and Hadaya (2018), smaller sample sizes can be used in applying PLS-SEM, if a researcher knows in advance that all 'the path coefficients of a model will be strong, resulting in large effect sizes.

5. Research Findings and Discussion

The results of the PLS-SEM analysis are reported in this section. Three models were built, based on the B&E, BA, and RS&EF,

5.1 Evaluation of measurement models

The factors, which were considered in evaluating the measurement models of B&E, BA, and RS&EF are included in Table 2. Cronbach's alpha, Rho A, Composite reliability, and AVE were used to evaluate the validity and the reliability of the constructs in the three models.

[Table 2: Constructs` reliability and validity measures of the developed models]

Variables that recorded factor loadings less than 0.5 were eliminated in all 3 models as explained in Liu and Wang (2020) to improve the models' reliability and validity. A rerun was then conducted to generate a more accurate and reliable models. Since reflected measuring is used primarily in this study, a strong correlation among the constructs is seen. According to Hair et al. (2014), in such cases, the general meaning of the construct can be preserved even if some of the metrics are left out. Nunnally (1978) therefore proffered that items with low factor loadings have insignificant influence on the model's explanatory power and may even produce erroneous estimates. Accordingly, PLBE 8 and FEBE 2 were removed from the B&E model,

FB 2, FB6, LSPB 4, LSPB 11, LSPB 12, SB 6, TB 2, TB 3 and TB 7 were removed from the BA model and SRF 2 was removed from the RS&EF model.

The coefficients recorded in these models were all greater than or close to 0.70 which is deemed satisfactory. Considering the AVE, it can be determined that the constructs' convergent validity is also satisfactory. Exhibiting a 50% of the variance in the measurement items, all factor loadings and AVEs are greater than 0.50. This is also an accepted level, which demonstrates reliability of the measurement items.

Table 3, 4 and 5 shows the constructs' discriminant validity of the developed models.

[Table 3: Discriminant validity of the constructs of the B&E model]

[Table 4: Discriminant validity of the constructs of the BA model]

[Table 5: Discriminant validity of the constructs of the RS&EF model]

Each latent construct's AVE value was higher than its maximum squared correlation with another construct, as indicated in Table 3, 4 and 5. The inference was that the Fornell-Larcker criterion was met. It was also established that the constructs had discriminant validity since the cross-loadings were lower than the factor loadings for each construct. These criteria, as mentioned above, mean that the reliability and validity of the measurement model are satisfactory.

5.2. Evaluation of structural models

The results of the bootstrapping (a statistical technique that involves resampling a single dataset to generate several simulated samples) for the B&E, BA and RS&EF structural models are presented in Table 6, as well as the distinction between S1, S2, and S3, since the constructs are indeed found to affect different stakeholders to varying degrees, as hypothesised in Fig. 3.

[Table 6: Bootstrapping results for the models]

The t-values for the pathways 'FEBE and S1', 'PLBE and S2', 'PLBE and S3', 'SBE and S1', 'TBE and S1', and 'TBE and S2' in Table 6 were higher than 2.56. The inference was that these relationships are significant at the 0.01% threshold of statistical significance. Consequently, it also meant that HE2a, HE1b, HE1c, HE4a, HE3a, and HE3b were appropriately supported. The t-value for the path linking SBE and S3 is greater than 1.96, depicting statistical significance at the 0.05 level. This meant that HE4c was well-supported as well. A high route coefficient indicates a more significant relationship between the variables (Darko et al., 2018; Aibunu and Al-Lawati, 2010). In that regard, the path between 'PLBE and S3' is the strongest link. The insignificant links are depicted by dashed lines in Figure 5. The R^2 values of the dependent variables were higher than 0.3 in the B&E model, thereby supporting the model's quality and prediction accuracy.

Examining the BA model t-values, six paths had t-values greater than 2.56. Those paths are LSPB- S1, LSPB- S2, SB- S1, SB- S2, and TB- S3. Consequently, HB2a, HB2b, HB3a, HB3b, HB3c, and HB4a received the necessary support. The pathway that links FB and S3 exhibits a t-value exceeding 1.96, thereby signifying statistical significance at the 0.05 level. Consequently, HB1c was also supported adequately. The strongest path can be seen between LSPB and S2. Figure 6 illustrates the insignificant paths with dashed lines. The model's quality and prediction accuracy may be further substantiated, since the R^2 of the dependent variables was more than 0.3.

The t-values of the RS&EF model, for the paths of the connecting FREF to S2, FREF to S3, LREF to S2, LREF to S3, SREF to S1, SRF to S3, and TREF to S1 were all greater than 2.56. This suggests that these paths are statistically significant at the 0.01-percent significance level. Consequently, the hypotheses HR5a, HR5b, HR2b, HR2c, HR1a, HR4c, and HR3a

were supported. The path connecting SRF to S2 and TREF to S3 also recorded a t-value greater than 1.96, indicating statistical significance at the 0.05 level. Therefore, HR4b and HR3c were adequately supported. Notably, the strongest path is observed between TREF and S1. The insignificant trajectories are visually represented in Figure 7 using dashed lines. Furthermore, the R² values of the dependent variables, which exceed 0.3, provide additional confirmation of the model's quality and predictive accuracy.

The resulting PLS-SEM model of the B&E, BA and RS&EF are shown in Figure 5, 6 and 7 respectively.

[Figure 5: B&E model]

[Figure 6: BA model]

[Figure 7: RS&EF model]

6. Model Validation (Findings of the Case Study) and discussion of the results of the models

In this section, initially, the findings of the developed models are discussed and next, validation of the three (3) developed models for developing regions/nations are discussed in three respective sections. Model validation was discussed in three (3) separate sub-sections explaining how the factors affect S1, S2 and S3. The numbers provided within brackets in each subsection below represent the t-value obtained from PLS-SEM analysis for each respective instance.

6.1 B&E for adopting PPPs in smart infrastructure development projects in developing nations

6.1.1 Evaluation of the Findings of the B&E model

The findings for B&E are summarised in Table 7 according to the impact on S1, S2 and S3 in developing nations. Important factors impacting S1, S2, and S3 are highlighted in Table 7.

[Table 7: Summary of the findings for B&E]

Considering S1 in a developing country, "technical B&E" (TBE) has been identified as the most influential factor. The effect of "financial and economic B&E" (FEBE) on S1 is also apparent, and this consequentially affects the acceptance and success of PPP in SI initiatives in developing countries. Given the limited technical competence and funds within the public sector, it is also evident that TBE and FEBE serve primarily as B&E for S1. As explained by Siokas et al. (2022), as SI required advanced technological applications, incorporating PPP would benefit the public sector as the private party is more upfront in introducing new technology to the field. The importance of FEBE for the public sector, which can be gained through pooling resources with the private sector was also discussed in Lam and Yang (2020). Further, it was observed that "social B&E" also has a considerable impact on S1. Nevertheless, it is evident that the "political and legal B&E" will not have a significant impact on S1, as they may not require any "political and legal B&E" (PLBE) to embrace PPP in SI developments, as they already have the authority.

It is obvious that the PLBE have a major influence on S2, which has significant implications for the widespread use and successful outcome of PPP in SI development activities in developing countries. This is probably due to the fact that private companies are eager to obtain PLBE for their projects while simultaneously meeting a public need. This factor was also notably mentioned in Castelblanco et al. (2022). The TBE has the second-highest impact on S2, while the SBE and FEBE have no significant impact. This can arise from the private sector already having the capital to create and carry out the kinds of projects that PLBE mandates. It can be determined that the PLBE have a considerable influence on S3, while the

SBE have the second highest influence. On the other hand, FEBE and TBE have no substantial effect on S3. This may be because end-users are more interested in PLBE because PLBE are required for project execution, while they also require SBE.

6.1.2 Model Validation: Findings of the case study

Public sector satisfaction (S1)

The expert interviewees from the project mentioned that “financial and economic B&E” is the most significant category, which affects S1. However, it was explained that “technical factors” also affect S1 as the government and public sector organisations do not have the required technical-know-how to develop SI. According to I3 “many public sector organisations are not familiar with advanced technological applications and how to manage them in developing SI generally in developing nations”. This provides validation for the developed PLS-SEM model presenting the causal relationship between B&E and S1 as there is no significant difference between the technical ‘benefits & enablers’ (t-value = 4.506) and financial and economic B&E (t-value = 4.216).

Private sector satisfaction (S2)

“Political and legal B&E” were determined by the expert interviewees as the most significant category for S2. This validates the causal relationship between S2 and the B&E in the developed PLS-SEM model for B&E as they also present “political & legal B&E” (t-value = 5.442) as the most significant category among the B&E affecting S2. This is because the private sector is looking for a favourable work environment in a PPP contract in the host country. As explained by I1 “private sector mainly looks at the political stability and the political views about PPP in the country to avoid political challenges in the future”. Moreover, the experts mentioned that the private sector looks more carefully into the “political B&E”, especially in

SI developments in developing nations as there may be more risks inherent in such developments compared to traditional infrastructure developments.

End-user satisfaction (S3)

The interviewees explained that the citizens in developing nations are more interested in projects with useful outcomes similar to those in developed nations. According to I2, “the end-users in developing nations like the benefits that they receive from the development projects”. Hence, the citizens tend to look at the best political environment to gain more development improving their quality of life. Further, this reflects the importance of “social B&E” for the citizens or the end-users. Therefore, the PLS-SEM model developed illustrating the relationship between B&E and S3 in developing nations can also be deemed validated, since “political and legal B&E” (t-value = 12.898) and “social B&E” (t-value = 2.453)’ were identified as the most significant categories affecting S3 in developing nations.

