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A desk study of road infrastructure performance measurement criteria

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Abstract

Transport infrastructure meets the demands for people and cargo delivery by providing access to working, shopping and travelling and improving the quality of life of citizens. Road infrastructure needs to be sustained for eons after its development. However, there is no consensus on the criteria upon which the operational performance of road infrastructure projects is assessed. This paper aims to identify all potential criteria for assessing road projects in operation. A desk study was conducted using relevant journal and conference papers obtained from databases including ASCE Library, Science Direct and Ebscohost. Thematic analysis was used to identify emerging themes from extant literature. The themes were tabulated and ranked based on their frequency of occurrence to determine the most important criteria for measuring the performance of road projects in operation. Findings indicate that institutional productivity and effectiveness, operational efficiency, health and safety, mobility, environmental element, public acceptability, asset value, legal and technical factors can be used to assess the performance of road projects. The study provides vital information which would be beneficial to project managers, and indeed investors, in assessing and projecting sustainable performance of road projects in operation.

KEYWORDS: performance, performance measurement, roads, transportation

1. Introduction

Transportation infrastructure meets the demands for people and cargo delivery by providing access to working, shopping and travelling and improving the quality of life of citizens. Countries require 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). Road transport infrastructure, in particular, facilitates mobility of people and specialized products and services

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which are essential for development and growth, meets the demands for access to working, shopping and travelling, enhances the value of land within the locality in which they are provided and improves the quality of life of citizens (Brown-Luthango, 2011). Road networks make the location of households and their business and social activities more attractive and lucrative, increase demand for properties and encourage changes in land use (Bon, 2015). In addition, employment opportunities are created for unskilled workers during construction and taxi ferrying of passengers to neighbouring areas (Renner and Gardner, 2010; Bon, 2015). Suffice to say, road transport infrastructure contributes to economic growth and social welfare (Doll *et al.*, 2009).

However, despite their contribution to the development of economies, road transport projects may become very complex, although they usually start with a single primary function (the interconnection of several urban nodes on a line of infrastructure) (Salet *et al.*, 2013). Along the line, they have to deal with the varying emerging purposes and interests in ever-changing and unpredictable context of possibilities and constraints (Salet *et al.*, ibid.). This unpredictability affects performance of road projects both in the short and long term and therefore they have to be managed to ensure that they continue to fulfill the objectives for which they were initially planned and constructed and do not disrupt the lifestyle, health, wellbeing and quality of life of the citizenry for which they are planned (Kaare and Koppel, 2012; World Bank, 2013). Hence, research on the indicators to measure performance of road transport projects is important. Performance measurement of road projects, which relates to how well a system is fulfilling or meeting its set of predicted goals and objectives, is essential for effective planning and management (Dhingra, 2011). It includes various parameters that track a system's ability to achieve intended objectives.

Copious studies have been conducted on the indicators of road transport performance. However, these studies were not really comprehensive, focusing on one or two factors, and/or excluding important aspects that affect the quality of life of the citizenry directly or indirectly. For instance, Dhingra (2011) focused on public transport service systems; Litman's studies (2011; 2017) dwelt on mobility and accessibility; Faturechi and Miller-Hooks (2015) reviewed performance measures related to physical performance (robustness, resilience, and so on) and travels only, and ability to withstand or absorb pressure or demand (travellers'behaviour) in the event of uncertainties such as natural disasters, bombings and/or terrorist attacks; and more recently, Yatskiv and Budilovich (2017) evaluated the transport system in Riga with a focus on sustainability. Another study (Haas *et al.*, 2009), although comprehensive, satisfaction of users among social values, as well as preservation of green spaces and wildlife welfare. In addition, Ramani *et al.* (2009) and Kaare and Koppel (2012) identified performance measures in terms of sustainability including financial, environmental and social indicators.

