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Critical Considerations in Transport Service Demand Forecasting: A Literature Review

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Abstract

Infrastructure plays important roles in the development of cities, improvement in the quality of lives and overall socio-economic development and growth of economies. Infrastructure projects are, however, fraught with uncertainties regarding costs, benefits and performance. These uncertainties, if not accurately predicted in the planning of projects, could result in undesirable financial, social and economic consequences. The aim of the current paper is to identify critical factors which influence transport infrastructure performance forecasting outcomes and which should essentially be considered in order to minimize or eliminate errors. A review of related literature was conducted from journals, conference proceedings, magazines, theses and dissertations using databases including Science Direct, Emerald, Ebscohost, Academic Search Complete and ASCE library. The studies reviewed were based on international and South African context. Results revealed that project characteristics including size of project, capacity improvement and time lapses between construction life cycle phases, availability and type of data used, methodology used as well as traffic demand factors influence the outcome and validity of transport infrastructure feasibility studies. The study provides invaluable information to built environment professionals and stakeholders as well as infrastructure policymakers in accurately assessing probable outcomes, positive, in terms of benefits and negative, with regard to costs of proposed projects in order to avoid financial and economic risks. In addition, the study will be indispensable to infrastructure financiers and developers in effective allocation of scarce construction/development funds.

Keywords: demand, forecasting, infrastructure, planning, traffic performance, transport

1. Introduction

Transportation infrastructure, like other forms of infrastructure, helps to shape an economy and quality of life, being a major component of economic activity and social sustainability, both in itself and as an input factor to most other sectors, meeting the demands for people and cargo delivery and providing access to working, shopping and travelling (Zou *et al.*, 2011; Kaare and Koppel, 2012; Cheteni, 2013).According to van der Westhuizen (2007), transit is perceived as a means of overcoming developmental and amenity challenges based on spill-over potentials such as the revitalization of neglected urban precincts. Countries require a well-developed transport infrastructure to compete internationally and to provide a high level of accessibility in terms of traffic and goods flows (Schuckmann *et al.*, 2012). Locations of households, businesses and social activities become more attractive and lucrative (Robins, 2015). Changes in land use,

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increase in property value and employment opportunities also emanate from transport infrastructure developments (van der Westhuizen, 2007; Renner and Gardner, 2010; Robins, 2015; Bon, 2015).

Despite the importance of transportation service to the economy and citizenry, transportprojects are complex and fraught with uncertainties with regard to cost, schedule, demand and risk estimation and control (Hampton, 2009; Kim, 2010; Salet *et al.*, 2013). These uncertainties, if not accurately predicted in the planning of projects, could result in undesirable financial, social and economic consequences. The aim of the current paper is therefore to identify critical factors which influence transport infrastructure performance forecasting outcomes and which should essentially be considered in order to minimize or eliminate errors.In order to achieve this, a review of extant literature is conducted with the objective of identifying critical factors for valid, reliable and holistically desirable estimates/predictions with regard to travel or transport service demand. The study provides information which will be useful to governments, project owners, financial institutions and investors in risk assessments of projects and decision-making regarding transport infrastructure investments. Low margins of inaccuracy in prediction of future performance and potential risks in transport infrastructure projects is critical as reliable predictions of performance can save significant amounts of public resources through better planning (Kuhi *et al.*, 2015).

The succeeding sections present the motivation/rationale for the study and related research on the subject area; a brief explanation of the research method employed; and results of this review. The paper concludes with a summary of the factors and recommendations to reduce forecasting accuracy as evinced from literature.

1.1 Motivation and related research

Transport infrastructure such as highways and railways, usually start with a single primary function (for instance, the interconnection of several urban nodes on a line of infrastructure), but in practice can become very complex (Salet *et al.*, 2013). Current approaches in handling these uncertainties and complexities in the planning of infrastructure projects are inadequate, adopting excessively simple structures to these complex projects and there is no consensus on how to improve (Salet *et al.*, 2013) in order to avoid undesirable financial, social and economic consequences. The inherent uncertainties and risks make it difficult for decision-making regarding investment in transport infrastructure. Transport project owners, decision makers, and investors decide to proceed with a given project based on the results of the feasibility study of travel demand on a particular project. Traffic/travel demand forecasts are used to determine the capacity of transport infrastructure. However, they appear to be uncertain, highly inaccurate and often displaying a concerning degree of bias (Nicolaisen *et al.*, 2012).

