Traffic demand determinants: A review of long-term scenario effects

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Abstract
Transportation infrastructure provision is critical to the development of urban areas. Transport infrastructure such as roads, bridges, and ports are increasingly becoming the corner stone in determining the strength of cities, improving the quality of lives and overall socio-economic development and growth of economies. However, these projects are stochastic in nature and fraught with uncertainties which, if not accurately predicted, can lead to inadequate assessment and management of risks. The aim of the present paper is to identify critical factors which moderate traffic demand over a long period of time, and which should ideally be included in transport demand forecasts. A detailed review of literature was conducted from online journals, conference proceedings and theses using databases including Science Direct, Ebscohost, Google, Emerald and ASCE Library. Findings show that socio-economic factors (such as income, age, employment, vehicle operating costs, fuel price and tax polices), socio-cultural factors (such as security, comfort, alternative/competing transport modes, leisure time), and environmental factors (such as pollution, traffic congestion, distance from station and frequency of trips) influence traffic demand. These findings would provide valuable evidence for adequate management of risks in infrastructure planning, and for public policy.

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

1. Introduction

Transport infrastructure, such as roads, railways, airports and bridges, facilitates mobility of people and specialized products and services which are essential for development and growth and enhances the value of land within the locality in which they are provided (Brown-Luthango, 2011). They make the location of households and their business and social activities more attractive and lucrative and increase demand for properties (Robins, 2015). Furthermore, employment opportunities are created for unskilled workers during construction and taxi ferrying of passengers to neighbouring areas (Robins, 2015). Suffice to say, transport infrastructure contributes to economic growth and social welfare (Doll et al, 2009). However, these projects are complex, stochastic and fraught with uncertainties, and if not accurately predicted, can lead to inadequate assessment and management of risks.

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. Along the line, they have to deal with the varying emerging purposes and interests in ever-changing and unpredictable context of possibilities, risks and constraints (Salet *et al.*, 2013).

Risk and uncertainty are issues of increasing concern in transport planning and inaccurate travel demand forecasts represent a major source of risk in the planning of infrastructure projects (Welde and Odeck, 2011). The proclivity to overestimate the demand for transportation infrastructure projects is profound. Travel demand forecasts appear to be uncertain, highly inaccurate and often displaying a concerning degree of bias (Nicolaisen et al., 2012). According to Flyvberg et al. (2006), inaccurate forecasts, especially with a large margin, result in substantial financial and economic risks which are profound, whatever the project. It appears that for most rail transportation projects, overestimation is common, with an average of 106% in 90% of the forecasted rail projects; while roadway traffic forecasts often underestimate the actual demand.

Likewise, van der Westhuizen (2007) argued that road projects around the world tend to notoriously underestimate demand by as much as 40%. In the author's opinion, proper risk analyses are not conducted and this results in substantially underestimated costs and risks. These views are echoed in Nicolaisen et al. (2012) who studied road and rail projects in Scandinavia and the United Kingdom and found an average overestimation of road projects by 11.12%. According to Nicolaisen et al. (2012) indicated a tendency for non-toll road projects to be underestimated whereas toll road and rail projects were overestimated. Parthasarathi and Levinson (2009) reached different conclusions, stating that highways, which have higher volumes and functional classifications, were generally underestimated. Such transport projects whose traffic demand forecasts were underestimated led to multi-million pound deficits because it was much more expensive to add capacity to the existing fully used roads than it was to build the capacity up front. The situation in South Africa is no different. Recently, it was reported that the Gautrain service demand was also underestimated, with passengers exceeding the forecasted number four years earlier than expected (Nicolaides, 2016). Consequently, more trains are required to cater for the current demand.

Therefore, estimates of the financial viability of projects are heavily dependent on the accuracy of traffic demand forecasts. Decision makers and investors base their investment decisions on the outcome of transport service demand forecasts. Furthermore, for highway infrastructure, traffic demand risk and risk factors associated with the project revenue are extremely critical because revenue from the traffic volume is almost the only source of capital recovery and profits from investments (Jeerangsuwan et al., 2014). 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 (Nicolaisen *et al.,* 2012). These include *inter alia* forecasting methodology used (Flyvberg et

al., 2006; Nicolaisen et al., 2012), incomplete information/availability/accessibility and type of data used (Locateli and Mancini, 2010; Nicolaisen et al., 2012; Litman, 2016), road quality/capacity improvement (Holmgren, 2013; Jeerangsuwan et al., 2014; Feng et al., 2015), managerial control, nature of the project, and time lapses between construction life cycle phases (Flyvberg et al., 2006; Holmgren, 2013). Other factors include variables related to the dynamics of demand for transport service and particular modes. These include inter alia, 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); level of economic activity (gross domestic product – GDP) (Wardman, 2006), living conditions and quality of life, cultural habits and societal norms (Zou et al., 2011; Jarv et al., 2012); as well as demographic factors such as income, employment and age (Nicolaisen et al., 2012).

