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Sustainability impact assessment of transportation policies – A case study for Bangalore city

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ABSTRACT

The first part of the current study proposes a model for assessing the impact of various transportation policies and projects based on the variation in three pillars of sustainability – environmental, economic and social. The methodology consists of determination of different indicators of sustainability pillars and thus the Composite Sustainability Index (CSI) before and after introduction of a transportation policy. Indicators include air pollution indicators, natural resource consumption indicators, health indicators, accessibility indicators, mobility indicators, commute indicators, and cost indicators. CSI is obtained by summing all these indicators after weighing them using an Analytical Hierarchy Process (AHP). The indicator value under a transportation policy scenario is obtained using the mode shift found using a mode choice model incorporated with the policy variable.

The second part consists of a case study for the city of Bangalore where the sustainability impact due to introduction of congestion pricing in the CBD, during peak hour, is tested. A choice model developed from Revealed Preference data (RP) is used in the study. The choice model estimated a reduction of 14.11% and 2.4% respectively in the total trip distance travelled by car and bike trips after introduction of congestion charging. There was also an increase of 1.7% in CSI because of congestion pricing.

1. Introduction

Urban form and transport system have an enormous impact on the way people travel. With the rapidly growing economies and population, typically seen in developing countries, there is an increasing trend of expansion of urban sprawl and auto-based mobilization. This has a direct effect on the level and form of the transport demand pattern. In the absence of the implementation of proper policy measures like parking charges, congestion charging, fare revisions, pedestrianization etc., it also leads to an increased additional cost for transportation infrastructure and its operation, while at the same time, creating many environmental, economic and social problems. In India, the Ministry of Urban Development (2013) has released an advisory for the Urban Local Bodies of various Indian cities for the introduction of Congestion Charging in the central business districts of the cities. Congestion Charge is a measure to reduce congestion by charging a fee on motor vehicles (cars and two-wheelers) entering the congested areas (central business districts) of the cities. The aim of this charge is to ease out the heavy motor vehicle volume found in the central areas of the cities and at the same time generating funds for transportation infrastructure development.

Sustainable transport systems are those which aim to reduce emissions, fossil fuel consumption, and the consumption of natural land, while providing easy access to people. Here more emphasis is laid on reducing the role of the private automobiles as the prime mode of transportation and shifting travel towards other sustainable modes such as public transit, cycling and walking. Sustainability of any system can be evaluated in terms of society, economy and environment – the three pillars of sustainability. For comprehensive sustainable development it is essential to monitor these three pillars with potential indicators that are reflective of changes in the travel behaviour of commuters. In the present study, a model is developed to quantify sustainability in terms of a Composite Sustainability Index (CSI) which captures the indicators of the three pillars of sustainability in a quick and comprehensible manner and that could be used to assess various transport policies and projects. Later, a case study is done using the proposed methodology to test the impact of congestion charging in

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Bangalore city. This is done by using the proposed sustainability model to find the Composite Sustainability Index (CSI) before and after the introduction of congestion charging. Bangalore is facing problems of inefficient mobility and decreased levels of performance in the urban transport sector with a peak hour speed of 13.2 kilometre/hour (km/h) (Comprehensive Traffic and Transportation Plan for Bangalore 2007).

2. Literature review

There has been a growing body of literature advocating the development of sustainable indicators to support urban planning process (Jeon and Amekudzi, 2005; Litman, 2013). Indicators in this context are standardized measures suitable for analyzing and evaluating the importance of targeted outcomes. For example, a measure such as vehicle kilometres travelled (VKT) per capita can be used as an indicator to evaluate the level of mobility in the part of city where the policy is to be brought in. Various methods have been proposed in the past to devise sustainable indicators that could be used to gauge progress towards sustainability. The general consensus is that urban sustainability can only be achieved by addressing various aspects that are related to the pillars of sustainability: (1) environment, (2) society, and (3) economy. The existing body of literature suggests that the sustainability of alternative future policies can be evaluated by calculating several indicators (i.e. quantifiable measures of particular outcomes) pertaining to a list of pre-defined themes that correspond to the three pillars of sustainability. The objective is then to combine those indicators to identify which of the alternative policies will result in minimizing negative environmental and social outcomes, while maximizing economic benefits. The following Table 1 summarizes the past studies done in related areas.

