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RESEARCH ARTICLE

Validity and reliability of a transportation infrastructure sustainable performance framework: a study of transport projects in South Africa

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Abstract

Transportation infrastructure contributes to the development of an economy. However, the performance of such infrastructure is hampered if sustainability elements are not considered at the initiation/conception and operation stages of the projects. The study aimed to validate a structure of transportation project sustainability measures to evaluate projects and ensure continual delivery of intended benefits in the long run. Empirical data were collected using a field questionnaire survey developed from the literature review and a preliminary qualitative inquiry. A total of 132 built environment professionals were included based on purposeful and snowball sampling techniques. A model-generating confirmatory factor analysis was undertaken to validate underlying structures of sustainability measures established from a

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preliminary common factor analysis. The findings validated that a four-factor structure, with eleven variables, could adequately measure transportation infrastructure project sustainability (PS). The CFA structure achieved construct, convergent and discriminant validity, with fewer variables than were theorised and subsequently established in the common factor analysis. The validated four-factor structure is envisaged to be useful to transportation infrastructure project stakeholders in better decision-making on project selection being cognizant of these factors, which are indicative of the worthwhileness of projects. In addition, monitoring of the projects during the operational stage, based on the identified indicators, could be done with the aim of delivering long-term benefits to generations of users.

Keywords

Infrastructure, South Africa, Sustainability, Transportation, Confirmatory factor analysis

Introduction

Transportation plays an essential role in countries' competitiveness, balanced and liveable urban spatial development, access to water and energy, and food security, and is critical for social inclusion and improved quality of life (United Nations, 2015). It confers mobility and impacts on the development and welfare of the population through employment and income creation, connecting and providing to businesses and vital services, and therefore enhances economic development and growth (Friedrich and Timol, 2011; Chen and Cruz, 2012; Vilana, 2014). Despite the significance of transportation infrastructure, such projects are fraught with uncertainties, which if not considered during the planning of the projects and/or continuous monitoring to sustain intended performance, is detrimental to the immediate community and society. Sustainability performance across the life cycle of an infrastructure project is a crucial aspect in achieving the goal of sustainable development (Amiril et al., 2014). This then behoves transportation planners, policymakers and indeed researchers to find ways to maintain sustainability of such projects.

Sustainability in infrastructure development enables sound economic development, job creation and productivity; enhances quality of life; and promotes a more efficient and effective use of financial resources (investors' margins) (Montgomery, 2015). However, sustainability of infrastructure is hampered by lack of finance, governance and policy problems, planning inefficiencies and technical capacity (Bueno, Vassallo and Chueng, 2015). Therefore, research on transportation infrastructure project sustainability is paramount in order to ensure that projects continue to deliver intended benefits to generations of users.

Although previous studies have explored key sustainability and performance elements, the focus has been singularly on one aspect. For instance, Amiril et al. (2014) developed a framework for railway infrastructure in Malaysia while Gamalath, Pereira and Bandara (2014) and Park et al. (2019) focused on environmental and social sustainability aspects, respectively. Likewise, Velazquez et al. (2015) focused on environmental sustainability of road transport infrastructure. Yu et al. (2018) conducted a simulation analysis using system dynamics but focused on effectiveness of transport policies. Rouhani (2018) and Xue et al (2017) dwelt on financial sustainability, while Karjalainena and Juhola (2019) focused on reduction of carbon footprint and climate change impacts in public transport systems. Further, Amiril et al. (2014) employed a literature review for their study and although Wai, Yusof and Ismail (2012) applied factor analytical techniques to determine important project success criteria, sustainability was regarded as a secondary factor. This is inadequate since failure to address all sustainability risks on projects is likely to result in long-lasting and potentially irreversible impacts on wellbeing, health and the economy (Bhattacharya, Oppenheim and Stern, 2015). Further, it is important to note that transportation sustainability assessments group and apply indicators differently, depending on the approach (system versus sub-system), data restrictions and local contexts (Karjalainena and Juhola, 2019). Since most studies focus on specific factors of the transportation system in different local contexts, the value of the current paper is in the holistic consideration of all factors that affect transportation system, as identified through literature review as well as interviews and document analysis, in the local context (Schiff, Small and Ensor, 2013; Velazquez et al., 2015).

