A Factor Analysis of Transportation Infrastructure Feasibility Study Factors: A Study among Built Environment Professionals in South Africa

Chioma Sylvia Okoro[1], Innocent Musonda[2], and Justus Ngala Agumba[3]

[1] Finance and Investment Management Department, Johannesburg Business School, College of Business and Economics, University of Johannesburg, South Africa
[2] Construction Management and Quantity Surveying Department, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa
[3] Building Sciences Department, Faculty of Engineering and the Built Environment, Tshwane University of Technology, Pretoria, South Africa
corresponding-author-chiomasokoro@gmail.com; chiomao@uj.ac.za

Abstract. Feasibility studies conducted at the initiation stage of transportation infrastructure projects inform decision-making regarding the proposed project's development. However, non-comprehensive feasibility studies lead to project failure at the operational stage. This study therefore investigated the critical factors that should be incorporated in a comprehensive feasibility study in order to make reliable investment decisions, which will in turn affect performance at a later stage. Empirical data collected from 132 built environment professionals in South Africa, were analysed to output descriptive and inferential statistics. The inferential statistics entailed factor analysis. Outputs were common factors and the minimum number of variables that contributed the most variance in the data set. Findings revealed that a six-factor structure including methods of appraisal, finance availability and source, user needs, local environment, available data and strategic support. By establishing critical factors to consider during the planning of infrastructure to ensure that a comprehensive feasibility study is achieved, the current study provides valuable evidence for transportation infrastructure stakeholders to make informed and reliable decisions about the worthwhileness of the projects they intend to invest in.

Keywords: Feasibility studies, Infrastructure, South Africa, Sustainability, Transportation

1 Introduction

Transportation infrastructure plays important roles in economic growth and development through by employment and wealth creation, trade costs reduction and facilitation of economies of scale and knowledge accumulation [1]. Therefore, achieving successful and sustainable projects should be the focus in transport project planning and development [2]. However, the sustainability of projects is partly marred by the inadequate extent to which factors that affect the development in its life cycle are considered at the planning stage. The success of a project is determined by the assumptions that are set during the feasibility process [3]. About 25% of projects fail; a further 20% perform better than expected; and the remaining 55% perform more or less as expected [4]. One of the main weaknesses in transport infrastructure sector is the lack of planning at the onset of projects, which has a ripple effect on the projects at the operational stage [5]. Often, the main cause of project failure is an inadequate understanding of the project viz-a-viz risks (deviation from expected or wanted results), rewards and a plethora of uncertainties which infrastructure developments are fraught with, with regard to costs, benefits, schedule, demand and risk estimation and control [6], [7]. Therefore, one of the ways to achieve sustainability of transportation projects is through attention to the factors considered during the feasibility stage (front-end considerations). This implies starting transportation infrastructure developments with the end in mind [8].

Previous studies have been conducted on the factors to consider during the planning of transportation infrastructure. For instance, [9] investigated sustainability element including social, economic and environmental factors, which should be considered during feasibility studies. [10] reviewed travel demand forecasting considerations. Similarly, [11] identified feasibility study considerations for transport infrastructure performance in an integrative review. Other studies identified that appraisal methods [12], criteria factors considered [13], [14], and data used in evaluation of projects [15], [16] are critical considerations in transportation infrastructure feasibility studies (TIFS). However, there is no consensus on the critical factors that should be considered in a comprehensive feasibility study.

The objective of the current study is therefore to establish the factors which are critical to a comprehensive feasibility study using factorial analytic techniques. The succeeding sections present brief overview of TIFS, the methods employed in conducting the study, the results and subsequently, conclusions drawn from the findings.

2 Transportation Infrastructure Feasibility Studies

2.1 Significance of feasibility studies

Proposed projects are analysed and evaluated to discover positions or situations, which may jeopardise the projects in the long run [17]. Feasibility studies identify risks to a project at the concept stage, which may affect the project during the operational stage. The feasibility study follows a process of conceptual ideation of a project and entails a detailed assessment of the viability of a project from different points of view including technical, financial, social and environment aspects as well as legal structuring to ensure value for money [18]. Feasibility studies entail testing the sustainability of structures and strategies (through indicators) and making statements about the future based on identified uncertainties.