Highly inaccurate forecasts combined with large standard deviations translate into large financial and economic risks, which are unfortunately downplayed by planners and decision-makers, to the detriment of social and economic welfare (Flyvbjerg *et al.*, 2006; 2008). To determine the capacity and viability of proposed transport infrastructure projects, accuracy in forecasts during planning and feasibility studies should be achieved. Inaccuracies in forecasting outcomes expressed as forecasting bias (general tendency of deviation in a specific direction) and/or imprecision (general tendency of a large spread or deviation from the mean), both pose problems to the validity of subsequent decision support based on such demand forecasts (Nicolaisen *et al.*, 2012). High estimation errors can lead to politically untenable levels of under-

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utilisation or at the other extreme, high levels of congestion (especially in the case of road projects) and increased need for capacity expansion, all of which reflect inefficient resource allocation as limited funds, which could otherwise have been utilized for other necessary infrastructure development projects may have been wasted or will be channeled into the existing transport project. A case in point is the Gautrain service which currently requires additional trains to cater for the unexpected surge in the demand for the train service (Nicolaides, 2016). Another noteworthy example is the Kazungulabridge which is currently catering for an unexpected traffic flow from neighbouring countries which was initially not allowed for.Other undesirable eventualities could include contract renegotiations and flexibility of concession period for cost recovery (Welde and Odeck, 2011; Tan *et al.*, 2012).

Research on critical factors which influence transport infrastructure performance forecasting outcomes and which should essentially be considered during planning in order to minimize or eliminate errors is warrantedbecause as Wardman (2006) aptly stated, there is a need to constantly update parameters and framework to accommodate the influence of those factors. Due to the complex interaction between transport related activities and other parts of society, there is a wide range of impacts that are desirable to evaluate when appraising transport infrastructure projects in order to reduce inaccuracies in forecasts (Nicolaisen *et al.*, 2012).

Previous studies which have either dwelt on forecasting methodology used, nature of the project (including quality and capacity expansion) and availability of data (Flyvberg *et al.*, 2007; Locateli and Mancini, 2010; Nicolaisen *et al.*, 2012; Litman, 2015). Other factors such as traffic demand factors including level of economic activity (Wardman, 2006), demography (Nicolaisen *et al.*, 2012), tax policies and legislation (Musso*et al.*, 2012; Feng *et al.*, 2012); competing alternative modes in terms of parking availability, travel time, comfort, security, etc. (Wardman, 2006; Taylor, 2008; Zou *et al.*, 2011; Panou, 2014); living conditions and quality of life, cultural habits and societal norms (Zou *et al.*, 2011; Jarv *et al.*, 2012) have also been identified as influencing forecasting outcomes. However, although there has been extensive research on forecasting inaccuracy and causes of large magnitudes of inaccuracies in estimation, very few studies have incorporated all possible factors which could influence accuracy in prediction. Some literature focused on methodology and data availability on specific projects (Flyvberg *et al.*, 2007); some literature focused on income level as a determinant of Swedish public transport demand; and others focused onother traffic demand factors (Wardman, 2006; Taylor, 2008; Zou *et al.*, 2011; Panou, 2014). Attention to more variables which determine and cause variations in transport service demand is important in order to predict the future demand (Holmgren, 2013).

1.2 Research method

A detailed review and distillation of extant literature from online journals, conference proceedings, magazines, theses and dissertationswere conducted. Databases including Science Direct, Emerald, Ebscohost, Academic Search Complete, Google and ASCE library were consulted. Articles spanning a 10-year period from 2006 to 2015 were included based on their relation to the subject. Keywords and phrases including transport infrastructure, traffic/travel demand factors, forecasting accuracy, and forecasting/estimation methods in transport service demand forecasting were used in the search. Common themes which emerged from thematic analysis wereidentified and are presented hereunder.