6.2 BA to adopting PPPs for Smart Infrastructure Development projects in developing nations

6.2.1 Evaluation of the Findings of the BA model

Table 8 provides an overview of BA results for developing countries based on its effect on S1, S2, and S3. Measurement items of the BA identified in this research were found to be significant given that they all had a substantial impact on the model's constructs. Significant parameters impacting S1, S2, and S3 are highlighted in Table 8.

[Table 8: Summary of the findings for BA]

Social barriers (SB) were identified as most influential factor category affecting S1 satisfaction in developing countries. This implies that citizens should always be considered vital project

stakeholders by the public sector. According to Staletić et al. (2020), citizens are considered as an important part of the development of smart initiatives. Hence, the government or the public sector cannot ignore the barriers raised by the general public. The second paramount influential factor category was legal and social-political barriers (LSPB). S1 was not affected by technical and financial hurdles, which will have an influence on the success of PPPs in SI projects in developing nations.

Regarding S2, it is evident that LSPB makes the most difference. Several LSPBs, such as an unstable legal PPP structure, hurdles to transferring management control of assets and/or repatriating finances, and frequent policy shifts all play an integral part in this phenomenon in a developing country. Muleya et al. (2020) also explained a similar perspective in their study on the application of PPP in Zambia, which is also a developing nation. Similar to S1, it is evident that SB has a significant impact on S2 as well. This can be expected as citizens are a principal category of stakeholders in a SI project. It was also revealed that TB had the greatest impact on S3. This may be due to the TB in the use of SI, and if there are a large number of TB, the project will fail, negatively impacting S3. Mondschein et al. (2021) also viewed smart cities as largely technology-intensive centres, where citizens require the technical knowledge to handle the developed SI. Although SB and FB were shown to have a significant effect on S3, it was deduced that LSPB had little to no effect on S3. This was to be expected, since public and private sector end users are not required to take LSPB into account in their operations.

6.2.2 Model Validation: Findings of the case study

Public sector satisfaction (S1)

When considering the BA, the experts from the project mentioned that there are many “social BA” affecting S1 was raised in their project. The experts explained that BA arose because of the involvement of a foreign party as the investor and because of the development being carried

out by that party as well. Hence, it is clear that “social BA” arise in developing SI through PPP. According to I1 “the citizens do not know the advantages that they receive because of the involvement of the private partner in the project”. Moreover, the experts mentioned that there are some “legal and political BA” as well in the system of their project as well. This was mainly because of the political instability. Therefore, the experts validated the PLS-SEM models developed for the BA affecting S1 in developing nations as it was identified that the “social BA” influence the most (t-value = 4.000) while, “legal and socio-political BA” (t-value = 3.637) is the next factor category to affect S1.

Private sector satisfaction (S2)

Through the case study, “legal and socio-political BA” were determined as the main factor category among the BA influencing the private sector. The private sector interviewee who participated in the case study interviews mentioned that there are many “legal and political BA” affecting S2. These BA included political instability, political influence and unavailability of rules and regulations in overcoming the political volatility in the projects. Moreover, this interviewee explained that there are “social BA” to the project affecting S2 as well, which arise due to the lack of knowledge among the citizens about the advantages of the project and the use of PPP in the development. Therefore, the experts validated the PLS-SEM models developed for the BA affecting S2 in developing nations as it was identified that the “legal and socio-political BA” (t-value = 11.880) influence the most and secondly, “social BA” (t-value = 3.208) affect S2.

End-user satisfaction (S3)

The expert interviewees believed that the end-users do not have the required technical know-how to operate or use the developed SI in a developing country. Hence, the experts confirmed that “technical BA” affect S3, especially in SI developments. Further, the interviewees

explained that the “social BA” also influence S3 as there can be some parties who are triggering public protests without any valid reasons. Hence, the experts mentioned the importance of the correct flow of information directly from the developers to the end-users. Explaining the above, the experts validated the PLS-SEM models developed for the BA affecting S3 in developing nations as it was identified that the “legal BA” (t-value = 9.020) influence the most and secondly, “social BA” (t-value = 3.018) affect S3 in developing nations.

6.3 RS&EF for improving PPPs in delivering smart infrastructure in developing nations

6.3.1 Evaluation of the Findings of the BA model

Table 9 highlights the RS&EF results for developing countries based on the effect on S1, S2, and S3. The measurement items of the BA identified in this research were found to be reliable since they all had significant effects on the model's constructs. The highlighted positions in Table 9 reveal the most influential factors of S1, S2 and S3.

[Table 9: Summary of the findings for RS&EF]

Under the RS&EF, it is evident that TREF and SREF affect S1 more substantially. PPP arrangements are more likely to be effective and have a positive impact on S1 if they undergo periodic high-level reviews and corrective measures throughout the project's entire delivery process, if minimum functional needs are defined with the appropriate technical specifications, and if contracts are organised, fair and enforceable, for example, SREF have the second largest impact on S1, which emphasises the significance of managing stakeholders in PPP developments. As explained in the Literature Review, there are many stakeholders involved in SI developments (Ferraris et al., 2020). Regarding S2, LREF is the most influential factor. This is because the private sector is increasingly cognisant of relevant legal factors and their

implications. In addition to LREF, FREF and SRF have an impact on S2. LREF is the most significant construct influencing S3, while all other constructs also have a significant impact on S3. This indicates that the S3 will rely on each identified construct.

6.3.2 Model Validation: Findings of the case study

Public sector satisfaction (S1)

“Technical related RS&EF” were identified as the most significant factor affecting S1 in developing nations by the expert interviewees. The experts explained that it is required to improve the specifications in the contracts and to do the bidding procedure more transparently. According to I1 “if the contracting process is more transparent there will be fewer problems in handling the public protests due to the involvement of the private sector”. Moreover, disseminating required knowledge and proper communication with the public, which are related to social factors, was also identified as important for the success of the project. Therefore, the experts validated the PLS-SEM model developed for the RS&EF affecting S1 in developing nations as it was also identified that the “technical related factors” (t-value = 8.579) and “social related factors” (t-value = 3.577) significantly affect S1.

Private sector satisfaction (S2)

For S2, the expert interviewees explained that “legal and political RS&EF” affect it the most. As per the interviewees, a supportive legal framework, proactive national policy for PPP in SI development and ensuring project continuity through a long-term commitment would enhance the success of PPP in SI development projects. Moreover, to the interviewees, the private sector will also be satisfied with the “financial related RS&EF” as they will affect the return on investment. The interviewees also mentioned that it is important to have a good stakeholder management procedure for S2 as well. Explaining the above, the experts validated the PLS-

SEM model developed for the RS&EF affecting S2 in developing nations as it was also identified that the “legal & socio-political related factors” (t-value = 4.594), “financial related factors” (t-value = 3.364) and “stakeholder related factors” (t-value = 2.425) affect significantly on S2.

End-user satisfaction (S3)

For S3, the interviewees from the project mentioned the significance of “stakeholder related factors”. Effective stakeholder management process and clarity of the roles and responsibilities were identified as important among the “stakeholder related factors”. The experts explained that all the factor categories mentioned under RS&EF were important to S3 as the combination of all those factors gives the end-users the best outcome. Explaining the above, the experts validated the PLS-SEM model developed for the RS&EF affecting S3 in developing nations as it also identified that the “stakeholder related factors” (t-value = 8.101), “legal & socio-political related factors” (t-value = 6.186), “financial related factors” (t-value = 4.744), “social related factors” (t-value = 2.577) and “technical related factors” (t-value = 2.221) affect S3 significantly in developing nations.

7. Theoretical contributions and practical implications of the study

There is a lack of research studies on the evaluation of the factors which would affect SI developments involving PPPs especially in developing countries. This lack of research is seen to be in both breadth and depth of coverage. Hence, this study will contribute to the theory by means of quantitative evaluation and modelling of the factors impacting the result of PPP involved SI projects. The developed models can be utilised by project managers, policymakers, and decision-makers in the planning stage of the project, pointing to useful practical applications of these study findings. Policymakers and decision-makers could now benefit from this sound and better-informed basis for reducing and factoring in the project complexities

and in managing the stakeholders of the project, which is a precursor to success. The industry practitioners, especially the project managers, could use the mapping of the factors provided in this study as a sound basis for establishing best practice guidelines in collaborating with the many other actors involved in a PPP SI project as well.

8. Conclusions

PPP in SI development is crucial in developing nations, where governments typically lack sufficient financial resources. There are various factors that have influenced PPP use in SI innovations as SI development involves a larger array of technological, financial, and human resources when compared to normal infrastructure developments. Since there is a paucity of quantitative research on the impacts of these factors, this study aimed at examining the factors influencing the effectiveness of PPP in SI initiatives specifically focusing on developing countries. In this study, success of the PPP involved SI projects were measured based on three factors: public sector satisfaction (S1), private sector satisfaction (S2), and end-user satisfaction (S3). PLS-SEM was used to evaluate and model the causal relationships of the identified influencing factors.