The objective of the current study is therefore to validate critical project sustainability (PS) indicators that should be used in the evaluation of transportation infrastructure. The study employs confirmatory factor analysis to validate the underlying structure of sustainability indicators established in a previous study through exploratory factor analysis (Okoro, Musonda and Agumba, 2019). By validating the common factors established from factor analysis, the study provides a reliable tool for ex-ante and ex-post evaluation of transportation infrastructure projects in order to ensure that lasting benefits are obtainable for generations of users.

Literature review

OVERVIEW OF SUSTAINABLE TRANSPORTATION CONCEPT

Sustainability connotes the ability of a project to maintain an acceptable level of benefit flows through its economic life or to maintain its operations, services and benefits during its projected lifetime (Muskin, 2017). Infrastructure sustainability is concerned with '"fit for purpose assets', where fitness is a function of an asset's capacity to be:

- continually useful over its entire life;
- a consistent and integral part of the wider infrastructure 'jigsaw', fulfilling community expectations by helping to solve sustainability challenges; and
- resilient and adaptable to changing circumstances (Stapledon, 2012).

Sustainability has been generally viewed and studied based on the three-dimensional aspects (environmental, economic and social aspects). However, transportation infrastructure sustainability entails a wider range of impacts beyond what is mostly studied (Stapledon, 2012). It incorporates the useful operational life of the assets since infrastructure projects need to deliver services over their lifetime, efficiently and reliably (Jeon, Amekudzi and Guensler, 2010). Thus, technical or structural quality of roads, with regard to the quality and long-lasting nature of construction materials, in addition to quality of life, project leadership, natural resource management and climate change, have been studied as sustainability elements (Ramani et al., 2009; Friedrich and Timol, 2011; Zou, Peng and Mei, 2011; Kaare and Koppel, 2012; Montgomery, Schirmer and Hirsch, 2015). Further, the sustainability concept includes system effectiveness (which captures the concept of mobility/fluidity of movement) and performance over a long term (Jeon, Amekudzi and Guensler, 2010). System performance is also related to its resilience and adaptability to changes, as supported by Stapledon (2012). These dimensions are interlinked in such a way that their self-producing and non-linear capabilities need to be effectively managed in order to guarantee sustainability of transport infrastructure. The implication therefore is that a clear distinction between and among economic, social, and environmental sustainability aspects or concepts is not always possible, since they overlap and interrelate (Litman, 2016). Thus, integrating economic, social and environmental sustainability aspects can only be effective if proper institutional arrangements are in place in the respective countries (Brouwer and van Ittersum, 2010).

Therefore, sustainability encompasses interrelated indicators that enable continual functioning and expected service over generations of users, without disrupting the quality of life of the citizenry. Since transport developments are intended to serve generations for a long time, such investments should provide assurance of lasting positive impacts and benefits (for example, mobility needs, access, efficiency and affordability) that are continually and satisfactorily experienced for eons, without compromising the ability of future generations to meet these needs (Yu et al., 2018; Karjalainena and Juhola, 2019). Sustainability in the current study therefore connotes the ability of a transportation infrastructure project to continue performing as was expected or projected over a long term, or throughout its life cycle (Bueno, Vassallo and Chueng, 2015).

TRANSPORTATION INFRASTRUCTURE PROJECT SUSTAINABILITY MEASURES

A plethora of infrastructure sustainability indicators exists in different contexts and sectors. Rating systems have been used, for instance, Leadership in Energy and Environmental Design (LEED), Civil Engineering Environmental Quality Assessment (CEEQUAL), Illinois Liveable and Sustainable Transportation (I-LAST), Green Leadership in Transportation Environmental Sustainability rating program (GreenLITES), Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), the Climate Bonds Initiative (Climate Bonds, 2019), and so on. However, albeit they are usually regionally-based and contain context-sensitive and desirable sustainability elements of the location where they were conceived, they are inadequate since they focus on either environmental, or economic assessments and therefore fail to fully address all components of sustainability holistically (Bueno, Vassallo and Chueng, 2015). Additionally, they are usually based on historical trends and relationships and thus could be biased (Lyons and Davidson, 2016). Consequently, it is necessary to review and identify specific factors used to measure sustainability in transport infrastructure sectors, and within a specified context.