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2. Critical Factors in Transport Infrastructure Performance Forecasting

Following the above discourse, this section reviews models which have been documented as predictive of performance of transport infrastructure projects in terms of traffic/travel demand.A panoply of factors have been propagated as influencing the outcome of estimation studies in infrastructure planning. These factors, which form the bases on which a project's benefits and implications can be evaluated, are indicated in extant literature and are discussed hereunder.

2.1 Forecasting method employed and variables included

Some studies contended that the forecasting methodology used for a given project influences the estimation outcome (Flyberg *et al.*, 2006; Jeerangsuwan *et al.*, 2014). The criterion for measuring adequacy of forecasts should ideally reflect the impact of the error into the decision that is going to be taken. Quantitatively, the forecast error in time Θ is the difference between the forecasted value and the actual value in time *t*, but subjective forecasting methods using judgements and opinions can also be employed (Hassan *et al.*, 2013). However, Etemadnia and Abdelghany (2011) opined that traffic forecasting methods/systems that have been used in recent times have been unable to meet the real-time processing needs, especially for large-size networks, and that there is a high dependency on historical information which could be misleading considering the highly dynamic and stochastic nature of congested urban networks. Rudžianskaitė-Kvaraciejienė *et al.* (2015) developed a model for prediction of effectiveness and impact of proposed and existing projects, based on return on investment/financial success and societal advantages. In the authors' opinion, environmental factors such as noise pollution, environmental protection measures, and health and ecological safety issues; social factors including creation of network places, local area image, service quality, and community consent; economic factors such as inherent risks, use of local resources, technology upgrading and business expansion; technical issues including performance qualities and durability; and financial factors such as degree of risk, financial sources, operation costs, investment demand and financial rates.

Rudžianskaitė-Kvaraciejienė *et al.* (2015) advocated the use of their model in early feasibility studies to determine the benefits and negative impacts of a proposed project which will reflect future acceptability and demand by the citizenry. However, the study included road infrastructure projects developed through PPPs and therefore might not be generalisable to other types of projects. This view was expressed in Flyvberg *et al.* (2006) and Jeerangsuwan *et al.* (2014) which concurred that projects develop and perform differently; concession rates and forecasting methodologies differ with project type, which may alter the traffic forecasted. For instance, variations in inaccuracy in rail projects occur due to trip distribution, deliberately slanted forecasts, forecasting model/methodology and trip generation, whereas, trip generation, land use development, trip distribution and forecasting models used, mostly cause inaccuracies with regard to prediction in road project performance (Flyvbjerg *et al.*, 2006). The traditional cost-benefits analysis of transport projects, such as used in Norway for road projects, relies heavily on the accuracy of the estimates being used (Welde and Odeck, 2011). If traffic levels turn out be significantly lower than the estimated, the total benefits derived from time savings, reduced accidents or lower-vehicle operating costs can be affected. On the other hand, the capacity relief on the congested links could turn out to be lower than planned, which may distort the viability of the project.

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Bianchi *et al*. (2014) developed a predictive model for financial performance and returns on infrastructure investment, using asset pricing models. Likewise, Kim (2010) propagated a cost-schedule-risk based model for assessing risks in mega construction projects. However, these models did not include risks associated with demand for services related to the projects.

In his study which assessed the strategies, actors and risks of Chinese infrastructure investment in Latin America, Gransow (2015) expressed that feasibility studies should include assessment of associated social and environmental risks. In the author's view, infrastructure expansion strategies should assess and promote associated social benefits such as poverty reduction. However, poverty reduction was unfortunately not high on the agenda of Japanese assistance to China in the infrastructure expansion strategies in 2008 and this resulted in large-scale consequences including displacements and environmental damage (air and water pollution).

Other studies contended that inclusion of factors which chiefly motivate the demand for a particular transport service is vital (Wardman, 2006; Jarv *et al.*, 2012; Musso *et al.*, 2012; Holmgren, 2013; Litman, 2015). Factors such as car ownership, quality of life, cultural habits, societal norms, vehicle operating costs, level of economic activity, policies and legislation (tax/toll fares), alternative land uses, competing transport modes (in terms of park-and-ride possibilities, length of trips and frequency of rides), security, extent of pollution, walking distance from station, travel time, income, employment, number in household, age, and so on, vary over time and should be critically considered in forecasting transport service demand performance.

