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Modeling urban transfer stations efficiency

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Abstract

Efficiency estimation of transit transfer stations (TTS) in densely populated urban areas is a mandatory step to define proper sustainable public transportation networks. However, due to the lack of data and the complexity of the operation patters, efficiency assessment is a cumbersome task in practice. This paper presents a novel approach to establish relative efficiencies in order to optimize TTS operation and design. Using the Data Envelopment Analysis method (DEA) three key efficiency dimensions are studied, which corresponds to the pillars of sustainability: technical, social and environmental. Efficiencies were computed using a database generated including 39 TTS located in Mexico City Metropolitan Area. Results show that none of the stations analysed are completely efficient considering the three dimensions simultaneously. Technically efficient TTS are those attending the highest number of passengers in a smallest given area. Social efficient TTS are those that provide enough services, such as automatization, multiple transport modes, and low transfer time, leading to high levels of users satisfaction. Finally, environmental efficient TTS correspond to those registering low values of air polluting emissions per passenger mainly due to the presence of non-oil fuel transport modes. In developing countries in Latin American and Asia, the application of this kind of models represent an excellent tool for the computation and understanding of TTS operations.

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Keywords: Data Envelopment Analysis; Transit transfer stations; Mexico City; Urban transit; Efficiency evaluation

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1. Introduction

Transit transfer stations (TTS) are essential elements in urban transit networks of highly populated cities. They facilitate the travel connection between public transportation, and in many cases even with private vehicles[1]. Moreover, they also contribute to urban integration and social equity. Although currently the importance of TTS is acknowledged, efficiency evaluation is still a difficult task in the design phase, due to the lack of a practice-oriented procedure. There are many parameters traditionally used as performance indicators, but their relative importance in the global station efficiency is not evident. Furthermore, the efficiency concept is commonly related to the technical efficiency of transit services and the service quality (e.g. acceptance or satisfaction) to effectiveness[2]. Lastly, another efficiency dimension in modern transfer stations is the environmental quality of the operation, which is often considered as an independent element of the stations performance.

The aim of this paper is to present a new methodology to evaluate TTS efficiency under a sustainable framework using a Data Envelopment Analysis (DEA) model, which explicitly incorporate the technical (economical), passenger service (social) and environmental quality as efficiency parameters of the global TTS performance. The methodology is introduced studying 39 of the most important TTS located in the Mexico City Metropolitan Area, MCMA. Their operation was characterized through the compilation of a database, which was analysed in order to determine the proper input and output variables related to their performance. The variable selection corresponding to each efficiency dimension (i.e. technical, social, and environmental quality) was conducted considering previous studies described by several authors, applying DEA models in diverse transportation systems such as bus companies, airports, intermodal terminals and airlines. These studies, along with a short description and input and outputs variables used, are compiled in Table 1. Then, the optimization study was carried out considering the technical (economical), passenger service (social) and environmental quality efficiency parameters simultaneously. This approach not only allows determining a relative efficiency rank among stations, but also provides information regarding potential operational improvement needs. This innovative methodology opens the door to a new scheme of TTS design and efficiency monitoring. Technical efficiency refers to the efforts made by the company operating the TTS to use the minimum level of inputs in order to satisfy the passengers demand. The social efficiency is related to the passenger service satisfaction based on the service provided by the company, using fixed infrastructure features. Environmental quality is related to the minimization of the air polluting emissions (CO_2 and BC), spending a certain amount of energy and transfer time.

Nomenclature

Trans. time	Transfer time (min)
P/B-P	Parking and Bicycle Parking (1)
Auto.	Automatization (%)
Energy consump.	Energy consumption (MWH/h)
CO_2 em.	CO_2 emissions (ton/day)
BC em.	Black carbon emissions (ton/day)
Sat.	Users satisfaction (%)
CCR	Charnes, Cooper and Rhodes
BCC	Banker, Charnes and Cooper

2. Methodology

DEA approach was designed by Charnes et al. (1978) [3] as a method to measure the relative efficiency of a set of decision-making units (DMU) characterized by multiple variables acting as inputs and outputs. Efficiency may be obtained either by seeking a way to minimize inputs while satisfying not less than the given level of outputs (i.e. input-oriented model); or by looking to maximize outputs without increasing the inputs observed (i.e. output-oriented). Then efficiency of a certain DMU group is defined as the ratio of the weighted sum of its outputs and the weighted sum of its inputs. Models CCR and BCC (initials of the authors) are the first DEA models published in the technical literature. Thus, they are considered basics models, also known as radial models. The rest of the DEA models are derived from