It has been determined that "technical B&E (TBE)" have a considerable impact on S1, while "political B&E" have the greatest impact on S2 and S3. "Social (SB)" is the most significant barrier construct for S1 among the BA, whereas "legal and sociopolitical" (LSPB) and "technical" (TB) are the most significant barrier constructs for S2 and S3, respectively. End-users must possess the technical expertise required to operate the developed SI. As the majority of people in developing nations lack the necessary technical knowledge and skills, it is evident that technical barriers have the greatest impact on user satisfaction. The "Technical factor group" is the most significant construct among the recommended strategies for S1 and "legal

related factor group” is the most significant construct for S2 and S3. Therefore, it can be determined that different constructs impact on S1, S2 and S3.

Through the results obtained in this study, it is seen that the private sector looks more into the political and legal background of the host country before entering into a PPP contract, while the public sector is more concerned about meeting the needs of the society. The end-users can be seen as a party who are more interested in the outcomes of the project, hence also interested in the political and legal factors, which drive their outcomes to be successful. Therefore, aiming at enhancing those factors, which have a larger influence on the success of PPP in SI development projects in developing nations, would enable prioritizing of relevant strategies in specific projects to boost the delivery of SI in developing nations. This integrated approach in boosting the enablers and recommended strategies and enhancing factors is a necessity for a successful PPP based SI project in a developing country. Further areas for productive research are opened up by the research and consequential findings presented in this paper. For example, this model can be tested in SI projects involving PPPs in specific developing nations and for different types of SI (e.g. roads systems, bridges, tunnels etc.), the outcomes being valuable for those domains as well as for comparisons.

9. References

- Adams, W. C. (2015). Conducting semi-structured interviews. *Handbook of Practical Program Evaluation*, 492-505.
- Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi-structured interviews. *Journal of the American College of Clinical Pharmacy*, 4(10), 1358-1367.
- Ahmadabadi, A. A., & Heravi, G. (2019). The effect of critical success factors on project success in Public-Private Partnership projects: A case study of highway projects in Iran. *Transport Policy*, 73, 152-161.
- Albino, Vito, Umberto Berardi & Rosa Maria Dangelico (2015). Smart cities: Definitions, dimensions, performance, and initiatives, *Journal of Urban Technology*, 22(1), 3-21.

- Al-Humairi, S. N. S., & Kamal, A. A. A. (2021). Design a smart infrastructure monitoring system: a response in the age of COVID-19 pandemic. *Innovative Infrastructure Solutions*, 6(3), 144.
- Amaratunga, D., Baldry, D., Sarshar, M., & Newton, R. (2002). Quantitative and qualitative research in the built environment: application of “mixed” research approach. *Work Study*, 51(1), 17-31.
- Agherdien, N. (2010). *A review of theoretical frameworks in Educational Information and Communication Technology Research at leading South African Universities*. University of Johannesburg (South Africa).
- Balmford, A., Chen, H., Phalan, B., Wang, M., O’Connell, C., Tayleur, C., & Xu, J. (2016). Getting road expansion on the right track: a framework for smart infrastructure planning in the Mekong. *PLoS Biology*, 14(12), e2000266.
- Berglund, E. Z., Monroe, J. G., Ahmed, I., Noghabaei, M., Do, J., Pesantez, J. E., ... & Levis, J. (2020). Smart infrastructure: a vision for the role of the civil engineering profession in smart cities. *Journal of Infrastructure Systems*, 26(2), 03120001.
- Bibri, Simon Elias, & John Krogstie. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable Cities and Society*, 31, 183-212.
- Birgisson, B. (2020). The role of modern research universities in advancing innovative transportation infrastructure renewal. In *Transportation, Land Use, and Environmental Planning* (pp. 555-568). Elsevier.
- Byrne, Barbara M. (2013). *Structural equation modeling with LISREL, PRELIS, and SIMPLIS: Basic concepts, applications, and programming*. Psychology Press.
- Castelblanco, G., Guevara, J., Mesa, H., & Hartmann, A. (2022). Social legitimacy challenges in toll road PPP programs: Analysis of the Colombian and Chilean cases. *Journal of Management in Engineering*, 38(3), 05022002.
- Chen, Yong Qiang, Yang Bing Zhang, Jun Ying Liu, & Peng Mo. (2012) Interrelationships among critical success factors of construction projects based on the structural equation model. *Journal of Management in Engineering*, 28(3), 243-251.
- Chileshe, N., Njau, C. W., Kibichii, B. K., Macharia, L. N., & Kavishe, N. (2022). Critical success factors for Public-Private Partnership (PPP) infrastructure and housing projects in Kenya. *International Journal of Construction Management*, 22(9), 1606-1617.
- Cho, K., Hong, T., & Hyun, C. (2009). Effect of project characteristics on project performance in construction projects based on structural equation model. *Expert Systems with Applications*, 36(7), 10461-10470.
- Costa, D. G., & Peixoto, J. P. J. (2020). COVID-19 pandemic: a review of smart cities initiatives to face new outbreaks. *IET Smart Cities*, 2(2), 64-73.
- Creswell, John W. *A concise introduction to mixed methods research*. SAGE publications, 2014.

- Cruz, C. O., & Sarmiento, J. M. (2017). Reforming traditional PPP models to cope with the challenges of smart cities. *Competition and Regulation in Network Industries*, 18(1-2), 94-114.
- Cui, C., Liu, Y., Hope, A., & Wang, J. (2018). Review of studies on the public-private partnerships (PPP) for infrastructure projects. *International Journal of Project Management*, 36(5), 773-794.
- Darko, A., Chan, A. P. C., Yang, Y., Shan, M., He, B. J., & Gou, Z. (2018). Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: The Ghanaian case. *Journal of Cleaner Production*, 200, 687-703.
- Dolla, T., & Laishram, B. S. (2018). Procurement of low carbon municipal solid waste infrastructure in India through public-private partnerships. *Built Environment Project and Asset Management*, 8(5), 449-460.
- Dykes, B. J., & Jones, C. D. (2016). Public-private partnerships in Africa: Challenges and opportunities for future management research. *Africa Journal of Management*, 2(3), 381-393.
- Ekanayake, E. M. A. C., Shen, G., Kumaraswamy, M., Owusu, E. K., & Xue, J. (2022). Capabilities to withstand vulnerabilities and boost resilience in industrialized construction supply chains: A Hong Kong study. *Engineering, Construction and Architectural Management*, 29(10), 3809-3829.
- Ekanayake, L. L., & Ofori, G. (2004). Building waste assessment score: design-based tool. *Building and Environment*, 39(7), 851-861.
- Ferraris, A., Belyaeva, Z., & Bresciani, S. (2020). The role of universities in the Smart City innovation: Multistakeholder integration and engagement perspectives. *Journal of Business Research*, 119, 163-171.
- Garson, G. David. (2012). Testing statistical assumptions. *Asheboro, NC: Statistical Associates Publishing*.
- Goodhue, D. L., Lewis, W., & Thompson, R. (2012). Does PLS have advantages for small sample size or non-normal data?. *MIS quarterly*, 981-1001.
- Grant, M. J., & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*, 26(2), 91-108.
- Grossi, G., & Trunova, O. (2021). Are UN SDGs useful for capturing multiple values of smart city?. *Cities*, 114, 103193.
- Hair Jr, J. F., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European Business Review*, 26(2), 106-121.

- Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, 31(1), 2-24.
- Hansen, S. (2021, August). Characterizing interview-based studies in construction management research: analysis of empirical literature evidences. In *International Conference on Innovations in Social Sciences Education and Engineering (ICOISSEE)* (Vol. 1, No. 1, pp. 1-12).
- Höjer, M., & Wangel, J. (2015). Smart sustainable cities: definition and challenges. In *ICT innovations for sustainability* (pp. 333-349). Springer International Publishing.
- Hon, C. K. H., Chan, A. P. C., & Yam, M. C. H. (2014). Relationships between safety climate and safety performance of building repair, maintenance, minor alteration, and addition (RMAA) works. *Safety Science*, 65, 10-19.
- Harvill, Jane L. (2010) An Introduction to Statistical Methods and Data Analysis. 96-96. Brooks/Cole, Belmont, California, US.
- Ibrahim, A. D., Price, A. D. F., & Dainty, A. R. J. (2006). The analysis and allocation of risks in public private partnerships in infrastructure projects in Nigeria. *Journal of Financial Management of Property and Construction*, 11(3), 149-164.
- Ibrahim, Maysoun, Ali El-Zaart, and Carl Adams. (2018). "Smart sustainable cities roadmap: Readiness for transformation towards urban sustainability." *Sustainable Cities and Society*, 37, 530-540.
- Jayasena, N. S., Chan, D. W. M., Kumaraswamy, M. M., & Saka, A. B. (2023). Applicability of public-private partnerships in smart infrastructure development: The case of Hong Kong. *International Journal of Construction Management*, 23(11), 1932-1944.
- Jayasena, N. S., Chan, D. W. M., & Kumaraswamy, M. M. (2021). A systematic literature review and analysis towards developing PPP models for delivering smart infrastructure. *Built Environment Project and Asset Management*, 11(1), 121-137.
- Jayasena, N. S., Chan, D. W. M., & Kumaraswamy, M. M. (2022). Is public-private partnership (PPP) a preferred strategy for procuring smart infrastructure in developed countries: an empirical study of the perceived benefits, barriers and recommended strategies. *Sustainability*, 14(11), Article Number 6421.
- Jayasena, N. S., Waidyasekara, K. G. A. S., Mallawaarachchi, H., & Peiris, S. (2021). Ensuring engagement of stakeholders in smart city projects: Case study in Sri Lanka. *Journal of Urban Planning and Development*, 147(4), 05021045.
- Ke, Y., Wang, S., Chan, A. P. C., & Lam, P. T. I. (2010). Preferred risk allocation in China's public-private partnership (PPP) projects. *International Journal of Project Management*, 28(5), 482-492.
- Khmel, V., & Zhao, S. (2016). Arrangement of financing for highway infrastructure projects under the conditions of Public-Private Partnership. *IATSS research*, 39(2), 138-145.
- Kline, Rex B. (2015) *Principles and practice of structural equation modeling*. Guilford publications.

