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## Performance assessment and evaluation method for passenger transportation: a step toward sustainability

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## ABSTRACT

Performance assessment of urban passenger transport is relevant since it causes economic, environmental and social impacts. Thus, this paper proposes a structured method to assess and evaluate the performance of passenger transport systems. Assuming that an eco-efficiency analysis is a step toward sustainability, we applied the method in a Brazilian case considering eco-efficiency measures, to show its potential as a tool to support decisions. We concluded that neither the most used alternative nor the one with the highest capacity attained the best eco-efficient performance, which can be explained by the low occupancy rates. Focusing on the latter, we propose some actions – based on the Brazilian and international literature – that can be implemented to improve its performance.

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### 1. Introduction

Transport activities are important for economic development, allowing flows of goods and services between production and demand zones, besides mobility and accessibility of the population. Nevertheless, they bring social and environmental impacts, which can be positives or negatives (Santos and Ribeiro, 2013).

From an economic standpoint, the transport sector creates jobs and contributes to the gross domestic product (GDP). In 2013, it was responsible for approximately R\$ 64 billion in the Brazilian economy (5.3% of GDP) (IBGE, 2014).

However, transport activities cause environmental impacts, mainly atmospheric pollution and greenhouse gas (GHG) emissions, noise, water and soil pollution and visual intrusion (Leal Jr and D'Agosto, 2011; Baptista et al., 2012). We highlight that in 2013, 57.3% of Brazilian consumption of petroleum-derived fuels was for transport, making this sector the largest consumer of fossil fuels (non-renewable) in the country (EPE, 2014).

Regarding social impacts, transport activities contribute to income distribution –creating jobs – and reduce the difference

between urban and rural zones, improving the quality of life. Although there is disagreement among the authors surveyed, the social impacts are mostly related to land use, accessibility, mobility, security and equity (Kennedy, 2002; Markovich and Lukas, 2011; Figueroa and Ribeiro, 2013; Smith et al., 2013; Alonso et al., 2014).

Concerning passenger transport in urban centers, the flow of people tends to be more intense (Alonso et al., 2014), especially if the work, study and/or leisure areas are geographically distant and far from residential areas. These aspects directly affect transportation demand (ANTP, 1997), and due to the configuration of Brazilian passenger flows, where 92% of trips are by road (MME, 2012), transport intensifies social and environmental problems.

Thus, in order to reach the goals of sustainable development, the transportation sector should be evaluated (Santos and Ribeiro, 2013) from the economic, social and environmental aspects. Assuming the possibility of modal choice, we ask: How can one evaluate the performance of urban passenger transport alternatives considering at least two aspects of sustainability?

This paper proposes a method to evaluate and assess the performance of urban passenger transport systems. We aim to: (1) analyze conceptually the aspects related to passenger transport alternatives and their economic, social and environmental impacts; (2) propose a set of indicators to assess the urban passenger transport alternatives; and (3) apply the proposed method in a

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Brazilian case, considering the eco-efficiency concept as a step toward sustainability.

This study is relevant because the transportation sector, as a driver of economic development, must fit the principles of sustainable development (United Nations, 1972, 2015; Santos and Ribeiro, 2013; Figueroa and Ribeiro, 2013). This theme is important to public and private sectors, which as grantors and operators should be concerned about economic, social and environmental factors (UNDESA, 2015).

## 2. Performance assessment and sustainability in passenger transport

According to WCED (1987), sustainable development means meeting current needs without compromising the ability of future generations to meet their own. Thus, reaching sustainability in transport implies in finding a balance (current and future) of economic, environmental and social aspects (Steg and Gifford, 2005). Moreover, sustainable transport must be integrated to sustainable development strategies (United Nations, 2015).

In this sense, a transportation system should satisfy the basic needs of sustainability, considering human and ecosystem health, maximum volumes of GHG and pollutant emissions, and at the same time meet the criteria of accessibility, equity and efficiency (Figueroa and Ribeiro, 2013; Alonso et al., 2014). This definition is according to the principles of the United Nations Conference on the Human Environment (1972), which involve environmental preservation and also, social and economic development (e.g., principles 8 and 15). With a slightly different focus, the Framework for Strategic Sustainable Development (FSSD) proposes, based on four sustainability principles (most of them about environmental concerns), a five-level framework to help plan sustainable complex systems (The Natural Step, 2015).