The present study identifies all possible indicators (measurable and immeasurable) that reflect road infrastructure performance, especially those which can be relatable to the users, and their wellbeing and satisfaction. The objective of this study is therefore to identify all possible criteria on which road infrastructure performance can be assessed and the level of attention given to the wellbeing and satisfaction of the citizenry (users). The findings from the study will be useful to planners,

investors and policy makers in assessing prosperity of investments in terms of holistic achievements of social, financial and economic objectives. Performance measurement allows transit planners and operators to determine if resources are used efficiently and equitably, as well as to identify potential problems, and verify whether a particular improvement strategy achieves its predicted targets with regard to satisfaction and quality of life of the public (users). Hence, it paves way for course correction which translates into a constant effort at improving services to match standards, whilst considering its impact on the community. The succeeding sections describe the methodology employed in conducting the study, the findings and conclusion drawn from the study.

2. Methodology

The current study is part of a preliminary investigation in a wider study investigating prefeasibility factors that should be considered to predict performance of road projects. A review of literature was conducted from databases including Science Direct, Google, Google Scholar, Taylor and Francis and ASCE Library. Materials for review were sought using relevant keywords including performance, roads and transport, and combined with words and phrases such as measurement, indicators, success and so on. Materials were chosen if they met the following criteria: possession of the relevant keywords, and currency (published in the last twelve years, from 2006 to date). Each piece of literature was reviewed and synthesized to determine the focus, context and key findings. Findings were synthesized using thematic analysis, to identify emerging road transport performance factors discussed in the literature, and to create new findings (Thomas and Harden, 2008). The indicators appearing mostly were also shown, to reflect the degree of consensus or agreement among the authors in the sampled literature.

3. Road Transport Infrastructure Performance Measurement

Road infrastructure performance measures or indicators are transport statistics which are used to evaluate progress toward established goals and objectives (Dhingra, 2011). According to Kaare and Koppel (2012) and Schiff *et al.* (2013), performance indicators depend on the objectives for which the investment was made. If a given road project performs as intended in terms of originally set objectives, then success is said to have been achieved performance of road projects in operation can be deemed successful if it achieves and continues to achieve the objectives for which it was initially implemented (Kaare and Koppel, 2012). This view was also supported in a report on a road transport project in Brazil (World Bank, 2013). The report indicated that the project was expected to contribute to economic development through reduction of road transport costs, increasing competitiveness in domestic and external markets, improving social benefits by facilitating access to social services, reducing travel times, sustainability of transport investment programs by supporting the federal transport agency in improving effectiveness of environmental and social impact mitigation policies. It was therefore evaluated based on the level of satisfaction by which those parameters were perceived.

Similarly, Estonia's road transport development whose objectives were to reduce transport costs, improve road safety and road administration and improve competitiveness in trade, was evaluated based on those measures. Other factors include cash flows, customer feedback and growth potential. These output measures can help to establish and quantitatively measure effectiveness of the project, transaction and transportation costs, which could partly be influenced by the degree of efficiency of roads (quality and speed), predictability, safety, security, comfort and reliability of travel, travel times, and so on. Nonetheless, performance measures used should be suitable and appropriate for planning and evaluation purposes (Dhingra, 2011).The factors which have been identified to measure performance of road projects are discussed in the next section.

3.1 Measures of road project performance

Extant literature indicated a plethora of road projects performance indicators. These are discussed hereunder, according to their frequency of occurrence in the sampled literature, to show the consensus and discourse on the themes in literature.

3.1.1 Productivity and effectiveness of the transport system

The level of efficiency and/or productivity and effectiveness of the transport system can reflect its performance. According to Haas *et al.* (2009), productivity and effectiveness of the transport system reflect costs and benefits ratio, maintenance costs and learning possibilities. Operational efficiency relates to the volume of service outputs and/or margins that are realised from the quality of resource inputs (capital, labour, fuel) (Matsuo, 2015). Indicators here include load factor, cost-per-vehicle-kilometer, response to accidents and injuries, rate of detection of accidents, response time to incidents and complaints, and traffic delay due to maintenance works (Haas *et al.*, 2009; Ramani *et al.*, 2009; Dhingra, 2011).