Feasibility studies are useful in reducing uncertainties in order to make better decisions, which otherwise, can lead to disastrous consequences [16]. Moreover, the usefulness of the FS is linked to the significant decrease of the risks taken by the one who undertakes them, when attempting to capitalise on identified economic opportunities [19]. A poorly defined project, at the feasibility stage, will not deliver the same outcome as a well-defined project no matter how well it is executed and operated [20].

Inadequate feasibility studies result in scarce financial and natural resources being wasted since investment decisions and projects, which are usually capital-intensive (huge amounts of funds injected), are made and built with misleading information regarding their potential capacity to succeed (financially and otherwise) while in operation and to serve generations of users [21]. Consequently, very intricate and influential problems, which could be averted to a great extent in the planning of such risky endeavors, arise, if they are not given adequate consideration. Proficient planning and proper evaluation are needed to identify potential impacts, costs and benefits accruable to a project and thus resulting in improved decision making. Infrastructure project owners, decision makers, and investors decide to proceed with a given project (new and/or otherwise) based on the results of the feasibility studies carried out at the planning stage to identify different elements/aspects of the project that pose risks and may affect the expected revenue/returns from the project. Therefore, based on the outcome of feasibility studies, projects that deserve to be built are undertaken and those that do not are abandoned [21].

2.2 Factors incorporated in a comprehensive feasibility studies

Comprehensive feasibility studies include all elements that may impact on a project's performance [22]. Such factors include finance availability and procurement strategies [2], local environment [23], institutional support [24], and users' needs [25], [26], [27]. Therefore, a comprehensive feasibility study should consider a wide variety of project performance-influencers.

Extant literature revealed that a number of factors are considered in feasibility study and they may affect the quality of feasibility studies. For instance, the methods used in the appraisal of the investment, could result in different margins of error [12]. Some methods used singly, for instance, environmental impact assessment, could result in inadequate consideration of the interactions between various complex systems and influencers which could affect the project during the operational stage [15]. Other studies argued that irrespective of the methods used, the data may be manipulated by the people involved [28]. This suggested that the nature and availability of data used could influence the quality of feasibility studies [15], [16].

Literature further identified that considerable attention should be accorded to a plethora of factors that influence the comprehensiveness of feasibility studies in order to reduce errors and develop appropriate strategies to ensure sustainability [23], [27].

3. Methods

A quantitative approach was adopted to conduct the study. A pilot-tested field questionnaire survey was used to collect data regarding transportation infrastructure feasibility studies, quality of feasibility studies and project sustainability on a five-point Likert scale, with responses ranging from 1=strongly disagree to 5=strongly agree. The questionnaire was developed from an integration of findings from a literature review and qualitative enquiry (using interviews and document analysis).

3.1 Data collection

Ethical clearance was granted by the university authorities prior to the questionnaire distribution. The respondents, comprising built environment professionals in the nine provinces of South Africa, were selected using purposive and snowball sampling techniques. Consent was obtained from some of the participants' superiors as and where required. The questionnaire was distributed by hand, as well as online via email and google forms. These techniques were used in order to improve the response rate. A total of 132 questionnaires were returned and used for analysis.

3.2 Data analysis

The data were analysed using SPSS Statistics version 25 and SPSS AMOS version 25. Common factor analysis was conducted on the conceptual constructs and variables using maximum likelihood factoring to examine their underlying structures. Prior to the factor analysis, preliminary tests entailed assessing the suitability of the data for factor analysis using the Kaiser- Meyer Olkin (KMO) and the Bartlett's Sphericity tests. The KMO values should be greater than 0.6 and the Bartlett's Sphericity must be significant ($p \leq 0.05$) for a good factor analysis [29].

Maximum likelihood factoring was used to extract the common factors. The maximum likelihood factoring technique considers the shared variance (unlike principal components analysis), avoids the inflation of estimates of variance accounted for and assumes that individual variables are normally distributed (unlike the principal axis factoring) and was observed to be suitable for the non-normal data which was obtained [30]. The outputs from the factor analysis were "common factors", which were believed to account for most of the variance in the observed variables. These were rotated and interpreted using oblique rotation to determine the items which defined them the common factors. Items cross-loading or loading below 0.4 were deleted and the test was rerun. In addition, the decision on which factors to retain was made based on the Kaiser's criterion (to retain only the factors with an eigenvalue larger than 1 was primarily used), the scree plot (the number of factors above the break or elbow of the scree plot) and variance explained (as displayed on the pattern matrix, which showed the number of factors that cumulatively accounted for more than 70% of the variance and thus gives the most interpretable solution). The results of the analysis are presented in the succeeding section.