- Kock, N., & Hadaya, P. (2018). Minimum sample size estimation in PLS-SEM: The inverse square root and gamma-exponential methods. *Information systems journal*, 28(1), 227-261.
- Kwak, Y. H., Chih, Y., & Ibbs, C. W. (2009). Towards a comprehensive understanding of public private partnerships for infrastructure development. *California Management Review*, 51(2), 51-78.
- Li, H., Lv, L., Zuo, J., Bartsch, K., Wang, L., & Xia, Q. (2020). Determinants of public satisfaction with an Urban Water environment treatment PPP project in Xuchang, China. *Sustainable Cities and Society*, 60, 102244.
- Liu, J., Love, P. E., Davis, P. R., Smith, J., & Regan, M. (2015). Conceptual framework for the performance measurement of public-private partnerships. *Journal of Infrastructure Systems*, 21(1), 04014023.
- Liu, J., Love, P. E., Smith, J., Regan, M., & Davis, P. R. (2015). Life cycle critical success factors for public-private partnership infrastructure projects. *Journal of Management in Engineering*, 31(5), 04014073.
- Liu, J., Yi, Y., & Wang, X. (2020). Exploring factors influencing construction waste reduction: A structural equation modeling approach. *Journal of Cleaner Production*, 276, 123185.
- Liu, J., Shahi, A., Haas, C. T., Goodrum, P., & Caldas, C. H. (2014). Validation methodologies and their impact in construction productivity research. *Journal of Construction Engineering and Management*, 140(10), 04014046.
- Luo, C., Ju, Y., Dong, P., Gonzalez, E. D. S., & Wang, A. (2021). Risk assessment for PPP waste-to-energy incineration plant projects in china based on hybrid weight methods and weighted multigranulation fuzzy rough sets. *Sustainable Cities and Society*, 74, 103120.
- Malek, M. S., & Bhatt, V. (2023). Examine the comparison of CSFs for public and private sector's stakeholders: a SEM approach towards PPP in Indian road sector. *International Journal of Construction Management*, 23(13), 2239-2248.
- Mao, C., Shen, Q., Pan, W., & Ye, K. (2015). Major barriers to off-site construction: The developer's perspective in China. *Journal of Management in Engineering*, 31(3), 04014043.
- Marvin, S., Luque-Ayala, A., & McFarlane, C. (Eds.). (2015). *Smart urbanism: Utopian vision or false dawn?*. Routledge.
- Mattoni, B., Pompei, L., Losilla, J. C., & Bisegna, F. (2020). Planning smart cities: Comparison of two quantitative multicriteria methods applied to real case studies. *Sustainable Cities and Society*, 60, 102249.
- Milenković, M., Rašić, M., & Vojković, G. (2017, May). Using Public Private Partnership models in smart cities-proposal for Croatia. In *2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 1412-1417). IEEE.

- Mladenovic, G., Vajdic, N., Wündsche, B., & Temeljotov-Salaj, A. (2013). Use of key performance indicators for PPP transport projects to meet stakeholders' performance objectives. *Built Environment Project and Asset Management*, 3(2), 228-249.
- Mondschein, J., Clark-Ginsberg, A., & Kuehn, A. (2021). Smart cities as large technological systems: Overcoming organizational challenges in smart cities through collective action. *Sustainable Cities and Society*, 67, 102730.
- Morimoto, R. (2010). Estimating the benefits of effectively and proactively maintaining infrastructure with the innovative Smart Infrastructure sensor system. *Socio-Economic Planning Sciences*, 44(4), 247-257.
- Muleya, F., Zulu, S., & Nanchengwa, P. C. (2020). Investigating the role of the public private partnership act on private sector participation in PPP projects: a case of Zambia. *International Journal of Construction Management*, 20(6), 598-612.
- Müller, R., & Turner, J. R. (2007). Matching the project manager's leadership style to project type. *International Journal of Project Management*, 25(1), 21-32.
- Nguyen, N. T., & Ha-Duong, M. (2009). Economic potential of renewable energy in Vietnam's power sector. *Energy Policy*, 37(5), 1601-1613.
- Offenhuber, D., & Schechtner, K. (2018). Improstructure-an improvisational perspective on smart infrastructure governance. *Cities*, 72, 329-338.
- Osei-Kyei, R., & Chan, A. P. C. (2016). Developing transport infrastructure in Sub-Saharan Africa through public-private partnerships: Policy practice and implications. *Transport Reviews*, 36(2), 170-186.
- Owusu-Manu, D. G., Kukah, A. S., Boateng, F., Asumadu, G., & Edwards, D. J. (2021). Exploring strategies to reduce moral hazard and adverse selection of Ghanaian public-private partnership (PPP) construction projects. *Journal of Engineering, Design and Technology*, 19(2), 358-372.
- Ozorhon, B., Arditi, D., Dikmen, I., & Birgonul, M. T. (2011). Toward a multidimensional performance measure for international joint ventures in construction. *Journal of Construction Engineering and Management*, 137(6), 403-411.
- Ozorhon, B., & Oral, K. (2017). Drivers of innovation in construction projects. *Journal of Construction Engineering and Management*, 143(4), 04016118.
- Rice, J., & Martin, N. (2020). Smart infrastructure technologies: Crowdsourcing future development and benefits for Australian communities. *Technological Forecasting and Social Change*, 153, 119256.
- Sandelowski, M. (2000). Combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed-method studies. *Research in Nursing & Health*, 23(3), 246-255.
- Sarstedt, M., Ringle, C. M., & Hair, J. F. (2014). PLS-SEM: Looking back and moving forward. *Long Range Planning*, 47(3), 132-137.

- Scuotto, V., Ferraris, A., & Bresciani, S. (2016). Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects. *Business Process Management Journal*, 22(2), 357-367.
- Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*. John Wiley & sons.
- Selim, A. M., Yousef, P. H., & Hagag, M. R. (2018). Smart infrastructure by (PPPs) within the concept of smart cities to achieve sustainable development. *International Journal of Critical Infrastructures*, 14(2), 182-198.
- Seo, H. C., Lee, Y. S., Kim, J. J., & Jee, N. Y. (2015). Analyzing safety behaviors of temporary construction workers using structural equation modeling. *Safety Science*, 77, 160-168.
- Sharifi, A., Allam, Z., Bibri, S. E., & Khavarian-Garmsir, A. R. (2024). Smart cities and sustainable development goals (SDGs): A systematic literature review of co-benefits and trade-offs. *Cities*, 146, 104659.
- Sharma, C. (2023). Who does it better and why? Empirical analysis of public-private partnership in infrastructure in Asia-Pacific. *Property Management*, 41(3), 309-335.
- Simon, M. K., & Goes, J. (2011). Developing a theoretical framework. *Seattle, WA: Dissertation Success, LLC*, 13-18.
- Siokas, G., Kelaidi, V., & Tsakanikas, A. (2022). The smart city as a hub for nourishing public-private partnerships. *Sustainable Cities and Society*, 76, 103466.
- Siokas, G., Tsakanikas, A., & Siokas, E. (2021). Implementing smart city strategies in Greece: Appetite for success. *Cities*, 108, 102938.
- Spicer, Z., Goodman, N., & Olmstead, N. (2021). The frontier of digital opportunity: Smart city implementation in small, rural and remote communities in Canada. *Urban Studies*, 58(3), 535-558.
- Staletić, N., Labus, A., Bogdanović, Z., Despotović-Zrakić, M., & Radenković, B. (2020). Citizens' readiness to crowdsource smart city services: A developing country perspective. *Cities*, 107, 102883.
- Stamopoulos, D., Dimas, P., Siokas, G., & Siokas, E. (2024). Getting smart or going green? Quantifying the Smart City Industry's economic impact and potential for sustainable growth. *Cities*, 144, 104612.
- Tan, S. Y., & Taeihagh, A. (2020). Smart city governance in developing countries: A systematic literature review. *Sustainability*, 12(3), 899.
- Tan, J., & Zhao, J. Z. (2019). The rise of public-private partnerships in China: An effective financing approach for infrastructure investment?. *Public Administration Review*, 79(4), 514-518.
- Tripathi, K. K., & Jha, K. N. (2018). Determining success factors for a construction organization: A structural equation modeling approach. *Journal of Management in Engineering*, 34(1), 04017050.

