



Evaluating the sustainability of urban passenger transportation by Monte Carlo simulation

Vanessa de Almeida Guimarães^{a,*}, Ilton Curty Leal Junior^b, Marcelino Aurélio Vieira da Silva^c

^a Centro Federal de Educação Tecnológica Celso Suckow da Fonseca - CEFET/RJ, Rua do Areal, 522, Sala 4D, Parque Mambucaba, Angra dos Reis 23.953-030, RJ, Brazil

^b Programa de Pós-Graduação em Administração, Universidade Federal Fluminense, Rua Desembargador Ellis Hermydio Figueira, 783, Bloco A, Sala 304, Aterrado, Volta Redonda 27.213-145, RJ, Brazil

^c Programa de Engenharia de Transportes, Universidade Federal do Rio de Janeiro, COPPE/UFRJ, Centro de Tecnologia, Bloco H, sala 111, Cidade Universitária, Rio de Janeiro 21.949-900, RJ, Brazil

ARTICLE INFO

Keywords:

Performance evaluation
Sustainability
Probabilistic behavior
Monte Carlo simulation

ABSTRACT

Evaluating the performance of transportation usually is based on average indicator values, incurring a risk of failure to diagnose the system's real performance. Besides this, despite the effort to improve sustainability in this sector, the evaluations generally focus on economic and environmental aspects, avoiding the social ones due to the difficulty in measuring it. Therefore, the general objective of this article is to assess the performance of passenger transportation alternatives by applying Monte Carlo simulation to economic, social and environmental indicators. For this purpose, we examined the alternatives for the route between the cities of Rio de Janeiro and Niterói (located on opposite sides of Guanabara Bay), because of its importance to circulation in the Rio de Janeiro metropolitan region. Besides this, we compared the results of the simulation with the performance ranking obtained by applying average values of the selected indicators. We found that the use of mean values can underestimate or overestimate the performance of the alternatives, besides not considering the uncertainty associated with the indicators. The collective transportation alternatives performed best in the assessment with average indicators, with a tendency to show better performance levels in the probabilistic evaluation. Finally, the indicator with the strongest influence on the performance of the individual transportation alternatives was cost, while trip time was most relevant in the collective alternatives.

1. Introduction

The sustainability of the transportation sector has attracted a great deal of interest by the scientific community [1] and public policy-makers [2], because at the same time that transport activities have economic importance, they also have environmental and social impacts [3,4]. Therefore, sustainable management of transport systems should be integrated with the strategies for sustainable development in general [5].

For a transportation system to be considered sustainable, it should meet the needs of commercial relations, be easily accessible to the population and at the same time be structured so as to minimize energy consumption and carbon emissions, besides being safe and assuring high quality of life [6]. As framed by Santos et al. [2], sustainability in the transport sector should be examined considering the social, environmental and economic aspects (a position corroborated by Litman [1] and Guimarães and Leal Junior [7]).

In the case of passenger transportation in urban centers, the

dispersion of daily activities in relation to residential areas increases demand for mobility [7–9]. In Brazil, 92% of passenger flows are by roadway and most cities face intense traffic problems [10], so the search for more sustainable transportation alternatives is particularly urgent since the impacts of transportation are generally more acute in urban regions [8].

One of the challenges of sustainability is performance assessment, in which respect studies [7,11,12] in general use deterministic values of performance indicators to represent the system's behavior, given the difficulty of obtaining data. However, statistically speaking these values may not be sufficient to reflect the true dimensions of the performance of a given transportation alternative [13,14]. The use of means, for instance, if related to high standard deviation, can lead to partial conclusions that may not represent the case under assessment in its real perspective.

Therefore, simulation techniques can be applied to consider the uncertainties of performance assessments, since they adopt the confidence intervals – a numerical interval that represents an estimated

* Corresponding author.

E-mail addresses: vguimaraes@id.uff.br (V.A. Guimarães), iltoncuty@id.uff.br (I.C. Leal Junior), marcelino@pet.coppe.ufrj.br (M.A.V. da Silva).

Nomenclature

MCS	Monte Carlo simulation
RJMR	Rio de Janeiro metropolitan region
AHP	Analytic Hierarchy Process
GRA	Grey Relational Analysis
TOPSIS	Technique for Order Preference by Similarity to Ideal

Solution

C	Cargo
P	Passenger
B5	Name of the blend of petroleum diesel oil and a percentage 5% of biodiesel
UN	United Nations

parameter of the population [15] – instead of means values of the variables. Then, it comes to Monte Carlo simulation (MCS), a technique used in many areas of science to simulate problems that can be represented by stochastic processes [16].

MCS relies on a sequence of random numbers to carry out a simulation [16]. This enables obtaining a probability distribution of the performance of transportation alternatives regarding sustainability instead of a single value to represent this performance. Thus, the decision making process might become more accurate since the manager would decide based on a set of possible performances related to the several values that an indicator can have in a interval of data. Then, it also could picture more scenarios than the classic sensitivity analysis, depending on the number of simulations performed (as presented in the literature discussion in Section 2).