Although these impacts have been extensively researched, there is a need to constantly update parameters and framework of demand variables, in particular, to accommodate their influence and make reliable decisions (Wardman, 2006; Holmgren, 2013). Moreover, it appears that few studies have focused on factors which potentially influence transport service demand in the long run. More often than not, short-term issues are often considered in forecasting models whereas long-term variables which reflect underlying drivers are rarely incorporated (Havenga and van Eeden, 2011). In contemporary times of major infrastructure spend in the developing world, and in the developed world as well, where infrastructure spend is attempted as a stimulus, underlying determinants over far longer periods should be considered (Havenga and van Eeden, ibid.). Furthermore, some literature focused on rail (Wardman, 2006) and airport (Panou, 2014) transport service demand.

The objective of the present paper is therefore to identify factors which moderate the demand for road transport service in the long run. The paper incorporates factors which chiefly motivate the demand for road transport services in relation to potential scenarios which could manifest in the long run. In the context of transport planning, scenarios adhere closely to the consensus definition of "narratives or sets of assumptions that explore plausible trajectories of change" (Liu, Balali, Wei & Peña-Mora, 2015), either in the short run (1 or 2 years), medium (5 to 7 years) or long run (more than 10 years) (Paulley et al., 2006; Musso et al., 2013). In addition, road transport infrastructure will be dwelt on because as Jarv et al. (2012), Musso et al. (2012), Holmgren (2013), Jeerangsuwan et al. (2014) and Litman (2016) rightly opined, inclusion of factors which moderate the demand for a particular transport service is vital since projects develop and perform differently while in operation.

A detailed review and distillation of extant literature from online journals, conference proceedings, magazines, theses and dissertations were conducted. Databases including Science Direct, Emerald, Ebscohost, Academic Search Complete, Google and ASCE library were consulted. Articles spanning an 11-year period from 2006 to 2016 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 were identified. The succeeding sections of this paper present the findings from the thematic analysis, a discussion and summary of findings and conclusion.

2. Road Transport Service Demand Determinants

As stated earlier, scenarios which explore plausible trajectories of change such as new developments, additional capacity or expansion, changes in policy and legislation, *etcetera,* and their influence on traffic demand are reviewed in this section.

2.1 Highway capacity improvement

According to Næss et al. (2012), the traffic generating effects of road capacity expansion are still often neglected in transport modeling and this omission can lead to grave bias in environmental impact assessments as well as the economic viability of proposed road projects, especially in situations where there is a latent demand for more road capacity. Concurring with these views, Litman (2016), in his study, demonstrated the elasticity of traffic volume in relation to road capacity expansion and found that more automobile-dependent urban fringe development is encouraged with highway capacity improvement. In other words, expanding urban roads brings about additional vehicle travel typically referred to as generated traffic, which should be taken into account in traffic demand estimation.

In addition, capacity expansion results in reduced congestion. Congestion impacts on travel behaviour by diverting traffic to alternative routes, destinations, times and modes, and reducing trip length and frequency (Jarv et al., 2012). According to Litman (2016), roadway improvements that alleviate congestion reduce the generalized cost of driving, making driving cheaper per mile or kilometer in terms of travel time and vehicle operating costs. However, Musso et al. (2012) argued that even when travelers appreciate the change in travel costs, their travel behaviour is mostly affected by habits (such as leisure trips, workplace and residential locations) which may eventually change gradually over the long run.

2.2 Level of economic activity

According to Musso et al. (2013), traffic demand is moderated by economic activity levels (represented by the Gross Domestic Product) or trends in an economy. This study investigated the effect of policy changes as a result of economic recession and subsequent price changes on traffic demand on a Greek motorway corridor. The authors opined that over time, price effects are taken into consideration by road users when making long-term decisions. The study further revealed that the Greek economic recession which brought about budget adjustments and tax policy changes increased fuel taxes and toll fares and as a result, traffic flows fell significantly (20.5%) over a five year period, especially on toll roads since people

tended to avoid the such routes, a view shared in a South African study on the e-toll road project in Gauteng (Matsiliza, 2016). Although tax policies (added to fuel price) and toll road fares are sustainable means through which federal governments fund infrastructure (Ngowi et al., 2006), unfavorable tax policies and toll legislations result in unwelcome travel price increases and generalized cost which in turn have a long-run effect on traffic demand (Musso et al., 2012; Feng et al., 2012).