- Jodie, B. U., & Ullman, B. (2006). Structural equation modeling: reviewing the basics and moving forward. *Journal of Personality Assessment*, 87(1), 35-50.
- Veselitskaya, N., Karasev, O., & Beloshitskiy, A. (2019). Drivers and barriers for smart cities development. *Theoretical and Empirical Researches in Urban Management*, 14(1), 85-110.
- Vilajosana, I., Llosa, J., Martinez, B., Domingo-Prieto, M., Angles, A., & Vilajosana, X. (2013). Bootstrapping smart cities through a self-sustainable model based on big data flows. *IEEE Communications magazine*, 51(6), 128-134.
- Vu, K., & Hartley, K. (2018). Promoting smart cities in developing countries: Policy insights from Vietnam. *Telecommunications Policy*, 42(10), 845-859.
- Xiong, Bo, Martin Skitmore, & Bo Xia. (2015). A critical review of structural equation modeling applications in construction research. *Automation in Construction*, 49, 59-70.
- Yuan, Jingfeng, Chao Wang, Mirosław J. Skibniewski, & Qiming Li. (2012) Developing key performance indicators for public-private partnership projects: questionnaire survey and analysis. *Journal of Management in Engineering*, 28(3), 252-264.
- Yuan, Jingfeng, Alex Yajun Zeng, Mirosław J. Skibniewski, & Qiming Li (2009) Selection of performance objectives and key performance indicators in public-private partnership projects to achieve value for money. *Construction Management and Economics*, 27(3), 253-270.
- Zahoor, Hafiz, Chan, Albert P.C., Utama, Wahyudi P., Gao, Ran & Memon, Shueb Ahmed. (2017), Determinants of safety climate for building projects: SEM-based cross-validation study, *Journal of Construction Engineering and Management*, 143(6), 05017005.
- Zhang, Xiaoling, Shen, Liyin & Wu, Yuzhe. (2011). Green strategy for gaining competitive advantage in housing development: a China study, *Journal of Cleaner Production*, 19(2-3), 157-167.
- Zhang, X. (2005). Critical success factors for public-private partnerships in infrastructure development. *Journal of Construction Engineering and Management*, 131(1), 3-14.

Table 1: Profile of expert interviewees and survey respondents

Profile of the expert interviewees			
<i>Interviewee</i>	<i>Designation</i>	<i>Experience (years)</i>	<i>Work Organisation</i>
I1	Lawyer and President's Counsel	Above 20	Private Developer
I2	President, Chamber of Construction Industry Sri Lanka	Above 20	Contractor
I3	Town Planner	9	Government
I4	Chief Financial Officer	Above 20	Private Developer
I5	Director/ CEO	Above 20	Private Developer
I6	Project Consultant	18	Consultant
I7	Senior Lecturer	Above 20	Government
I8	Senior Lecturer	16	Government
I9	Deputy CEO (Finance)	Above 20	Private Developer
I10	Town Planner	12	Government
Profile of the survey respondents			
<i>Demographics</i>	<i>Category</i>	<i>Number of responses</i>	<i>Percentage</i>
Profession	Engineer	34	34%
	Surveyor	27	27%
	Town Planner	7	7%
	Researcher	12	12%
	Project Manager	11	11%
	Architect	9	9%
	Public Sector	38	38%
Sector type	Private Sector	56	56%
	Both Sectors	6	6%
	Above 15 years	24	24%
Experience (Years)	10-15 years	37	37%
	5-10 years	28	28%
	Less than 5 years	11	11%

Table 2: Constructs` reliability and validity measures of the developed models

Constructs` reliability and validity measures of the B&E model						
Construct	Measurement item code	Factor loading	Cronbach's alpha value	Rho A	Composite reliability	AVE
PLBE	PLBE 1	0.696	0.863	0.866	0.895	0.549
	PLBE 2	0.774	-	-	-	-
	PLBE 3	0.808	-	-	-	-
	PLBE 4	0.734	-	-	-	-
	PLBE 5	0.652	-	-	-	-
	PLBE 6	0.759	-	-	-	-
	PLBE 7	0.753	-	-	-	-
FEBE	FEBE 1	0.750	0.661	0.682	0.801	0.510
	FEBE 3	0.516	-	-	-	-
	FEBE 4	0.850	-	-	-	-
	FEBE 5	0.698	-	-	-	-
TBE	TBE 1	0.745	0.783	0.793	0.852	0.537
	TBE 2	0.795	-	-	-	-
	TBE 3	0.778	-	-	-	-
	TBE 4	0.598	-	-	-	-
	TBE 5	0.731	-	-	-	-
SBE	SBE 1	0.787	0.830	0.836	0.880	0.596
	SBE 2	0.780	-	-	-	-
	SBE 3	0.701	-	-	-	-
	SBE 4	0.793	-	-	-	-
	SBE 5	0.794	-	-	-	-
Note: PLBE 8 and FEBE 2 were removed because their factor loadings were below 0.50						
Constructs` reliability and validity measures of the BA model						
Construct	Measurement item code	Factor loading	Cronbach's alpha value	Rho A	Composite reliability	AVE
FB	FB 1	0.693	0.706	0.709	0.818	0.530
	FB 3	0.712	-	-	-	-
	FB 4	0.753	-	-	-	-
	FB 5	0.752	-	-	-	-
LSPB	LSPB 1	0.726	0.853	0.856	0.884	0.459
	LSPB 2	0.650	-	-	-	-
	LSPB 3	0.644	-	-	-	-
	LSPB 5	0.690	-	-	-	-
	LSPB 6	0.729	-	-	-	-
	LSPB 7	0.687	-	-	-	-
	LSPB 8	0.647	-	-	-	-
	LSPB 9	0.674	-	-	-	-
	LSPB 10	0.640	-	-	-	-
	LSPB 11	0.640	-	-	-	-
SB	SB 1	0.656	0.802	0.807	0.852	0.420
	SB 2	0.653	-	-	-	-
	SB 3	0.634	-	-	-	-
	SB 4	0.753	-	-	-	-
	SB 5	0.647	-	-	-	-
	SB 7	0.643	-	-	-	-
	SB 8	0.569	-	-	-	-
	SB 9	0.618	-	-	-	-
	SB 10	0.618	-	-	-	-
TB	TB 1	0.670	0.796	0.802	0.855	0.497
	TB 4	0.733	-	-	-	-

	TB 5	0.598	-	-	-	-
	TB 6	0.751	-	-	-	-
	TB 8	0.731	-	-	-	-
	TB 9	0.736	-	-	-	-
Note: FB 2, FB6, LSPB 4, LSPB 11, LSPB 12, SB 6, TB 2, TB 3 and TB 7 were removed because their factor loadings were below 0.50						
Constructs` reliability and validity measures of the RS&EF model						
Construct	Measurement item code	Factor loading	Cronbach's alpha value	Rho A	Composite reliability	AVE
FREF	FREF 1	0.933	0.832	0.838	0.922	0.856
	FREF 2	0.917	-	-	-	-
LREF	LREF 1	0.689	0.876	0.879	0.901	0.505
	LREF 2	0.780	-	-	-	-
	LREF 3	0.787	-	-	-	-
	LREF 4	0.716	-	-	-	-
	LREF 5	0.732	-	-	-	-
	LREF 6	0.606	-	-	-	-
	LREF 7	0.684	-	-	-	-
	LREF 8	0.678	-	-	-	-
	LREF 9	0.707	-	-	-	-
SREF	SREF 1	0.803	0.841	0.843	0.893	0.67
	SREF 2	0.835	-	-	-	-
	SREF 3	0.815	-	-	-	-
	SREF 4	0.837	-	-	-	-
SRF	SRF 1	0.801	0.537	0.561	0.759	0.515
	SRF 3	0.706	-	-	-	-
	SRF 4	0.636	-	-	-	-
TREF	TREF 1	0.764	0.797	0.801	0.857	0.503
	TREF 2	0.735	-	-	-	-
	TREF 3	0.769	-	-	-	-
	TREF 4	0.764	-	-	-	-
	TREF 5	0.649	-	-	-	-
	TREF 6	0.544	-	-	-	-
Note: SRF 2 was removed because their factor loadings were below 0.50						

Table 3: Discriminant validity of the constructs of the B&E model

Measurement item code	FEBE	PLBE	S1	S2	S3	SBE	TBE
FEBE	0.714	-	-	-	-	-	-
PLBE	0.634	0.741	-	-	-	-	-
S1	0.692	0.517	1.000	-	-	-	-
S2	0.670	0.705	0.701	1.000	-	-	-
S3	-0.525	-0.798	-0.377	-0.668	1.000	-	-
SBE	0.427	0.235	0.638	0.444	-0.067	0.772	-
TBE	0.534	0.414	0.747	0.640	-0.318	0.585	0.733

Table 4: Discriminant validity of the constructs of the BA model

Measurement item code	FB	LSPB	S1	S2	S3	SB	TB
FB	<i>0.728</i>	-	-	-	-	-	-
LSPB	0.626	<i>0.677</i>	-	-	-	-	-
S1	0.629	0.756	<i>1.000</i>	-	-	-	-
S2	0.593	0.816	0.710	<i>1.000</i>	-	-	-
S3	-0.489	-0.431	-0.409	-0.425	<i>1.000</i>	-	-
SB	0.599	0.613	0.738	0.659	-0.448	<i>0.648</i>	-
TB	0.539	0.551	0.567	0.505	-0.764	0.708	<i>0.705</i>

Table 5: Discriminant validity of the constructs of the RS&EF model

Measurement item code	FB	LSPB	S1	S2	S3	SB	TB	TREF
FREF	<i>0.925</i>	-	-	-	-	-	-	
LREF	0.680	<i>0.711</i>	-	-	-	-	-	
S1	0.638	0.682	<i>1.000</i>	-	-	-	-	
S2	0.742	0.786	0.668	<i>1.000</i>	-	-	-	
S3	-0.686	-0.767	-0.564	-0.699	<i>1.000</i>	-	-	
SREF	0.728	0.798	0.752	0.735	-0.628	<i>0.823</i>	-	
SRF	0.548	0.467	0.548	0.576	-0.248	0.480	<i>0.718</i>	
TREF	0.677	0.723	0.862	0.658	-0.641	0.749	<i>0.529</i>	<i>0.709</i>