Based on United Nations (1972, 2015) and Alonso et al. (2014), Fig. 1 summarizes the relation between the sustainability concept and its main aspects. It shows that the intersection between two aspects creates a new one – eco-efficiency – which is composed of economic and environmental aspects (WBCSD, 2000). It partly explains the conceptual confusion related to the sustainability concept (which requires consideration of economic, environmental and social aspects jointly). It also helps to understand why the same indicator sometimes is related to two different aspects. Total travel time, for instance, can be considered economic, when it is understood as productive time (Santos and Ribeiro, 2013; Alonso et al., 2014), and social, related to the service level (Kennedy, 2002).

Thereby, in the transportation sector, these three aspects (Fig. 1) are in constant interaction (either for passengers or goods). Besides this, transportation modes cause different impacts with diverse intensities. These impacts vary according to the type of vehicle and

its average age, the intensity of use, the occupancy rate, and the type of fuel, among other factors. Table 1 summarizes the main impacts found in the literature, focusing on passenger transportation.

In order to evaluate the economic, environmental and social impacts of different transport modes, performance assessment methods can be applied. The evaluation can consider these aspects jointly (as sustainability, congregating the three of them, or eco-efficiency, considering only economic and environmental aspects) or individually, depending on the decision-maker's goals.

Thus, performance assessment in transport is defined as a set of procedures that allow analyzing with reasonable certainty whether the movement demands (of people or goods) are according to the predefined criteria and/or attributes (Leal Jr and D'Agosto, 2011). Based on this diagnosis, the main intention is to improve service (Manhein, 1980; Morlok, 1980).

According to Leal Jr and D'Agosto (2011), there are five interdependent elements used to evaluate transport performance, as presented in Table 2.

Regarding the performance assessment in passenger transportation, Table 3 presents a survey of studies that consider aspects of sustainability.

Although the analysis of Table 3 cannot be generalized, the evaluation considering economic aspects is predominant (84% of the papers), followed by environmental (68%) and social (40%). Besides this, 64% of them evaluate at least two aspects together.

Regarding the categories of evaluation, seven papers are concerned about sustainability in transport (28%), six about efficiency (24%), six about eco-efficiency (24%) and six cover other categories (e.g., efficacy).

Given these findings, eco-efficiency is a step to achieve a sustainable development (Charmondusit and Keartpakpraek, 2011; Kiellenniva et al., 2012). The basic difference among them is that eco-efficiency disregards the social dimension – despite its importance (Mickwitz et al., 2006).

Thus, eco-efficiency analysis is considered a step toward sustainability, since most times the latter cannot be evaluated due to the lack of data and the difficulty of measuring the social aspect (as Lemos et al., 2014).

The adoption of eco-efficiency measures for performance analysis of transportation can bring benefits, since this concept leads organizations to become both more environmentally responsible and profitable, by applying innovations to increase their competitiveness (WBCSD, 2000, 2006).

Eco-efficiency analysis requires specific measures based on the relative value of the service (or product) and environmental influences, as presented in Eq. (1), proposed by WBCSD (2000). Value of service is represented by indicators related to the passenger movement (number or monetary value), while environmental influences are related to environmental impact indicators.

$$\text{Ecoefficiency} = \frac{\text{Value of service}}{\text{Environmental influences}} \quad (1)$$

Eq. (1) shows that an increase in the value of service and/or a reduction in environmental influences improve the eco-efficiency measure, and hence corporate performance. Performance is measured by the direct relationship between how much is produced (value of service) and the resources used (environmental influences).

## 3. Evaluation and assessment method for passenger transportation

Considering that method is a set of ordered procedures and/or steps applied to evaluate and assess the performance in the transport sector, we conducted a survey to find structured methods

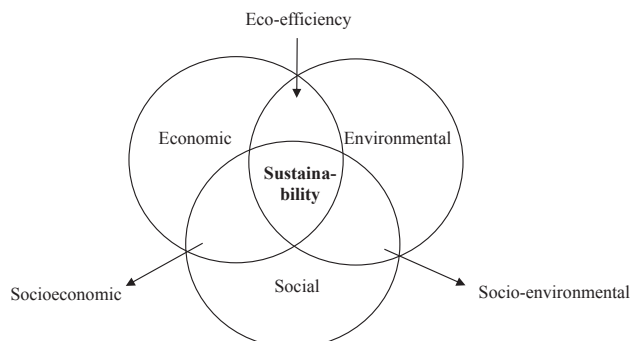


Fig. 1. Relation among the aspects of sustainability.

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