Considering the possibility of modal choice (and of the transportation alternatives that compose each mode), the following question arises: How accurate would estimation of the sustainability of urban passenger transportation alternatives be considering that the system has probabilistic behavior?

Therefore, the main objective of this article is to assess the performance of passenger transportation alternatives based on application of Monte Carlo simulation to the economic, social and environmental indicators. For this purpose, we focus on the alternatives for the route between the cities of Rio de Janeiro and Niterói, chosen because of its importance to the circulation of people in the Rio de Janeiro metropolitan region [17]. This route can be covered basically by two means: (i) private vehicle or bus over the Rio-Niterói Bridge; or (ii) passenger ferry between the downtown regions of the two cities.

The specific objectives are: (i) to formulate indicators that can be used to evaluate the sustainable performance of the passenger transportation alternatives between the two cities; (ii) to apply the method proposed by Guimarães and Leal Junior [7] to evaluate the sustainable performance of those alternatives; and (iii) to compare the results found with MCS to those obtained by application of mean values.

This research is relevant since the performance evaluation in transport sector usually applies scenarios or sensitivity analysis to deal with the stochastic behavior of the data; while MCS can combine a huge set of possibilities (100,000 cases, in this paper), ranging the values of different indicators at the same time. Then, future academic researches, feasibility projects or new public policies in transport could be more accurate if they adopted MCS in the assessments.

Besides, including the social dimension in the performance analysis is a great contribution of this paper, considering that the literature surveyed (and presented in Section 2) points out the difficult in incorporate this aspect in the assessment due to the complexity in measuring it.

Moreover, sustainability is a topic of interest of different stakeholders due to the several kinds of negative impacts that come from the transport activities, crossing over other sectors (e.g. influencing the economic feasibility of a whole supply chain, or environmentally, by pressing for extra carbon credits needs). Therefore, as propelling of economic development, transportation sector must be aligned to the sustainable principles [4,5,18].

The article is divided into four more sections after this introduction: (i) discussion of sustainability involving transportation; (ii) description of the methodological procedures; (iii) presentation and discussion of

the results; and (iv) final considerations.

2. Sustainability involving transportation

The discussion of sustainable development, originally focused on consumption of resources, is now defined more broadly as involving a combination of economic and social well-being, fairness, human health and environmental integrity [3]. Therefore, the planning of sustainable transportation entails recognition that the decisions in this sector cause varied impacts that need to be considered in the decision-making process [1].

Besides covering economic aspects, many works discuss the environmental impacts of transportation systems or modes [12,19–24], while social aspects are examined by others [4,8,18,25–27]. We searched the international literature for works on sustainability of transport systems, finding that the theme has attracted a good deal of attention from the scientific community. The discussion is concentrated on the proposal of indicators to assess the sustainability in this sector.

From the 96 papers raised, we evaluated those that consider, at least, three dimensions of sustainability (economic, social and environmental), as presented in Table 1. We verified that the theme is investigated either to passenger or freight transportation. Further Bojkovi et al. [28], Litman [1] and Litman and Burwell [3] evaluate these two modalities of transportation in their research.

Besides the traditional dimensions of sustainability, some authors as Litman [1], Rajak et al. [33] and Miller et al. [34] propose other categories that should be included in the assessment, such as: Transportation System Effectiveness and Good Governance and Planning. In the other hand, although [7] deal with the traditional dimensions, the case of study only considers the environmental and economic ones.

All papers in Table 1 propose and/or apply indicators related to different dimensions of sustainability. Figueroa and Ribeiro [18], Litman [1], Litman and Burwell [3], Santos and Ribeiro [4] and Rajak et al. [33] perform a literature review and propose indicators to assess the sustainability of the transportation system or specific modes. The others go beyond and evaluate the sustainable performance in transport with some of the proposed indicators.

There is certain coherence in relation to the indicators. Regarding the economic dimension, they are mainly related to productivity, impacts of transport activity in GDP, costs and investments in transportation. With respect to the environmental aspect, the papers deal mostly with energy consumption, atmospheric emissions, noise pollution and land use. Concerning to social dimension, there is greater occurrence of indicators related to: health and safety of population, mobility, accessibility, trip time and equity.

Table 1 also shows that the papers consider the different transportation alternatives available, either to freight or passenger transportation. About the methodological concerns, we found that they apply literature review and content analysis methods, fuzzy logic, multi-criteria decision aid techniques (as GRA, AHP, TOPSIS) or a combination of two or more techniques. Nevertheless, only Awasthi et al. [29] and Guimarães and Leal Junior [7] perform sensitivity analysis. Despite of applying MCS, Miller et al. [34] did not generate the probability curves of performance with the sustainable indicators. The authors analyzed the changes in the performance rankings by modifying the weights of the selected variables.

Download English Version:

<https://daneshyari.com/en/article/8110793>

Download Persian Version:

<https://daneshyari.com/article/8110793>

[Daneshyari.com](https://daneshyari.com)