Table 6: Bootstrapping results for the B&E, BA and RS&EF models

Bootstrapping results for the B&E model			
Paths	Standard Deviation	t-value	p-value
FEBE- S1	0.072	4.394	0.000
FEBE- S2	0.118	1.670	0.095
FEBE- S3	0.095	0.933	0.351
PLBE- S1	0.063	1.521	0.128
PLBE- S2	0.079	5.476	0.000
PLBE- S3	0.058	13.124	0.000
SBE- S1	0.082	3.056	0.002
SBE- S2	0.064	1.204	0.229
SBE- S3	0.077	2.447	0.014
TBE- S1	0.087	4.520	0.000
TBE- S2	0.096	3.240	0.001
TBE- S3	0.092	0.723	0.470
Bootstrapping results for the BA model			
Paths	Standard Deviation	t-value	p-value
FB- S1	0.073	1.644	0.100
FB- S2	0.089	0.710	0.478
FB- S3	0.089	2.095	0.036
LSPB- S1	0.122	3.647	0.000
LSPB- S2	0.055	11.820	0.000
LSPB- S3	0.116	0.124	0.901
SB- S1	0.108	3.920	0.000
SB- S2	0.092	3.122	0.002
SB- S3	0.091	3.001	0.003
TB- S1	0.061	0.716	0.474
TB- S2	0.069	1.321	0.186
TB- S3	0.095	8.968	0.000
Bootstrapping results for the RS&EF model			
Paths	Standard Deviation	t-value	p-value
FREF - S1	0.059	0.541	0.589
FREF - S2	0.085	3.330	0.001
FREF - S3	0.089	4.782	0.000
LREF - S1	0.066	0.268	0.789
LREF - S2	0.098	4.514	0.000
LREF - S3	0.099	6.214	0.000
SREF - S1	0.068	3.624	0.000
SREF - S2	0.107	1.088	0.276
SREF - S3	0.114	1.612	0.107
SRF - S1	0.071	1.549	0.121
SRF - S2	0.070	2.509	0.012
SRF - S3	0.112	2.583	0.010
TREF- S1	0.075	8.696	0.000
TREF- S2	0.103	0.315	0.752
TREF- S3	0.089	2.220	0.026

Table 7: Summary of the findings for B&E

Code	t-values	Construct	Rank for the impact		
			S1	S2	S3
PLBE 3	26.842	PLBE	4 (1.480)	1 (5.423)	1 (13.214)
PLBE 2	15.161				
PLBE 4	14.891				
PLBE 6	11.107				
PLBE 7	10.686				
PLBE 1	8.688				
PLBE 5	6.520				
FEBE 4	25.503	FEBE	2 (4.278)	3 (1.674)	3 (0.942)
FEBE 1	9.209				
FEBE 5	6.116				
FEBE 3	5.524				
TBE 5	17.528	TBE	1 (4.566)	2 (3.270)	4 (0.743)
TBE 1	12.989				
TBE 2	9.679				
TBE 3	8.758				
TBE 4	6.735				
SBE 5	16.943	SBE	3 (3.040)	4 (1.182)	2 (2.393)
SBE 4	14.954				
SBE 2	13.134				
SBE 3	11.839				
SBE 1	10.446				

Table 8: Summary of the findings for BA

Code	t-values	Construct	Rank for the impact		
			S1	S2	S3
FB 5	12.049	FB	3 (1.609)	4 (0.727)	3 (2.060)
FB 4	11.797				
FB 1	10.323				
FB 3	7.420				
LSPB 1	13.244	LSPB	2 (3.560)	1 (11.914)	4 (0,124)
LSPB 7	10.840				
LSPB 9	10.351				
LSPB 2	9.718				
LSPB 8	9.665				
LSPB 5	9.329				
LSPB 6	8.932				
LSPB 10	7.669				
LSPB 3	7.194				
SB 4	14.449	SB	1 (3.920)	2 (3.145)	2 (2.909)
SB 3	9.681				
SB 2	9.567				
SB 1	9.009				
SB 5	8.939				
SB 7	7.974				
SB 9	7.324				
SB 8	6.887				
TB 1	9.129	TB	4 (0.713)	3 (1.346)	1 (8.733)
TB 4	11.276				
TB 5	7.550				
TB 6	14.610				
TB 8	10.106				
TB 9	13.788				

Table 9: Summary of the findings for RS&EF

Code	t-values	Construct	Rank for the impact		
			S1	S2	S3
SREF 4	21.659	SREF	3 (1.613)	4 (1.068)	3 (3.626)
SREF 3	20.625				
SREF 2	20.615				
SREF 1	19.363				
LREF 1	8.777	LREF	1 (6.072)	1 (4.534)	5 (0.268)
LREF 2	16.702				
LREF 3	12.384				
LREF 4	15.265				
LREF 5	14.853				
LREF 6	8.244				
LREF 7	7.243				
LREF 8	11.609				
LREF 9	9.593				
TREF 4	13.476	TREF	2 (2.236)	5 (0.3004)	1 (8.587)
TREF 1	12.716				
TREF 2	12.544				
TREF 3	11.929				
TREF 5	6.814				
TREF 6	4.496				
SRF 1	7.382	SRF	4 (1.532)	3 (2.505)	4 (2.590)
SRF 3	5.955				
SRF 4	3.276				
FREF 1	59.605	FREF	5 (0.550)	2 (3.317)	2 (4.772)
FREF 2	35.378				



Figure 2: Hypothesised research framework for the study

‘Barriers’	
‘Social’ (SB) SB 1: Lack of related knowledge and competencies SB 2: Citizens’ general reluctance to accept private sector involvement SB 3: Public opposition due to perceptions of risks of involving private sector SB 4: Inconsistency between the interests of citizens and private investors SB 5: Privacy concerns (e.g. the need to maintain confidentiality of personal information) SB 6: Unawareness due to absence of well-defined benefits in smart infrastructure that would improve citizens’ quality of life SB 7: Multi-stakeholder coordination complexities SB 8: Lack of a PPP-conducive national culture SB 9: Lack of private sectors’ consideration on sustainable construction and development	‘Financial & Economic’ (FB) FB 1: Restrictive and/or complex financial structure FB 2: Currency rate fluctuations FB 3: Unavailability of investor friendly tax conditions FB 4: Tariff changes FB 5: Uneven and inefficient risk allocation of PPP projects FB 6: Lack of adequate local and foreign investors with financial capacities to fund smart infrastructure ‘Legal & Socio-Political’ (LSPB) LSPB 1: Weak/ inconsistent legal PPP framework LSPB 2: Unavailability/lack of relevant policies LSPB 3: Political influences and instability in selecting and administering private sector collaborations LSPB 4: Lack of government support for private sector collaboration LSPB 5: Inconsistent administrative systems LSPB 6: Dishonest/ unethical practices and corruption LSPB 7: Barriers to transferring ownership/ management control of the assets and/or repatriating funds LSPB 8: Lack of confidence of the government in private sector collaborators LSPB 9: Frequent political/ policy shifts affecting smart infrastructure development and operations LSPB 10: Lack of accountability in governance LSPB 11: Lack of mechanisms to attract long-term finance from private sources LSPB 12: Less competition due to high tendering costs
‘Technical’ (TB) TB 1: Unclear scope of work TB 2: Higher construction risk of using smart technologies TB 3: Difficulties in evaluating dissimilar PPP Proposals/ Tenders and their potential impacts TB 4: Complex decision making process due to excessive variables and scenarios involved in smart-infrastructure projects TB 5: Lack of ‘intellectual property rights’ protection TB 6: Lack of critical resources available to the private parties TB 7: Security shortfalls (against ‘hacking’/ sabotage) and resilience of some smart systems TB 8: Inefficient provisions in facility operation & maintenance TB 9: Lack of reliable support-infrastructure	

‘Recommended Strategies & Enhancing Factors’	
‘Legal & Socio-Political’ related (LREF) LREF 1: Stable and consistent laws, regulations and policies LREF 2: Proactive national policy for PPP in smart infrastructure development LREF 3: Proactive ‘PPP and smart infrastructure’-friendly laws and regulations LREF 4: Protection mechanisms against political volatility LREF 5: High transparency of the procurement process LREF 6: Extensive vendor and end-user engagement in designing the appropriate PPP structure LREF 7: Encouraging competitive bidding from private participants with innovative alternative smart solutions LREF 8: Ensuring project continuity and end-user benefits through a long-term commitment LREF 9: Enabling public and/or private sectors’ equity stakes in innovative PPP smart infrastructure projects	‘Technical’ Related (TREF) TREF 1: Defining minimum functional needs with requisite technical specifications TREF 2: Well-structured, equitable and enforceable contracts TREF 3: Highly transparent contracting process TREF 4: Periodic high-level reviews and remedial actions throughout the whole project delivery process TREF 5: Mechanisms for faster project implementations TREF 6: Moving from silo-based to collaborative team working ‘Social’ Related (SRF) SRF 1: Effective frequent engagement with end-users and the general public SRF 2: Community capacity building SRF 3: Citizen centric decision-making process SRF 4: Ensuring more tangible benefits for the general public ‘Financial’ Related (FREF) FREF 1: Proactive facilitation of capital and finance FREF 2: Proactive addressing of the private sector’s financial priorities and concerns
‘Stakeholder’ related (SREF) SREF 1: Appropriate equitable risk allocation and sharing SREF 2: Clarity of roles, responsibilities and potential rewards, among contracting parties SREF 3: Effective stakeholder management SREF 4: Strong support from local banks and other relevant bodies	

