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Assessment of transport performance index for urban transport development strategies — Incorporating residents' preferences

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ABSTRACT

The performance of urban transport depends on a variety of factors related to metropolitan structure; in particular, the patterns of commuting, roads and public transport (PT) systems. To evaluate urban transport planning efforts, there is a need for a metric expressing the aggregate performance of the city's transport systems which should relate to residents' preferences. The existing metrics have typically focused on a measure to express the proximity of job locations to residences. A Transport Performance Index (TPI) is proposed in which the total cost of transportation system (operational and environmental costs) is divided by willingness to pay (WTP) for transport plus the willingness to accept (WTA) the environmental effects on residents. Transport operational as well as the environmental costs are derived from a simulation of all transport systems, to particular designs of spatial development. Willingness to pay for transport and willingness to accept the environmental effects are derived from surveys among residents. Simulations were modelled of Surabaya's spatial structure and public transport expansion. The results indicate that the current TPI is high, which will double by 2030. With a hypothetical polycentric city structure and adjusted job housing balance, a lower index occurs because of the improvements in urban transport performance. A low index means that the residents obtain much benefit from the alternative proposed. This illustrates the importance of residents' preferences in urban spatial planning in order to achieve efficient urban transport. Applying the index suggests that city authorities should provide fair and equitable public transport systems for suburban residents in the effort to control the phenomenon of urban sprawl. This index is certainly a good tool and prospective benchmark for measuring sustainability in relation to urban development.

1. Introduction

Rapid expansion of urban areas, a worldwide phenomenon, causes imbalances in the spatial set-up of cities areas and shortcomings in transport performance. This phenomenon results in congestion and air pollution and also living conditions for residents are strongly affected. Assessment of improvements to urban development, including its transportation systems, should include the preferences of the residents comprising economic, environmental and social aspects. Ultimately, the goal for improvement of a city is the optimization of residents' welfare. As a consequence, residents' preferences are required to assess and to evaluate the importance and contribution of investments in urban transport planning. This concept forms the background for the formulation and application of a performance index as proposed in this paper. The proposed performance index focuses on transportation systems related to spatial development and is henceforth known as Transport Performance Index (TPI).

The TPI shows the extent to which the transport systems satisfy residents' demands; it could also be called more generally an index of sustainability. Optimization of a bottom up approach aims to encourage residents to cooperate with city planners which can be realized by employing TPI. This study focuses on prioritising residents involvement alongside city planners, government staff and housing developers in urban transport planning.

The phenomenon of urban sprawl driving development has resulted in an inefficient mismatch between employment, living and transport. The supply of transport infrastructure does not keep pace with housing expansion in the suburbs. Most cities in developing countries are expanded dramatically. The extensive growth in economic and residential development has significant consequences for mobility. Traffic congestion in most cities in developing countries

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has risen since the late 1990s; predominantly due to increasing numbers of motorcycles and cars. To solve traffic problems related to the phenomenon of urban sprawl, it is necessary to consider an urban space-transport development by including residents' preferences. The preferences are required to evaluate the performance of transport infrastructure as well as the residential locations and conditions. The aim to incorporate residents' preferences is to consider the requirements for adequate sustainable development; from the environmental to the economic and social aspects.

Previous research has formulated an assessment tool for determining sustainable development, namely the ISSI (Integrated Global Sustainable Development Index) based on public welfare, environmental quality, and resource use (Ronchi et al., 2002). The introduction of a multidimensional vector presentation tool is to assess the trends of each index component and the whole indices. Another index related to assessment of the current mobility conditions of cities in Brazil is the Index of Sustainable Urban Mobility (I_SUM). This index was designed to assess urban mobility and to anticipate the impact of strategies on sustainable mobility in nine groups covering thirty-seven criteria. The index is expected to become a benchmark for sustainable mobility (Costa, 2008; Miranda and Rodrigues da Silva, 2012).

Mori and Christodoulou (2012) reviewed some indicators in order to introduce a new city sustainability index aimed at evaluating and assessing a city's sustainability performance in developed and developing countries. This index was intended to provide local authorities with sustainable guidelines, focusing on the global impact of cities on the environment and human life, more than on economic contributions. Awasthi et al. (2010) used AHP and Dempster-Safer theories to evaluate a sustainable transport solution according to a number of criteria, i.e. cost, fuel consumption, air quality, noise perception, number of users, congestion levels, user's satisfaction, security and accessibility. The criteria were selected in a design of Transport Sustainability Index (TSI) for evaluating car sharing in Canada based on stakeholders' preferences.