A cornucopia of factors was therefore identified from extant literature as indicative of sustainability. These include the following:

- Financial and economic factors (affordability, costs, revenue/cash flow) (Jeon, Amekudzi and Guensler, 2010; Litman, 2016; Xue et al., 2017; Rouhani, 2018; Kermanshachi and Safapour, 2019);
- Environmental factors (preservation of the environment and compliance with environmental regulations (Karlaftis and Kepaptsoglou, 2012);
- Social factors (accessibility, public acceptability/complaints, demand, willingness to pay set fees, user satisfaction, safety, comfort and convenience (Dhingra, 2011; Pavlina, 2015; Karjalainena and Juhola, 2019);
- Physical infrastructure factors (condition and capacity of infrastructure) (Ramani et al., 2009);
- Institutional factors (coordination, service quality, structures for management and operations, service quality, responsibilities and capacity of partners) (Quium, 2014; Cottrill and Derrible, 2015).

Essentially, sustainability assessment measures should possess representativeness, relevance, policy sensitiveness and predictability, to cater for the complexity of factors that must be considered in infrastructure sustainability (Cottrill and Derrible, 2015).

In summary, sustainability in the current study connotes the ability of a project to continue performing as was expected or projected over a long term, or throughout its life cycle (Bueno, Vassallo and Chueng, 2015). Therefore, twenty-eight variables, grouped into six factors, were observed to adequately measure sustainable performance of transportation infrastructure projects (Table 1), from literature review and a subsequent qualitative phase (which refined the framework). The variables included socio-economic environment (SE1 – SE8), financial factors (FI1 – FI3), condition of physical infrastructure (CI1 – CI4), safety and security (SS1 - SS5), stakeholder satisfaction (ST1 – ST5), and service quality (SQ1 – SQ3) as shown in Figure 1. These were theorised to adequately measure transport project sustainability as identified from the literature review and multi-case study qualitative inquiry and used for the quantitative investigation.

Table 1 Theorised transport infrastructure sustainability measures

S/No.	Factors	Measures	Labels
1	Socio-economic environment	There are no complaints about travel times	SE1
		There are no complaints about user discomfort during travel	SE2
		There are no complaints about inconvenience during travel	SE3
		There is no competition between different modes of transport	SE4
		Property values have increased after the infrastructure was built	SE5
		New business ventures have developed after the infrastructure was built	SE6
		Infrastructure is accessible by all including the disabled and elderly	SE7
		Demand for the infrastructure services is as expected	SE8
2	Financial factors	Capital invested has been recovered	FI1
		There are no complaints about maintenance resources	FI2
		There are no complaints from investors about revenue	FI3

Table 1 continued

S/No.	Factors	Measures	Labels
3	Condition of physical infrastructure	The infrastructure is in good condition	CI1
		There are no complaints about the cleanliness of the infrastructure	CI2
		There is no traffic overload	CI3
		The infrastructure, in its present condition, is able to withstand common adverse weather	CI4
4	Safety and security	Signage for safety is adequate	SS1
		Fencing (median) is in place for safety	SS2
		Security officers are visible	SS3
		Security cameras are in place	SS4
		Formalised sidewalks are in place for pedestrians	SS5
5	Stakeholder satisfaction	The needs of the stakeholders are satisfied	ST1
		Users are satisfied with pricing/charges	ST2
		There are no operational problems	ST3
		The actors are able to work in collaboration with other stakeholders	ST4
		There is clarity of responsibilities among partners	ST5
6	Service quality	Management responds quickly to user complaints about infrastructure services	SQ1
		Management responds quickly to user complaints about safety incidents	SQ2
		The infrastructure services (rides) are predictable	SQ3

Research method

RESEARCH DESIGN

The current paper is part of a wider study, which investigated the influence of feasibility studies on project sustainability. The broad study adopted a sequential exploratory approach, whereby the results from a qualitative multi-case study (in conjunction with the theoretical findings) phase informed and guided the data collection in the second quantitative phase, and developed theories were refined, to be subsequently tested using survey research in the quantitative phase (Darke, Shanks and Broadbent, 1998). However, only the results of the project sustainability framework validation are presented here. The underlying structure of sustainability indicators found in Okoro, Musonda and Agumba (2019) is validated in the current paper.

Prior to data collection for the broader study, ethical clearance was obtained from the university authorities. Consent was also obtained from some of the participants' superiors as and where required. Prior to the main research (qualitative and quantitative phases), a pilot study was undertaken to simplify and clarify some of the questions. Unstructured interviews as well as a draft questionnaire were pilot-tested. During the pilot study, it was discovered that a qualitative phase could precede the quantitative phase (in lieu of the concurrent approach initially proposed). It was therefore necessary to refine the questions and reduce the length of the questionnaire. A number of questions were subsequently rephrased considerably, and others deleted, prior to the qualitative research, and ensuing quantitative phase. The pilot study therefore improved test or content validity of the research tools. In addition, pilot-testing served to identify essential research approval processes in the government entities sampled, which were observed to differ from one to another.