Other studies suggested that productivity and effectiveness of the funding institution also reflects the performance of the road transport system since it affects the flow and adequacy of finance for the transport activities to remain in a state as to continuously command the set fares or tolls. The measures of institutional effectiveness include internal rate of return, net present value, incitement of commerce to communities, assurance of liquidity cushion, cost recovery(revenues/expand ratio, revenue/maintenance expenditure ration), economic or expenditure productivity (total, expansion and betterment, presentation, operations and administrative expenditures), economic returns (cost effectiveness, benefits, network depreciation – current value of roads and replacement cost), shortfalls or lags (quantity and value of backlogs); and service demand (Briefing Memorandum, 2007; Bryce, 2008; Haas et al, 2009; Kaare and Koppel, 2012; Bivens, 2014; Liepziger and Lefevre, 2015; Liu *et al.*, 2015; Liyanage and Villalba-Romero, 2015; Rudžianskaitė-Kvaraciejienė *et al.*, 2015).

3.1.2 Environmental elements

Environmental elements include environmental protection and quality factors such as air and noise pollution (atmospheric levels of carbon monoxide, nitrous oxides and particulates), proportion of green area preserved, welfare of wildlife, and percentage of investment in environmental protection (Ramani *et al.*, 2009; Haas *et al.*, 2009; Kaare and Koppel, 2012; Liu *et al.*, 2015; Liepziger and Lefevre, 2015; Rudžianskaitė-Kvaraciejienė *et al.,* 2015; National Geographic, 2016). Road transport activities produce pollutants, which can cause unfavourable and undesirable changes in the environment by altering a species' growth rate, interfering with food chains, and disrupting health, comfort, amenities and human property values (Razak et al., 2013). In the opinion of the National Academies of Sciences (NAS), 2005), ecological concerns should be balanced with goals of transportation mobility, capacity and social needs in determining whether and how to undertake projects. Street ambience and aesthetics (trees, public art, scenic views, *etcetera*), parking and pedestrian countdown signals enhance the attractiveness of the environment as well as lifestyle and should be considered in road transport (VanZerr and Seskin, 2011; Schmale et al., 2015).

3.1.3 Acceptability

The level of acceptability or opposition to the subject project reflects performance. According to Carter (2015) and Mišic and Radujković (2015), public acceptability should be a vital consideration in road transport performance measurement since it affects the demand for services provided by the network, which in turn invariably affects the cash flow accruing to an investor. For instance, in Mišic and Radujković (2015), it was reported that public opposition to the development of the Lignes a` Grande Vitesse Me´diterrane´e in Paris resulted in the passing of a statute to ensure that there is public debate about future infrastructure developments at the time of decision to build and understanding and subsequent acceptability by the public. Other studies suggested that willingness to pay, number of complaints, acceptable tariff levels, and perceived level of satisfaction from services (security and delays) reflects acceptability (Briefing Memorandum, 2007; Canterelli *et al.*, 2010; Liu *et al.*, 2015; Liepziger and Lefevre, 2015; Osei-Kyei and Chan, 2016).

3.1.4 Social benefits

Social benefits relate to the experience of users, which are important for developing public transport systems that respond to demands and so are able to attract even choice riders. This needs serious attention in most developing cities today, but are sometimes ignored in transport planning (Dhingra, 2011; Randolph, 2016). Measures of social benefits consist of rider comfort/convenience (ride quality, road smoothness and quality), travel speed and reliability, affordability, integration and satisfaction, cost reduction of accidents, number of displaced families/individuals, travel time reduction, vehicle operating costs reductions, increase of welfare of communities, and unit saving in fuel (Briefing memorandum, 2007; Bryce, 2008; Haas *et al.*,

2009; Dhingra, 2011; Liepziger and Lefevre, 2015; Liu *et al.*, 2015; Rudžianskaitė-Kvaraciejienė*et al.*, 2015; Mišic and Radujković, 2015).