3.3 Validity and reliability

The qualitative information was obtained from the actual feasibility reports conducted on the projects as well as the custodians of the reports. This enhanced convincingness (validity of case research) [31]. The piloting and reviews of the questionnaire by the researcher's supervisors and statistician refined the tool and increased face or content validity. Internal reliability consistency tests for the TIFS measures was assessed before and after the EFA using the Cronbach's alpha test. The results of the constructs measuring TIFS before the EFA are presented in Table 1. The table indicates that the sub-scales had good internal validity, with values exceeding the recommended 0.7 [29]. Likewise, the collective results of the TIFS factors revealed that the measures before and after EFA were 0.94 (N=38) and 0.92 (N=23), respectively, and thus indicating good internal consistency [29].

Table 1. Cronbach's alpha test results before factor analysis

Construct		Cronbach's alpha	Mean inter-item correlations	Number of items
Transportation infrastructure feasibility study (TIFS)	Data used	0.72	0.25	8
	Criteria factors considered	0.93	0.39	21
	Methods used	0.89	0.51	9

4 Data analysis

4.1 Demographic characteristics of respondents

The respondents were made up of 69% public and 31% private entity professionals, with directors, deputy director and heads of departments forming the majority (25%) of the responses. Project managers made up 15%, and engineers and safety officers made up 12% and 10% of the population, respectively. Other positions indicated were executive/deputy managers (8%), development managers/ agents (6%), feasibility study consultants (4%), planners (4%), quantity surveyors (4%), academics (3%), and technical assistants on project (2%). The projects were new and expansion projects, comprising road (74%); rail (12%); bridge (8%); airport (3%) and tunnel (2%) projects. These statistics indicated that a varied and representative population was obtained, with the respondents having been involved in the different projects.

4.2 Factor analysis results

Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) value for the measure of sampling adequacy, the Bartlett's Spericity tests, as well as the communalities and anti-image matrix. The KMO value was 0.824, exceeding the recommended value of 0.6, and the Bartlett's test of sphericity reached statistical significance at p = .000 (χ^2 (703) = 3520.135), indicating factorability. Inspection of the correlation matrix revealed the presence of many coefficients greater than 0.03, and all the variables correlated with at least one other variable, indicating suitability of data for factor analysis. The anti-image correlation matrix, with diagonals all above 0.5 (ranging from 0.604 to 0.931) also supported the factorability of the data set. The initial communality estimates all had values greater than 0.4 and thus further indicating that the data was suitable for factor analysis.

The exploratory factor analysis revealed that nine factors, accounting for 73.27% of the total variance in the model, could be retained. This was also supported by the scree plot, which showed eigen values greater than 1, above the breaking point. However, since the purpose of the EFA was to determine the minimum number of factors underlying the structure, correlations among items, as well as items that did not load or had low loadings (below 0.4) on any of the extracted factors, the pattern matrix was examined for such items. Items loading below 0.4 and cross-loading on two or more items with > 0.32 were therefore deleted, respectively, and the test rerun. A six-factor structure emerged with item loadings well above 0.4 on the common factors (Table 2). It is notable that the fifth factor had only two items loading on it. However, it was still considered acceptable because the items were related to data and since data is indispensable in feasibility studies, these were considered important and therefore retained. The emerging common factors were named methods of appraisal, finance availability and source, user needs, local environment, available data and strategic support.

5. Discussion

The measures emerged as a six-factor solution, as opposed to the three-factor structure. The resultant factors were named as discussed hereunder, in relation to extant literature.

5.1 Methods of appraisal

This common factor contained elements which were initially theorised as methods used in feasibility studies [15], [32]. The first common factor had items loading strongly on them, including *best scenario outcome, site/location characteristics, design and scope requirements, traffic growth analysis*, *costs and benefits analysis,* and *multi-criteria analysis.*

5.2 Finance availability and source

The second factor comprised items related to financial connotations, which are critical in feasibility studies. These included *financial input from private investors, financial self-sustenance of the system, financing alternatives relative to costs (financial),* *existing financial and tender records* and *sources of project finance*. These were therefore named “finance availability and source” [33].