Similarly, Wardman (2006) reported that the level of economic activity causes variations in car costs and journey times in Great Britain. Although this study dwelt on demand factors for rail travel, it explored external factors which could influence diversion to other modes of transport (including roads). The level of economic activity was identified as one of the external factors which appear to be beyond the control of a particular transport mode.

2.3 Competing alternative transport modes

Competing alternative modes of transport are external influences beyond the control of a particular mode or form of transport (Wardman et al., 2006). Travel time, length of trip, frequency of trips or waiting times, walking distance from stations as well as park-and–ride possibilities influence decisions made about use of a particular mode of transport (Holmgren, 2013; Panou, 2014). According to Zou et al. (2011), commuters are increasingly paying attention to the most economical mode of transport, the lowest energy consumption and pollution-free traffic modes. Reasonable transport modes, which offer a swift, secure and comfortable trip, advance social economy and reduce pollution and destruction of the environment to a maximal extent. In addition, the ease with which desired destinations may be reached or the ease with which people are able to participate in desired activities in different locations at a specific time determines the use of a particular mode of transport (Taylor, 2008).

2.4 New developments

According to Paaswell (2013), new transport developments increase access in a given locality and results in travel time savings; and access increases demand for developments (not limited to transport). Development in turn increases demand for travels, in addition to needs for additional energy, water, new bandwidth for IT and communications, which in turn attracts more people to the locality, resulting in urbanization and urban sprawl, which in turn increases demand for transport service (Bhatta, 2010; Jarv et al., 2012). However, Næss et al. (2012) argued that travel time saving benefits not materialize due to additional traffic, since demand could become so high on the new infrastructure that congestion occurs.

2.5 Land use changes

The study by Jarv et al. (2012) revealed that urban sprawl in turn results in varying land use changes which influence traffic demand. This study explored the relationship between suburban land use (in terms of road usage for different purposes such as work, leisure,

shopping, *etcetera*), and transportation. The authors determined that land use changes due to suburbanization and urban sprawl influence traffic demand. The authors further observed that societal structures and dynamics including growth in prosperity, shift in labour market, globalization (constant increase in movement of people, goods and information, adoption of information and telecommunication technologies and growing social networks influence travel behaviour in the long run.

2.6 Socio-economic factors

Factors such as level of income, lifestyles, car ownership, living conditions/quality of life, and employment levels affect demand for transport services, especially for public transport (Khoo, 2012; Musso et al., 2012; Holmgren 2013). As people become wealthier, the proportion of income devoted to transport increases (Musso et al., 2013).

3. Summary of Findings

Traffic demand is influenced by a plethora of factors, and at varying degrees over varying time periods. Elasticity values of traffic and the magnitude of influence are mainly determined by economical, financial conditions and geographical frameworks (Musso et al., 2013). These factors which influence demand for road transport services in the long run, as evinced in extant literature, can also be classified as:

- *Environmental factors*, new developments, technological advancement, road quality, alternative land uses and traffic congestion;
- *Economic and financial factors,* consisting of policies, population, level of economic activity, fuel price changes, vehicle price and operating costs and time value (Wardman, 2006; Musso et al., 2012; Holmgren, 2013); and
- *Socio-cultural factors,* encompassing living conditions/quality of life, leisure time, car ownership, business time, walk distance from station, competition with other modes of transport (travel time, park and ride possibilities, and waiting time for rides/frequency) and security (Zou et al. 2011; Holmgren, 2013; Panou, 2014).

It is notable that these factors are inter-dependent and do not influence traffic demand in isolation (Wardman, 2006; Jarv et al., 2012). For instance, car ownership in a household depends on income levels which depend on employment which could in turn be dependent upon the level of economic activity. Road developments facilitating traffic speeds result in generated and induced (additional) traffic by influencing land use and quality of public transport services in the long term (Næss et al., 2012). Therefore, consideration of these factors holistically will result in greater accuracy in prediction of traffic demand.

4. Conclusion

The study sought to identify critical factors which moderate traffic demand in the short and long term, and which should ideally be included in transport demand forecasts. The objective

has been met. The identified wide range of factors and their effects make it difficult for policy makers and investors to decide whether a project is worthwhile to invest in or to undertake and prioritise among different competing projects and with limited availability of resources. More accuracy in forecasting during transport infrastructure planning will achieved if all potentially demand-related determinants are included. Since forecasting is a vital input for broader policy-making in land use decisions, economic growth and environmental impact assessments and cost-benefit analysis, the findings of this study would influence transport policy and investment decisions.

The current study has one obvious limitation, being a review paper. Therefore, future studies could explore the relationship amongst these factors and traffic demand variations as well as prediction accuracy, using alternative research techniques.

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