3.1.5 Mobility and accessibility

According to Litman (2017), mobility refers to the physical movement, measured by trips, distance and speed. Accessibility is the ease with /which people reach desired destinations and/or participate in activities from specific locations to a destination using a mode of transport at a specific time (Taylor, 2008). Increased mobility increases accessibility, which refers to people's overall ability to reach services and activities and therefore the time and money that people and businesses must devote to transportation. Factors that affect accessibility includes motor vehicle travel conditions (car travel speeds, affordability and safety), quality of other modes (walking, cycling, public transit, delivery service speeds, convenience, comfort, affordability and safety), transport network connectivity (quality of connections between modes such as the ease of walking or cycling to public transport stations), and land use proximity (development density and mix and thus, distance s between activities). These measures include congestion, average travel speed, detours, closures and road restrictions and access to jobs and labour (Taylor, 2008; Ramani *et al.*, 2009; Haas *et al.*, 2009; Kaare and Koppel, 2012; Liepziger and Lefevre, 2015).

3.1.6 Asset value

Asset value has to do with preserving and maintaining the quality of existing assets to continuously be consistent with set toll fees, and thus leveraging the maximum possible funding (Ramani *et al.*, 2009). Due to declining fuel tax revenue on existing highway infrastructure and possibility of new highway projects, the quality of highways must be maintained. Measures here include rate of depreciation, reduced replacement cost, reduced impact of expansion, leveraging non-traditional funding sources (Haas *et al.*, 2009; Ramani *et al.*, 2009; Kaare and Koppel, 2012). Asset value also has to do with the technical aspects of roads including design risks and functionality, designed life span of road (in years), adoption of sustainable material and renewable resource, and improved road network density (Liu *et al.*, 2015; Liyanage and Villalba-Romero, 2015).

3.1.7 Health and safety

Vehicle safety, pedestrians' and cyclists' protection as well as serious road injuries reduction are priority interests and major concerns with most agencies and countries (Transportation Association of Canada (TAC), 2006: European Transport Safety Council (ETSC), 2016). Safety can be compromised by use of mobile phones while driving, drivers' fatigue, etc. (ETSC, 2015). The performance measures include accidents rates per million vehicle kilometers (number of accidents), rates of crash risk and stress (TAC, 2006; Haas *et al.*, 2009; Kaare and Koppel, 2012; Liepziger and Lefevre, 2015).

4. Implications and Conclusion

The afore-discussed factors were identified from the sampled literature, as being reflective of road transport performance. They are summarized in Table 1 based on their frequency of occurrence among the sampled literature. The way in which transportation is evaluated can affect planning decisions. Institutional productivity and effectiveness, followed by environmental elements, acceptability, social benefits, and mobility and accessibility, seemed to be the most frequent indicators emerging among the sampled literature. This implies that in addition to the economic returns attracted by road transport infrastructure investments, environmental and social benefits/values are also attached and should be given consideration in transport planning. If social benefits such as travel time reduction, comfort and convenience (ride quality) and reduction in congestion are the bases of evaluation, then roadways' quality should be improved. Likewise, if acceptability is the basis, then engagement with the public/users of the system should be a priority since this will in turn increase service demand and willingness to pay which will invariably contribute to the rate of cost recovery and return on investment.

Furthermore, mobility and accessibility is considered to be important in evaluating performance of transport system. On these bases, transit service and alternative modes of transport (cycling and walking) should be improved to avoid congestion, improve travel speed and provide alternative routes and modes of access to opportunities (work, school, etc.). Health, safety and security seemed to be the least considered factors among the sampled study. This is concerning since the health and wellbeing of the users should be of paramount concern given that they are the one who inhabit and use the transport networks and structures and are expected to be for the services accruing from the existence of the network. As such, their health and safety should be given considerable attention. Another possible explanation for the health and safety outcome could be that the elements are intertwined and related to other factors. For instance, improving the quality of the transit service will improve their response to accidents and complaints (operational efficiency) and increase acceptability as well. This suggests that the factors could be interrelated and further studies could explore this relationship.