‘Benefits & Enablers’	
‘Political & Legal’ (PLBE) PLBE 1: Clear government objectives PLBE 2: Favourable investment climate PLBE 3: Supportive legal framework PLBE 4: Flexible existing regulations and procurement guidelines PLBE 5: ‘PPP-friendly’ (favourable) policies PLBE 6: Statutory/ Regulatory provisions to supplement Government resources PLBE 7: Clear and proactive PPP guidelines PLBE 8: Desire to have public sector administration cost reductions	‘Financial & Economic’ (FEBE) FEBE 1: Sound economic policies FEBE 2: High cost of smart infrastructure development FEBE 3: Tax benefits FEBE 4: Independent competitive tendering FEBE 5: High potential for financial investments
‘Technical’ (TBE) TBE 1: Efficient PPP project management TBE 2: Private sector innovativeness in smart technologies TBE 3: Drivers to upgrade and/or adapt technological capacities TBE 4: Previously used PPP frameworks/ management models TBE 5: Drivers to increase “value for money” from smart infrastructure services through more-efficient, lower-cost, and/or reliable services	‘Social’ (SBE) SBE 1: Societal needs/ ‘demand’ for smart-infrastructure SBE 2: Public/ community support SBE 3: General publics’ understanding and acceptability of PPP delivery methods SBE 4: Ensuring proper knowledge transfer from the private partner to the public partner SBE 5: Drivers to create more local job opportunities

Figure 2: Proposed constructs and their associated measurement items

HE1a: PLBE have positive influence on S1	HE1b: PLBE have positive influence on S2	HE1c: PLBE have positive influence on S3
HE2a: FEBE have positive influence on S1	HE2b: FEBE have positive influence on S2	HE2c: FEBE have positive influence on S3
HE3a: TBE have positive influence on S1	HE3b: TBE have positive influence on S2	HE3c: TBE have positive influence on S3
HE4a: SBE have positive influence on S1	HE4b: SBE have positive influence on S2	HE4c: SBE have positive influence on S3
HB1a: FB have negative influence on S1	HB1b: FB have negative influence on S2	HB1c: FB have negative influence on S3
HB2a: LSPB have negative influence on S1	HB2b: LSPB have negative influence on S2	HB2c: LSPB have negative influence on S3
HB3a: SB have negative influence on S1	HB3b: SB have negative influence on S2	HB3c: SB have negative influence on S3
HB4a: TB have negative influence on S1	HB4a: TB have negative influence on S2	HB4a: TB have negative influence on S3
HR1a: SREF have positive influence on S1	HR1b: SREF have positive influence on S2	HR1c: SREF have positive influence on S3
HR2a: LREF have positive influence on S1	HR2b: LREF have positive influence on S2	HR2c: LREF have positive influence on S3
HR3a: TREF have positive influence on S1	HR3b: TREF have positive influence on S2	HR3c: TREF have positive influence on S2
HR4a: SRF have positive influence on S1	HR4b: SRF have positive influence on S2	HR4c: SRF have positive influence on S3
HR5a: FREF have positive influence on S1	HR5b: FREF have positive influence on S2	HR5c: FREF have positive influence on S3