2.2 Project characteristics

Causes of inaccuracy in predictions vary with the nature of project (Flyvberg *et al.*, 2006). Projects are dissimilar in terms of nature, size, type, participants and location (Jeerangsuwan *et al.*, 2014). For instance, for highway infrastructure, traffic demand risks and factors associated with project revenue are extremely critical because revenue from traffic volume is almost the only source of recovery of investments and making profits (Jeerangsuwan *et al.*, ibid.). In addition, the size of the project, which could influence the time-span, is critical. Attention to the traffic forecasted at the time of decision-making is critical as traffic volume generally follows a time sequence (Flyvberg, 2006; Liu and Sharma, 2007). Furthermore, forecasting outcomes could become obsolete if there are huge time lapses between construction life cycle phases, especially in the case of mega projects, which usually takes a number of years to implement (Flyvberg *et al.*, 2006; Kennedy, 2015). Improvements in capacity also influences demand for a particular transport service (Lee, 2008; Holmgren, 2013; Jeerangsuwan *et al.*, 2014).

2.3 Availability and type of traffic data

Accuracy of forecasts depends on accuracy of historical demand data used (Etemadnia and Abdelghany, 2011). In their study, Flyvbjerg *et al.* (2006) found that availability of/incomplete data influences feasibility outcomes. Obtaining data availability from public sector is an uphill and time-consuming process. Sometimes, "embarrassing data" that could make a project look bad in the public eye, might be held back, which may influence the outcome of prediction. This is especially prevalent in privately owned projects and in cases where forecasted traffic is much higher than the actual traffic. Readiness of project

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managers to release actual data to use in predictions, and use of adjusted data (instead of actual data) influence outcome and accuracy of predictions. Generated traffic data made up of excess, induced and diverted traffic data should be taken into account in estimation (Litman, 2015). Reference data used in forecasting (for instance, in some cases, data from the first year of operation of a similar project may not yield reliable results because the project has not stabilised) (Flyvberg *et al.*, 2006).

3. Summary

Extant literature revealed that non-validity of feasibility studies, managerial control, forecasting methodology used, time lapses between construction life cycle phases, nature of data used/available, nature of project as well as traffic demand factors such as level of economic activity, demography, tax policies and legislation, competing alternative modes in terms of parking availability, travel time, comfort, security, living conditions/quality of life, cultural habits and societal norms, and so oninfluence forecasting outcomes. These factors influence the degree to which forecasting outcomes are accurate with regard to knowledge and understanding of the variables and the processes involved in forecasting.

The uncertainty of traffic demand can be addressed by analyses of the above-discussed individual key variables taken one at a time. Although Tan *et al.* (2012) argued that some of the undesirable consequences of inaccuracy in forecasts can be overcome with improved flexibility in contracts (that is, shortening the term in case of high demand and *vice versa*), especially where the contract term is endogenously determined by the realized level of future demand and subsequent revenue/cash flow. In other words, the revenue from demand uncertainty could be moderated by the selection of flexible and adjustable contract variables (such as the toll charges and concession period) and the realized demand in turn depends on the road capacity and investment level.

4. Conclusion

The study set out to establish factors which could influence the accuracy of transport service demand forecasts. The factors have been established. The objective of the current study has therefore been met. There is a need to continuously review parameters and framework for more valid estimates especially with the numerous uncertainties and realities attributable to transport infrastructure investments.

The current study has a major limitation being a review paper. Therefore future studies could adopt primary data collection techniques to investigate the factors which should be included in transport infrastructure demand performance forecasting for infrastructure planning. In addition, the future research could explore application of different scenarios to investigate factors which could alter/moderate the demand for particular/specific modes of transport, especially in South Africa, where such research appears to be limited. There is a need to develop a more comprehensive and holistic model of feasibility factors for transport infrastructure planning.

These findings would provide invaluable information to built environment professionals and stakeholders as well as infrastructure policymakers in accurately assessing probable outcomes (positive and/or negative) of projects to avoid risks. In addition, the study will be indispensable to infrastructure financiers and developers in effective allocation of scarce construction/development funds.

ISBN 978-0-620-70336-9

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