Table 1a: Summary of identified road project performance indicators

Indicator	**Measures**	**Source**	**Year**
Institutional (funding structure) and operational productivity and efficiency	- Internal rate of return	- Briefing Memorandum	2007
	- Net present value	- Bryce	2008
	- Incitement of commerce to communities	- Haas *et al.*	2009
	- Assurance of liquidity cushion	- Ramani *et al.*	2009
	- Cost recovery	- Kaare and Koppel	2012
	- Economic productivity	- Bivens	2014
	- Service demand	- Liepziger and Lefevre	2015
	- Response to accidents and injuries	- Liu *et al.*	2015
	- Rate of detection of accidents	- Liyanage and Villalba-Romero	2015
	- Response time to incidents and complaints	-Matsuo	2015
	- Traffic delay due to maintenance works	- Rudžianskaitė-Kvaraciejienė *et al.*	2015
Environmental elements	- Air and noise pollution	- NAS	2005
	- Proportion of green area preserved	- Ramani *et al.*	2009

	- Percentage of investment in environmental protection - Street ambience and aesthetics	- Haas *et al.* - VanZerr and Seskin - Kaare and Koppel - Liu *et al.* - Liepziger and Lefevre - Rudžianskaitė-Kvaraciejienė *et al.* - Schmale *et al.* - National Geographic	2009 2011 2012 2015 2015 2015 2015 2016
Acceptability	- Acceptable tariff levels - Willingness to pay - Number of complaints - Level of opposition - Perceived satisfaction from services (security and delays)	- Briefing Memorandum - Canterelli *et al.* - Liu *et al.* - Mišic and Radujković - Carter - Liepziger and Lefevre - Osei-Kyei and Chan	2007 2010 2015 2015 2015 2015 2016
Social benefits	- Cost reduction of accidents - Number of displaced families/individuals - Travel time reduction - Vehicle operating costs reductions - Increase of welfare of communities - Unit saving in fuel - Comfort/convenience (ride quality, road smoothness, quality) - Congestion	- Briefing memorandum - Bryce - Haas *et al.* - Liepziger and Lefevre - Liu *et al.* - Rudžianskaitė-Kvaraciejienė *et al.* - Mišic and Radujković	2007 2008 2009 2015 2015 2015 2015

Table 1b: Summary of identified road project performance indicators (continued)

Indicator	**Measures**	**Source**	**Year**
Mobility and accessibility	- Congestion - Average travel speed - Detours - Closures and road restrictions - Access to jobs and labour	- Taylor - Ramani *et al.* - Haas *et al.* - Kaare and Koppel - Liepziger and Lefevre - Litman - Yatskiv and Budilovich	2008 2009 2009 2012 2015 2017 2017
Quality /Asset value/ Technical/engineering aspects	- Ride quality (convenience) - Rate of depreciation/maintenance frequency/replacement cost - Maintaining quality consistent with the set toll fees - Reduced impact of expansion - Design risks and functionality - Designed life span of road (in years)	- Haas *et al.* - Ramani *et al.* - Kaare and Koppel - Liu *et al.* - Liyanage and Villalba-Romero	2009 2009 2012 2015 2015

	- Adoption of sustainable material and renewable resource - Improved road network density		
Health and safety	- Perception of safety - Number of accidents - Rates of crash risk - Stress	- TAC - Haas *et al.* - Kaare and Koppel - Liepziger and Lefevre	2006 2009 2012 2015

The objective of the study, which was to identify road performance measurement indicators, has been achieved. Through a review of selected literature, institutional productivity and efficiency, acceptability, social benefits, environmental elements, mobility and accessibility emerged as the most considered indicators. With these findings, the current paper adds to the body of knowledge on road performance measurement indicators and in addition, presents evidence of the most considered indicators in performance measurement to ensure that road projects continue to perform as they were intended.

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