Numerous studies have been conducted on public preferences, as the power of citizens is a concern of planners and any stakeholder groups in urban and infrastructure developments. Public participation is required in virtually every country or political jurisdiction in order to establish laws for environmental impact assessment (Seymoar, 2001). Public involvement is needed to control spatial development related to transport improvement, particularly in developing countries. Limapornwanitch et al. (2004) carried out a review of group stakeholders to evaluate transportation improvements and land-use controls in large-urban regions in Bangkok. Regarding some stakeholders' preferences, this study highlighted the importance of public preferences by proposing a Zonal Impact Analysis (ZIA). This framework was designed to evaluate strategic planning to balance travel demands resulting from land development and the performance of the transport system in urban areas. It was applied in the Bangkok Metropolitan Region, comparing single as well as simultaneous development cases. In evaluating transport diversity in the Taipei Metropolitan Area, George (2001) focused on the importance of stakeholders' preferences for measuring the gap between the goal and present values of stakeholders' needs in the form of the Shannon-Weaver Index.

The above previous studies, such as Mori and Christodoulou (2012) ; Awasthi et al. (2010) on the assessment of urban transport performance have insufficiently addressed the effect of urban sprawl on transport. An integrated approach comprising spatial and transport solutions is deemed necessary to address these problems; simply improving public transport is not expected to effectively solve these mobility and environmental problems. Furthermore, residents' preferences are required to evaluate sustainability with reference to housing development in the suburbs and to enhance residents' role in this development.

The purpose of this paper is to formulate and apply a TPI to integrated space-transport options for the city of Surabaya based on residents' preferences. Alternative developments, consisting of combinations of different spatial planning and transport systems are formulated and tested using simulation modelling. The total residents' values for the transport system in terms of the willingness to pay for transport and the willingness to accept the environmental effects have been derived based on a survey of residents' preferences. This research focuses on assessing TPI based on residents' preferences in the public transport performance and living conditions aimed at choosing an optimal spatial transport system in order to minimise the impact of urban sprawl. The index is drawn up as an assessment tool to manage spatial development related to the supply of public transport. The previous indices from other studies focused on assessing mobility and the supply of transport, while TPI is based on integrated space-transport developments.

The results of the analyses of this paper will be valuable to city planners and the government for assessing the best options to improve mobility, to decrease air pollution and to assess the performance of the city on mobility relative to residents' preferences; the results will set up a benchmark for controlling housing development, particularly in the suburbs, incorporating local residents' preferences on mobility and living conditions. This research focuses on solving urban transport problems by considering residents' preferences related to the public transport performance and living conditions. The city authorities should supply satisfactory public transport systems and living conditions for residents in suburbs. This index is expected to be a valuable tool, a prospective benchmark, for measuring sustainability in relation to city development.

Analyses methods are presented in Section 2. Section 3 summarizes the current situation pertaining to space and transport development in the city of Surabaya. Section 4 elaborates on residents' preferences and the estimation of Willingness to Pay (WTP) for transport and Willingness to Accept (WTA) environmental consequences. The results of the assessment of the TPI to various space and transport interventions for the city of Surabaya are elaborated in Section 5. Conclusions and recommendations are presented in Section 6.

2. Methodology

This section describes the survey/data collection in the case study area, the computational framework used to analyse the performance of space-transport interventions and the set-up of the transport performance index.

2.1. Data collection based on the survey

Four space-transport alternatives for the development of the city of Surabaya were analysed to illustrate the application of the TPI. The alternatives were analysed by two models; that is, the Java Spatial Model (JSM): a spatial settlement model which uses input from statistics on population and employment in the 2010 census, socio-economic scenarios, and spatial planning interventions and a transport model, OmniTRANS, which used a population/employment projection to generate transport demand and to compute transport flows for these different modes of transport, such as motorcycle, car, bus, minibus, bicycle, monorail (MRT), tramline (LRT), and bus rapid transit (BRT) .

The transport and spatial models required socio-economic and transport behaviour data as well as the schemes on zones and transport networks. Analysis of population, employment, attractiveness variables and land-use for each of the 163 "desas" (sub districts) in the city was based on 2010 Census data.

Fig. 1 presents a map of Surabaya City showing its subdivisions in "desas". The city has a population of approximately three million,