DATA COLLECTION

The questionnaire was distributed by hand, as well as online via email and google forms, and contained questions which sought information regarding transportation infrastructure sustainability measures, on a five-point Likert scale, with responses ranging from 1=strongly disagree to 5=strongly agree. Empirical quantitative data were amassed from 132 respondents selected through purposive and snowball sampling techniques. This sample size was considered to be adequate in producing reliable results in studies of this nature (structural equation modelling (SEM). Sample sizes as small as N = 50 can produce reliable SEM results with normally distributed data and at least three reliable indicators per factor (Hoyle and Gottfredson, 2015).

The respondents in the quantitative phase (reported in the current paper) comprised built environment professionals in the nine provinces of South Africa, who had been involved in transportation infrastructure projects, at the feasibility and/or operational stages. The respondents comprised 69% and 31% public and private entity professionals, respectively, consisting of directors, deputy directors and heads of departments that formed majority (25%) of the respondents. Others were project managers (15%), engineers (12%) and safety officers (10%). In addition, respondents included executive/deputy managers (8%), development managers/ agents (6%), feasibility study consultants (4%), quantity surveyors (4%), planners (4%), academics (3%), and technical assistants on projects (2%). These were involved in various transportation projects (road, bridge, rail, airport and tunnel), at different project stages. Therefore, effort was made to obtain responses from a variety of entities to increase generalisability and reliability of the results.

DATA ANALYSIS

Data was analysed using AMOS software version 25. The AMOS software was preferred because of its intuitive graphical user interface, ability to read SPSS data as an input and accommodate plugins for automatic programming and building of a series of paths, unlike the other packages such as EQS, LISREL and MPlus (Nokelainen, 2007). Prior to the analysis, preliminary analysis considerations were made, including missing data, sample size, univariate and multivariate normality and outliers, definability of the model, theoretical specifications, method of estimation, model fit criteria and modifications. Although a sample size of 200

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cases is generally the rule, a ratio of 5 to 1 was considered sufficient (with 132 cases) in the current study (Kenny, 2015). The maximum likelihood method used in the analysis accommodated missing data (Carter, 2006). However, missing data was still treated in order to enable assessment of multivariate normality and the presence of outliers, which gravely affect parameter estimates and model fit (Gao, Mokhtarian and Johnston, 2008). Missing values were treated using mean imputation, which entailed computing the average response on a particular variable with missing data and imputing the value for the missing data, respectively.

Multivariate normality and outliers were assessed using univariate skewness and multivariate kurtosis (*Mardia's* coefficient), as well as Mahalanobis d-squared distance tests. An absolute skewness value of 1.0 or lower indicates a normally distributed data (Awang, 2012). Kurtosis values greater than 1.96 and large multivariate kurtosis (*Mardia's*) coefficients indicate significant non-normality (Byrne, 2001). The outliers were thus identified and removed from further analysis, using Mahalanobis squared distance (D), which identified seven cases with the highest d-squared values (with p values less than 0.005) as outliers and were deleted. The definability of the model was assessed using the degrees of freedom, *df*, which should be positive (greater than 1) for a model to be considered analysed or defined (Byrne, 2001). The degrees of freedom, which is the difference between the known and unknown parameters (to be estimated) in a model should be positive. When the number of degrees of freedom is negative, the model is under-identified and cannot be estimated or defined (Weston and Gore, 2006).

The model-generating CFA was thereafter undertaken to determine the model of factors that best fit or represented the data underlying the theory. Absolute and comparative fit indices were used and the two-index presentation strategy as advocated by Hu and Bentler (1999) was adopted. Absolute fit indices show how well a hypothesised model reproduces or matches the sample data, while comparative, relative or incremental fit indices compare the fit of one model to the data to the fit of another model to the same data (Iacobucci, 2010). These included Comparative fit index (CFI) (close to 0.95 or 0.90), Relative chi-square (CMIN/df) ($\chi 2$ *to df* ≤ 2 or 3). Standardised root mean square residual (SRMR) (> 0.05 to 0.08; the lower the better), and Root mean square error of approximation (RMSEA) (Close to 0.06; 0.08 – reasonable fit; > 0.10 – poor fit) (Hu and Bentler, 1999; Schreiber et al., 2006).