Most of the studies in the past have emphasized more on environmental parameters, and social and economic factors have not be addressed adequately. While studies in the past have devised various indicators, they have not attempted to build the sustainability model out of them and demonstrate their use to assess transport policies. This study is an endeavour to address this limitation of the previous research projects.

Many studies in the past have also looked at the impact of congestion pricing on modal split. Xu et al. (2008) in their study had established that congestion pricing influences the choice of mode and in turn the modal split. The study used the discrete choice model for modal split calculation by using SP survey data of Beijing city. Meng and Liu (2012) have proposed a combined modal split and traffic assignment problem assuming binary logit model for calculating modal split for a bimodal system. Using traffic data from downtown Singapore, they concluded that cordon-based congestion pricing has significant influence on the mode-share of public transport system. Some of the studies also dealt with the environmental and socio-economic impacts of congestion charging. Beevers and Carslaw (2010) studied the impact on vehicular emissions for London and observed that the vehicle speeds increased significantly after congestion charging. They also found a 19.5% decrease in CO_2 emissions. Rich and Nielsen (2007) compared various road pricing schemes for socio economic benefits in terms of the reduction in congestion time, car mileage, accidents, noise, maintenance cost, etc. They established that the socio-economic surplus of the projects depended crucially on the congestion level.

However, these studies are limited to evaluating the impact of congestion charging on the modal split and evaluating the environmental, economic and social impact separately. The current study addresses this limitation by providing a composite measurement of sustainability impact of congestion pricing combining environmental, social and economic impact.

3. Methodology

This section presents a methodology framework for determination of impact of polity decisions like charging for parking, congestion charging, fare revision, pedestrianization etc. on composite sustainability. The three components of this frame work are the Composite Sustainability Index determination, mode choice analysis, and the Analytical Hierarchy Process. The aim here is to determine the variation in the Composite Sustainability Index occurring as a result of implementation of a policy decision. A Composite Sustainability Index is a function of sustainability pillars (Section 3.1) which in turn are defined by its sustainability indicators under various themes (Table 2). The sustainability pillars are a linear additive function of its weighed sustainability indicators (Section 3.1) wherein in the weights are determined using the Analytical Hierarchy Process (AHP). These sustainability indicators identified are dependent on the vehicular composition and the vehicular composition is in turn dependent on the mode choice model consisting of policy variables. So a Composite Sustainability Index may be defined as a variable expressing the combined effect produced by the different contributing indicators which capture the policy impacts, as a single variable. A policy maker can find the vehicular composition under the current scenario, and under the new policy scenario by varying the policy variable (in the case study to follow in Section 4 travel cost is taken as the policy variable to accommodate the effect of congestion pricing), and consecutively determine the sustainability indicators and the Composite Sustainability Index for pre and post policy scenarios. Sections 3.1–3.3 explain in detail each component of the methodological frame work.

3.1. Composite Sustainability Index determination

Kelly (1998) identified several criteria for evaluating sustainability indicators in the study of an urban system. He notes that any devised indicator should be:

Table 1
Summary of past studies.

Quantifying sustainability	Testing policies
Strategic environmental assessment for sustainable urban development (Shepherd and Ortolano, 1996)	Utilization of sustainability indicators and impact through policy learning in the Malaysian policy process (Hezri, 2004)
An indicator based approach to measuring sustainable urban regeneration performance (Hemphill et al., 2004)	Incorporating sustainability into transportation planning and decision making: definitions, performance measures and evaluation (Jeon and Amekudzi, 2005)
A tool for evaluating urban sustainability via integrated transportation and land use simulated models (Maoh and Kanaroglou, 2009)	Impact of modal shift on transport ecological footprint: a case study of proposed BRTS in Ahmadabad, India (Brajacharya, 2008)
Developing a sustainability assessment model: the sustainable infrastructure, land-use, environment and transport model (Yigitcanlar and Dur, 2010)	