Figure 3: A series of research hypotheses established for the study

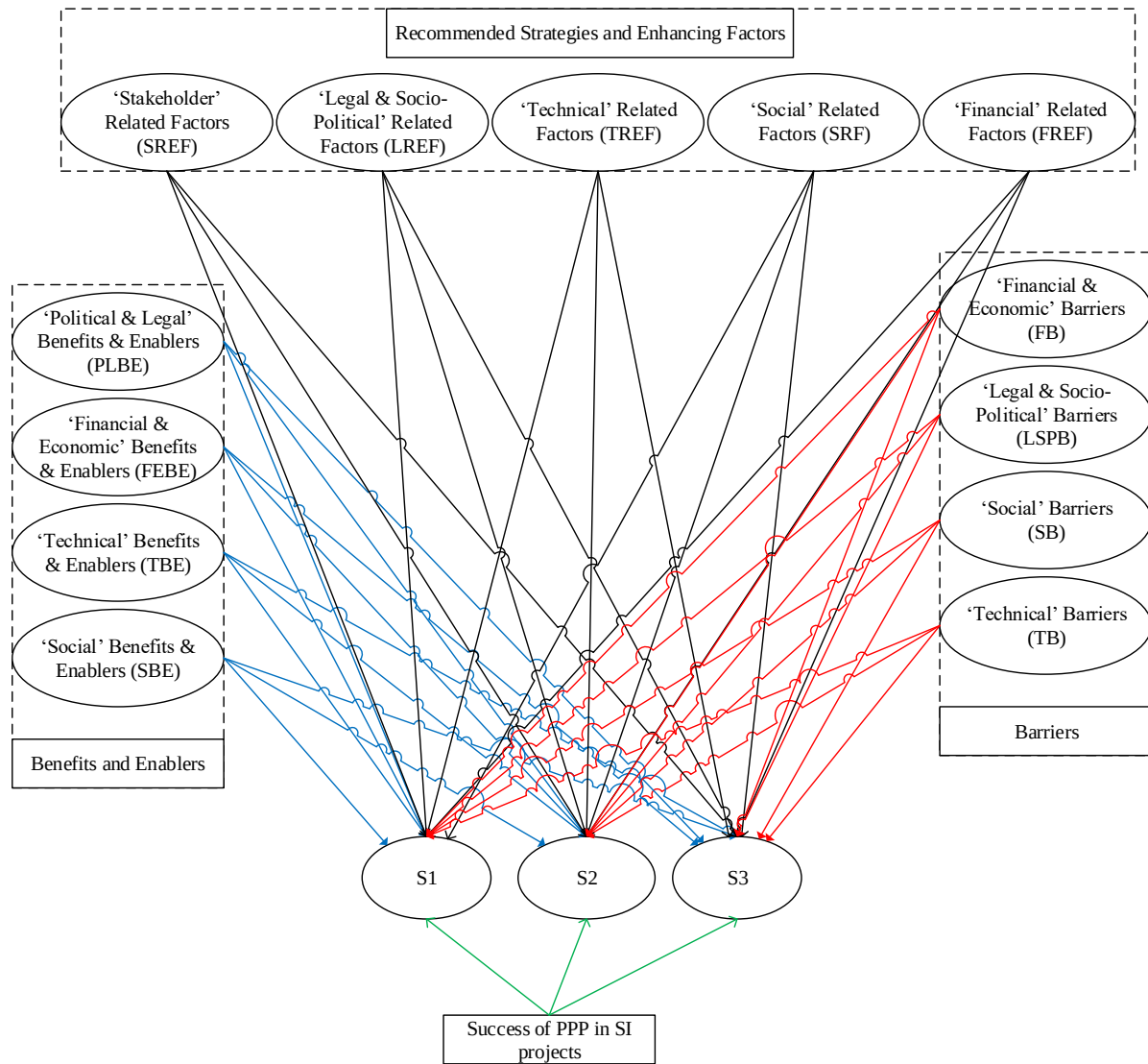


Figure 4: Hypothetical model of the research study

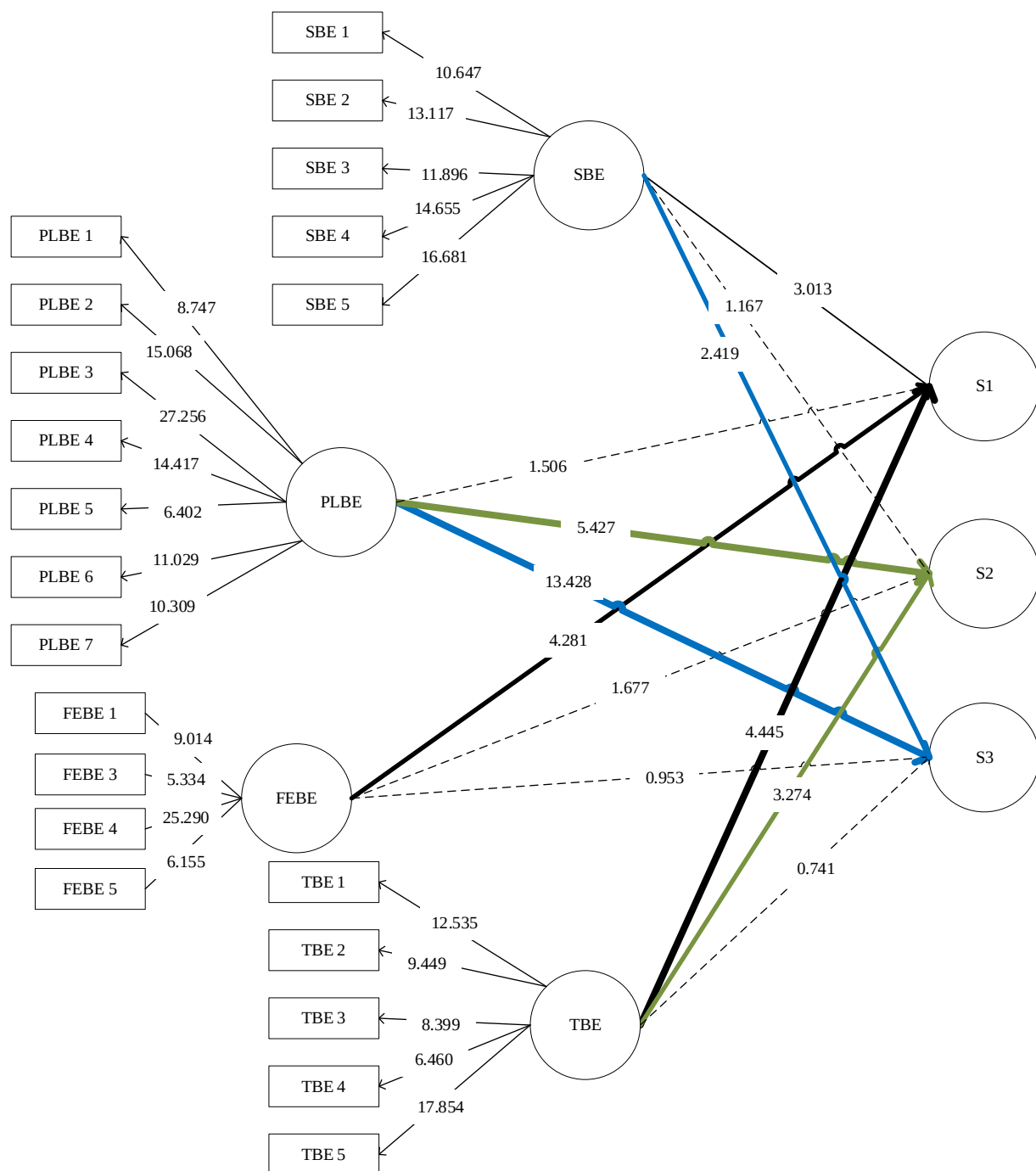


Figure 5: B&E model after PLS-SEM analysis

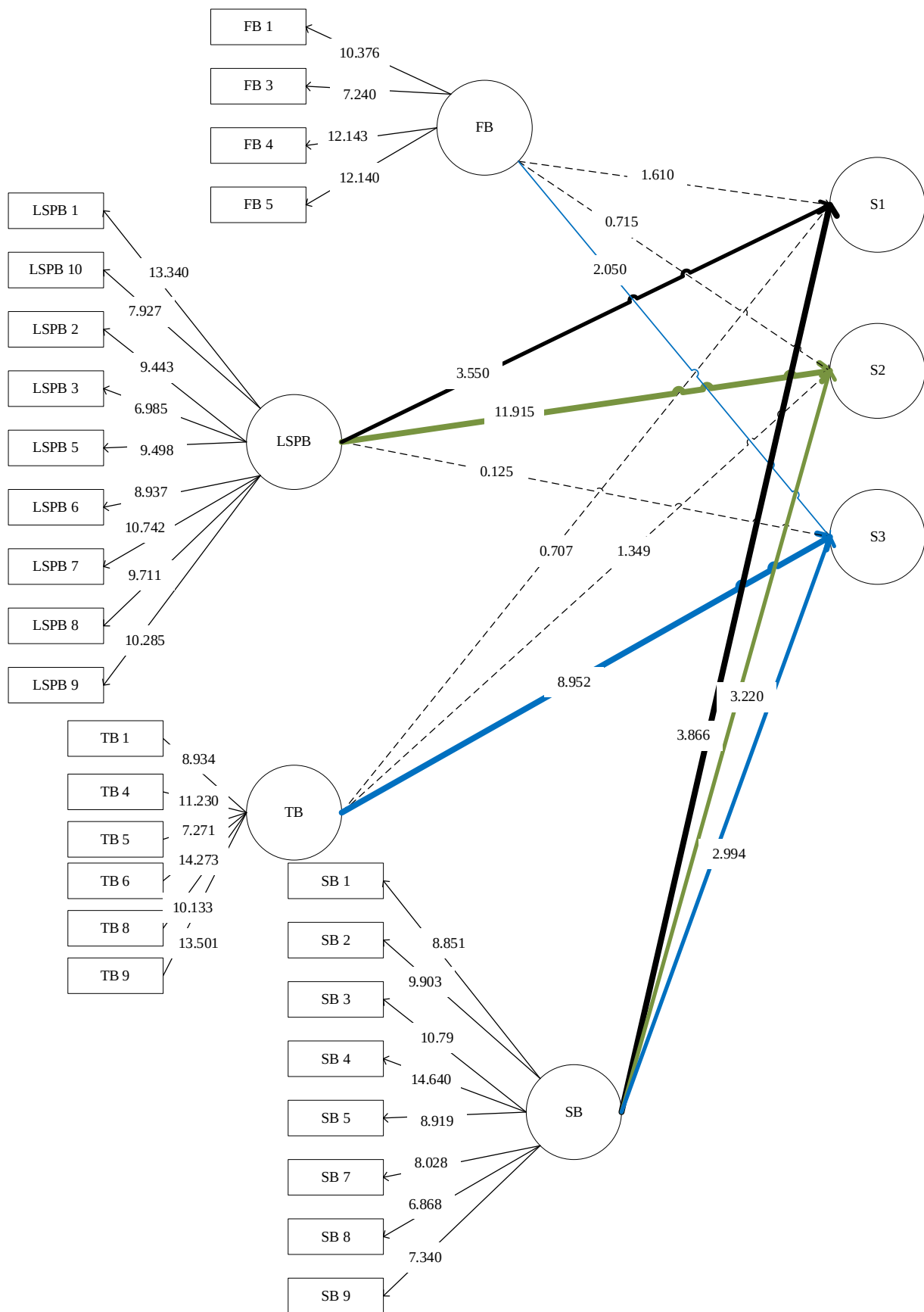


Figure 6: BA model after PLS-SEM analysis

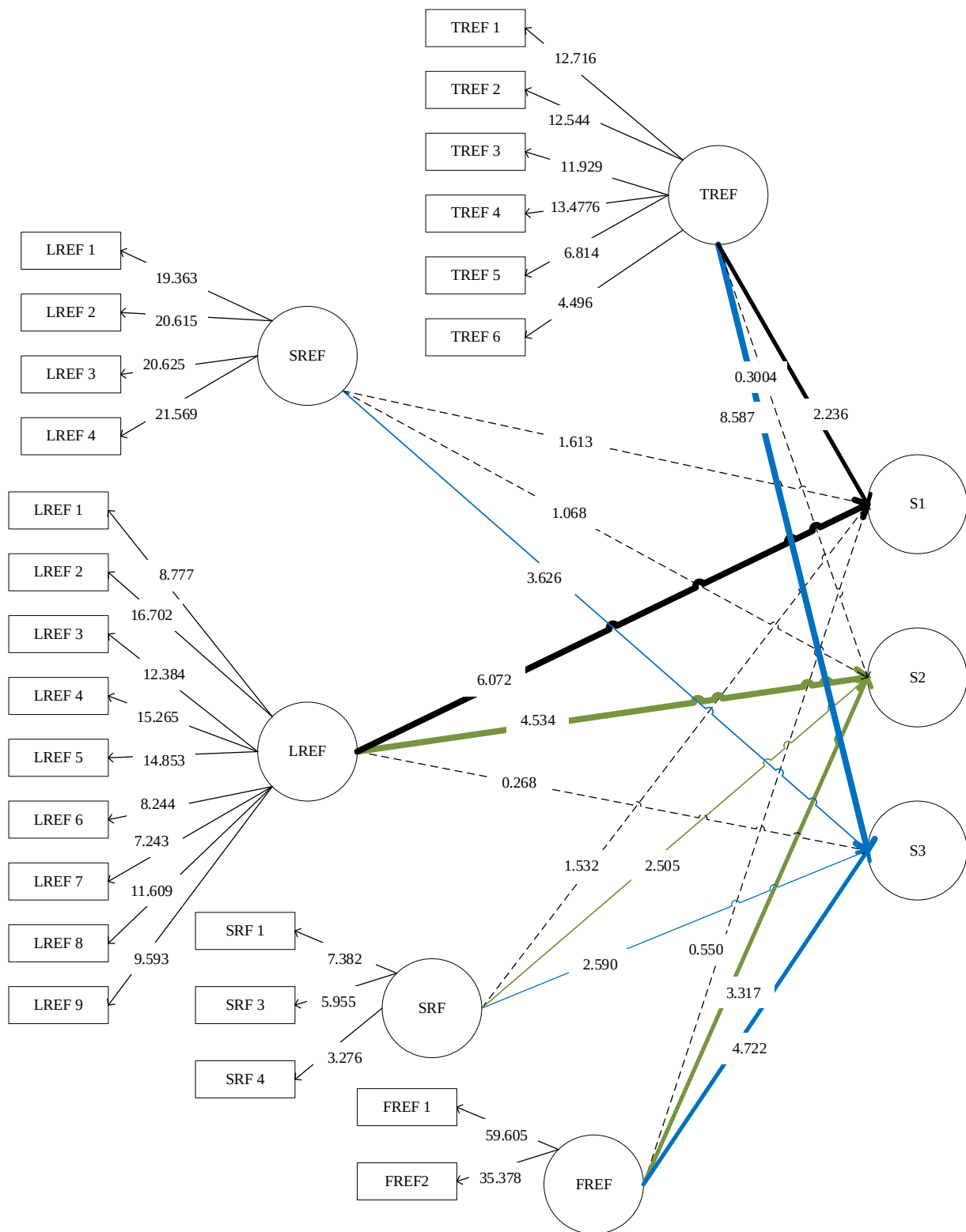


Figure 7: RS&EF model after PLS-SEM analysis