Additionally, the standardised residual matrix (items with high correlations above 1.0), factor loadings or variance explained in the model ((squared multiple correlations below 0.5 were problematic items), and the modification indices (items that may be redundant in the model) were assessed. Problematic items were deleted iteratively, and the model was rerun, bearing in mind that item deletion may not exceed 20% of the total number of items and latent constructs should have at least two or three items. Further, statistical significance of the parameter estimates was established in order to make reliable conclusions on whether the measurement model is appropriate or needs to be revised further. This was done with reference to the squared multiple correlation and the factor loading values, which should be less than 1.0, and the critical ratio values, akin to Z statistic, which should be greater than 1.96 at the 0.05 significance level (Byrne, 2006).

VALIDITY AND RELIABILITY CONSIDERATIONS

The piloting and reviews of the questionnaire by the researcher's supervisors and statistician refined the tool and increased face or content validity of the questionnaire. Internal reliability consistency tests for the project sustainability measures was assessed before and after the

EFA using the Cronbach's alpha test and the results indicated good internal consistency with values ranging from 0.76 to 0.84 before EFA and 0.92 (N=14) after EFA. The inter-construct reliability of the EFA model, which was the CFA input model, was good. The inter-construct correlations should not be more than 0.85 to achieve discriminant validity (Ahmad, Zulkurnian and Khairushalimi, 2016). The CFA model was assessed for uni-dimensionality, reliability and validity. Uni-dimentionality requires that all factor loadings should be positive and above 0.5 for newly developed items and 0.6 or higher for established items and this was attained through the item-deletion procedure for low loading items (Awang, 2012). The reliability and validity of the measurement models were assessed using model fit indices, composite reliability (CR) and average variance extracted (AVE) statistics as stated below (Awang, 2012). The CR measures the confidence level of latent variables in the CFA model considering the factor loadings an error-variance, and a value greater than 0.6 or 0.7 is needed to achieve composite reliability (Xue, Liu and Shu, 2018). An AVE > 0.5 is required for the respective constructs to achieve reliability (Awang, 2012).

$$\mathrm{CR} = \frac{(\Sigma\lambda_j)^2}{[(\Sigma\lambda_j)^2 + \Sigma(1-\lambda_j^2)]} \qquad \text{Equation 3.1}$$

$$\mathrm{AVE} = \frac{\Sigma\lambda_i^2}{n} \qquad \text{Equation 3.2}$$

where λ is the factor loading (standardised regression weights), and *n* is the number of items in the construct.

Further, convergent validity was achieved during CFA in this study with all the AVE values exceeding 0.50 (Awang, 2012). The model fit indices, which met the required levels, indicated that the model was reliable and achieved construct validity (Marsh et al., 2004). Discriminant validity was also achieved when all the redundant items in the model were either deleted or constrained as "free parameters", discriminant validity was reached (Awang, 2012). The modification indices results indicated pairs of items, which were redundant or covarying highly with each other, having values greater than 15, resulting in poor model fit. In addition, when the square root of the AVE was greater than the inter-construct correlations, then discriminant validity was achieved (Ahmad, Zulkurnain and Khairushalimi, 2016). In other words, the inter-construct correlations were not high (not greater than 0.85) and thus the values were not measuring the same thing; discriminant validity was achieved (Musonda, 2012; Ahmad, Zulkurnain and Khairushalimi, 2016).

Results and analysis

The CFA analysed the relationships between the latent constructs and their variables as presented in the input diagram in Figure 1, using the 125 cases remaining (data set with outliers deleted). The rectangles are the observed variables or indicators of each latent construct. The ovals represent the latent constructs. The error terms for each observed variable are represented as circles. These are residual or error variances, which uniquely cause response variations in the observed variables. The results of the model-generating CFA are presented hereunder.