Table 2. Factor loading of transportation infrastructure feasibility study measures

S/No.	Label	Measures	Factor					
			1	2	3	4	5	6
1	ME2	Best scenario outcome	.982					
2	ME5	Site/locational characteristics	.888					
3	ME6	Design and scope requirements	.780					
4	ME1	Traffic growth analysis	.771					
5	ME4	Costs and benefits analysis	.731					
6	ME3	Multi-criteria analysis	.707					
7	CF15	Financial input from private investors		.981				
8	CF16	Financial self-sustenance of the system		.847				
9	ME7	Financing alternatives relative to costs (financial)		.546				
10	DA6	Existing financial and tender records		.540				
11	CF14	Sources of project finance		.516				
12	CF1	User comfort during travel			1.056			
13	CF2	Convenience to users			.920			
14	CF6	User safety			.601			
15	CF4	Speed and travel time			.571			
16	CF11	Condition of existing infrastructure, for upgrade projects				.935		
17	CF10	Structural capacity of existing infrastructure, for upgrade projects				.829		
18	CF12	Existing businesses/vendors				.493		
19	DA3	Audit observations and performance reports, for upgrade projects					.924	
20	DA2	Existing design and structural reports, for upgrade projects					.702	
21	CF20	Stakeholders' interests and needs						.832
22	CF21	Competing transportation modes within the locality						.569
23	CF18	Management capacity at operational stage						.482

Extraction Method: Maximum Likelihood.
Rotation Method: Promax with Kaiser Normalisation.
Rotation converged in 6 iterations.

5.3 User needs

Elements that related to users and their travel needs of transportation infrastructure congregated on the third common factor. These included *user comfort during travel, convenience to users, user safety* and *speed and travel time.* These items suggested reference to the experience or perceptions of end users or consumers of transportation infrastructure while in operation. Users of transportation infrastructure are external factors which could act on the level of investment, value-add or costs, with their input, perception or opposition and should be taken into account during feasibility studies [33]. Users are instrumental in directly influencing decision-making regarding transportation infrastructure and should be considered in feasibility studies [34]. Based on this notion, the user-related items, which loaded on the third factors, were collectively encoded as *user needs.*

5.4 Local environment

The fourth common factor consisted of factors connoting status quo with regard to infrastructure condition, structural capacity and businesses or vendors to be considered in the vicinity. Transportation infrastructure planning considers previous developments and current status in a catchment area (including the beneficiaries' and physical infrastructure conditions) in order to compare and develop and compare scenarios while predicting future impact, opportunities and benefits accruable from the project [18], [35]. Information on current trends and activities or patterns of behavioural and professional activities around the area, as well as services and facilities that could modify traffic flows (origin and destination) are vital considerations in transportation infrastructure feasibility studies. On this premise, *the condition of existing infrastructure and structural capacity for upgrade projects* as well as *existing businesses/vendors* were denoted as *local environment*.

5.5 Available data

The fifth common factor had two item-loadings on it. These included statements related to sources of data referred to during feasibility studies. These included *audit observations and performance reports, for upgrade projects* and *existing design and structural reports, for upgrade project.* This factor, although having only two item loadings, was retained because data is an essential component of feasibility studies. Data availability is an essential feature in the development of criteria to assess the level of sustainability of planned infrastructure during feasibility studies [34]. The term *available data* was therefore used for the fifth common factor.

5.6 Strategic support

The emerging structure on the sixth common factor showed variables that influence people's preferences among different modes and fulfil strategic intents and needs of various stakeholders in a bid to achieve failure-free infrastructure [36]. To avoid failures, operators make decisions regarding the performance of the project by involving different levels of executives and expertise in making strategic decisions based on stakeholder and professional input [37]. Based on these conceptions, the sixth common factor, with items including *competing transportation modes within the locality, stakeholders' interests and needs, management capacity during operations* and *was conducted by professionals with relevant experience on feasibility studies,* was denoted as "strategic support".

6. Conclusion

The study set out to establish critical factors which should be incorporated in a comprehensive transportation infrastructure feasibility study (TIFS). The objective of the current study was achieved through a factorial analysis of the TIFS measures. Findings revealed that methods of appraisal, finance availability and source, user needs, local environment, available data and strategic support are critical factors which should be considered during feasibility studies to ensure that comprehensive outcomes are obtained. This would in turn result in better and more reliable decision-making regarding the potentialities of proposed projects with regard to delivering intended objectives in the long run.

The validity and reliability of the research tool was demonstrated. A confirmatory factor analysis in further studies is recommended to validate the study.

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