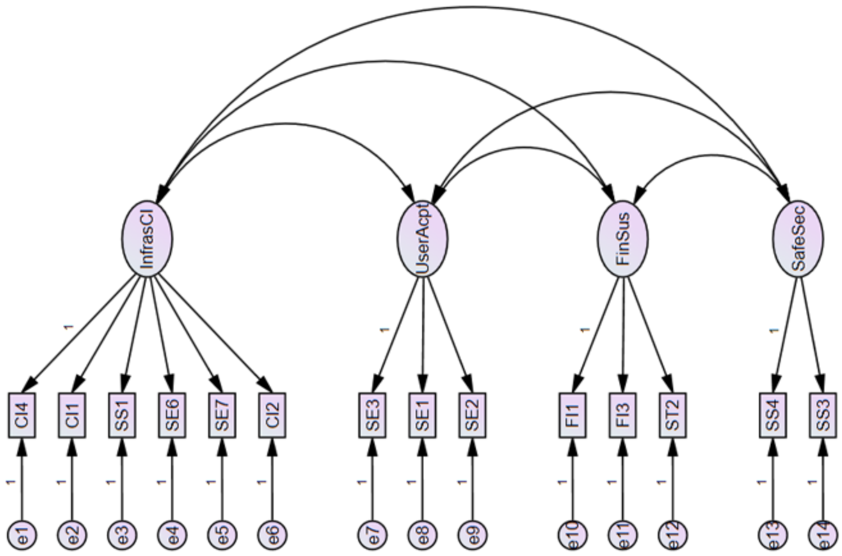

Figure 1 CFA input model (framework after EFA)

DIAGNOSTIC FIT ANALYSIS AND MODEL MODIFICATION

The evaluation of the input model showed that there were no high correlations (exceeding 0.80) between the latent constructs. This indicated that there was discriminant validity for the PS input model. However, the input model did not match the data as indicated by the CFI = 0.888 (cut-off value = 0.90) and RMSEA = 0.122 (cut-off value = 0.09) indices in Table 2. An examination of other output from the first run was therefore undertaken to determine if the model fit could be improved.

An examination of the standardised residuals covariance matrix revealed that there were no high residual covariances (above 2.58). However, SE6 and SS1 covaried with four and three other items in the model, respectively, with values more than 1.0 and they were deleted successively. The model fit indices (Table 2) showed the results after the deletion. It was notable that the model fit improved significantly after the third run with CMIN/df = 1.986, falling below the recommended 2.0, CFI = 0.949, close to 0.95 (cut-off value > 0.90), RMSEA = 0.089 (cut-off value = < 0.09), and SRMR = 0.0586 (cut-off value > 0.05 to 0.08). Based on the two-index presentation strategy advocated by Hu and Bentler (1999), the model after the third run was observed to be an excellent fit to the sample data.

However, the item ST2 was found to have a low contribution of 34%, indicating that the item was contributing more error variance than explained variance in the model and it was removed, and the test rerun. The final model (Figure 2), displayed acceptable fit (Table 2), with values within the recommended ranges: CMIN/df = 2.087 (cut-off value < 2 or 3), CFI= 0.95 (cut-off value > 0.90), RMSEA = 0.094 (cut-off value 0.09), and SRMR = 0.0570 (cut-off value > 0.05 to 0.08). These results indicated that the hypothesised PS model matched the sample data by 95% and with a residual value of 5.7%, the model can be deemed to be an excellent fit to the data. It was notable that approximately 20% of the number of items (three out of 14) were deleted, and this was observed to be permissible in a model-generating CFA (Byrne, 2001; Awang, 2012).

Table 2 Model fit indices for input and final PS model

Fit indices	Cut off value	Estimate (input model)	Estimate (final model)
Chi-square $\chi 2$		203.084	85.579
Degrees of freedom *df*	> 0 ; positive	71 (acceptable)	41 (acceptable)
Relative chi-square (CMIN/*df*)	≤ 2 or 3	2.860 (acceptable)	2.087 (acceptable)
Comparative fit index (CFI)	≥0.90	0.888 (not acceptable)	0.950 (acceptable)
Standardised root mean square residual (SRMR)	> 0.05 to 0.08	0.0687 (acceptable)	0.0570 (acceptable)
Root mean square error of approximation (RMSEA)	< 0.09 – good fit; < 1.0 – reasonable fit	0.122 (not acceptable)	0.094 (acceptable)

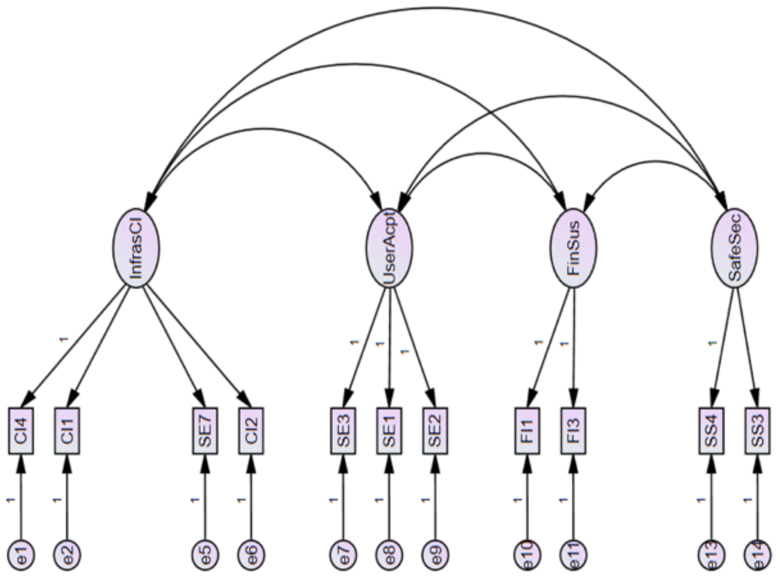

Figure 2 Validated project sustainability model

STATISTICAL SIGNIFICANCE OF PARAMETER ESTIMATES

An examination of the factor loadings (regression weights), standard errors and critical ratio estimates was undertaken to determine if the model parameters were statistically significant (Byrne, 2006). The PS final measurement model parameters exhibited statistical significance with the squared multiple correlations values all less than or equal to 1.0 and therefore reasonable. The parameter estimates had high correlation values (above 0.4). The correlation values suggested a high degree of linear association between the indicator variables and their latent constructs, and therefore reasonable.

In addition, the critical ratio test statistic, analogous to Z scores, was used to test the significance of the parameters. The critical ratio, which is the parameter estimate divided by its standard error, had to be greater than 1.96 at the 0.05 significance level for it to be said to be statistically different from zero and considered significant. Table 3, containing the parameter estimates, showed that the critical ratio values were all above 1.96 and therefore statistically significant.

Table 3 Parameter estimates of the selected PS measurement model

Latent construct	Variable	Squared multiple correlations R^2	Factor loading (unstandardised λ)	Factor loading (standardised λ)	Critical ratio	Significant at 0.05 level?
Infrastructure condition and impacts	CI4	.559	1.000	.748	…	Yes
	CI1	.633	.972	.795	8.645	Yes
	SE7	.442	.822	.665	7.174	Yes
	CI2	.705	1.150	.839	9.100	Yes
User Acceptability	SE3	1.000	1.000	1.000	…	Yes
	SE1	.773	1.000	.879	…	Yes
	SE2	.808	1.000	.899	…	Yes
Financial sustainability	FI1	.548	1.000	.740	…	Yes
	FI3	.622	1.000	.789	…	Yes
Safety and security	SS4	.689	1.000	.830	…	Yes
	SS3	.717	.871	.847	7.454	Yes

… Values not determined due to unstandardised regression weight of 1.0

RELIABILITY AND VALIDITY OF THE PROJECT SUSTAINABILITY MODEL

The inter-construct correlations between the constructs from the EFA (CFA input diagram) ranged from 0.46 to 0.78, and thus indicating discriminant validity of the four-factor structure. The reliability of the CFA model was evaluated using the CR and AVE tests. Table 4 indicated that the required levels were met as the CR and AVE values exceeded recommended thresholds of 0.6 and 0.5, respectively (Awang, 2012). Convergent validity was achieved by the AVE values all being above 0.5. Construct validity was achieved by the model being of good fit, with all the fit indices within the recommended cut-off ranges. Discriminant validity was also achieved by the modification indices being below 15 and the inter-construct correlations were lower than 0.85.

Furthermore, discriminant validity was achieved by the inter-construct correlation values being below the square root of the AVEs, as shown in Table 5. The table showed the diagonals in bold, which are the square root values of the AVE for the constructs, and the other values in rows and column are the correlation between the constructs related. The square root of the AVE values should be greater than the inter-construct correlations for discriminant validity to be achieved (Awang, 2012).

Table 4 Reliability results for selected PS measurement model

Latent construct	Item	Factor loading λ	CR (> 0.6)	AVE (> 0.5)	Comment
Infrastructure condition and impacts (n = 4)	CI4	.748	0.762	0.585	Required level was achieved
	CI1	.795			
	SE7	.665			
	CI2	.839			
User acceptability (n = 3)	SE3	1.000	0.926	0.860	Required level was achieved
	SE1	.879			
	SE2	.899			
Financial sustainability (n = 2)	FI1	.740	0.765	0.586	Required level was achieved
	FI3	.789			
Safety and security (n = 2)	SS4	.830	0.839	0.703	Required level was achieved
	SS3	.847			

Table 5 Discriminant validity for PS measurement models

Construct	Infrastructure condition and impacts	User acceptability	Financial sustainability	Safety and security
Infrastructure condition and impacts	**0.76**			
User acceptability	0.57	**0.93**		
Financial sustainability	0.73	0.44	**0.77**	
Safety and security	0.63	0.46	0.46	**0.84**

Discussion

The validated CFA four-factor solution revealed that critical transportation infrastructure project sustainability measures include:

- condition and impacts - including ability to withstand common adverse weather, infrastructure is in good condition, accessibility to all including the disable and elderly, and no complaints about cleanliness;
- user acceptability - including no complaints about inconvenience during travel, no complaints about travel times, and no complaints about user discomfort during travel;
- financial management factors - including capital invested has been recovered and no complaints from investors about revenue; and

- safety and security – including security cameras are in place and security officers are visible).

The above findings slightly align with Amiril et al. (2014) study which found that in addition to the traditional iron-triangle consideration of social, economic and environmental sustainability aspects, the quality and functionality as well as project financing are critical sustainability elements. The criticality of the wide-range of factors, which emerged from the analysis, has also been emphasised. The condition of transportation infrastructure with regard to its ability to withstand poor weather conditions or natural disasters and being in good condition (generally) were identified as important performance measures for road infrastructure in South Africa (Friedrich and Timol, 2011). These views were also shared by Jeon, Amekudzi and Guensler (2010) and Stapledon (2012) who emphasised the importance of technical and structural conditions and network capacity in sustainability assessments. Likewise, user acceptability was defined in line with the satisfaction of travel needs of the stakeholders including the end-users (Amiril et al., 2014; Yu et al, 2018). Safety and security were classified under social factors in Amiril et al. (2014) and Litman (2019).

The findings, which excluded institutional factors, are somewhat inconsistent with Karjalainena and Juhola's (2019) views, which stressed the importance of effective and comprehensive management of transport systems through political will and good governance. Nonetheless, given the range of objectives, impacts and options considered in transportation developments, which invariably affect different people in many ways, a variety of factors need to be considered in order to ensure that decisions are consistent with strategic long-term goals of sustainable transportation development (Litman, 2019).

Conclusion

The study sought to validate the underlying structure of transportation infrastructure project sustainability framework established from a previous study by the author. The objective of the study has been achieved. Project sustainability was initially theorised to be measured by a six-factor structure comprising socio-economic factors, financial factors, condition of physical infrastructure, safety and security, stakeholder satisfaction and service quality, with twenty-eight items. However, the EFA indicated a four-factor solution including infrastructure condition and impacts, user acceptability, financial sustainability as well as safety and security, with fourteen items. Using a model generating approach to CFA, the primary focus was to validate a measurement model that best described the sample data, and as such, modifications were necessary based on the sources of misfit identified.

Findings from the CFA revealed that the four-factor structure established during the EFA could adequately measure project sustainability, albeit with fewer variables (eleven). This model achieved construct, convergent and discriminant validity and is therefore deemed reliable and generalisable in sustainability assessments of transportation infrastructure projects in South Africa. Additionally, the techniques employed in the current study could be applied to a different and larger data set from other geographical locations. It is argued that some of the problems and challenges encountered in the operational stage of transport infrastructure projects could be mitigated by according considerable attention to sustainability factors before and after implementation or development of such infrastructure. The performance of transportation infrastructure projects can be sustained if attention is given to developing robust strategies to overcome or mitigate the impact of sustainability risks associated with the identified factors.

It is notable that environmental sustainability factors were not included explicitly in the study, albeit literature evidence as to their import. Sustainability in the current study was taken to be "the ability of a project to continue performing as was expected or projected over a long term, or throughout its life cycle. Therefore, the environmental sustainability aspect included was with respect to the impact on the condition of the infrastructure. Future studies could incorporate a wider scope to include environmental aspects to a greater extent. Additionally, the relative importance of the factors was not presented in the current study. Future studies could be dedicated to establishing the relative importance of the measures as well as the relations among the variables.

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