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Using entropy-TOPSIS method to evaluate urban rail transit system operation performance: The China case

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ABSTRACT

Urban rail transit system operation performance evaluation results are important for government, transit operators and passengers. In this paper, we formulate an entropy-Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method to evaluate the urban rail transit system's operation performance from the operator's, passenger's and government's perspectives. Firstly, we establish the evaluation indicator system with 8 indicators and a total of 41 sub-indicators, the operational data of the 41 sub-indicators will be used as the input of the approach. Second, we formulate our new approach to obtain the performance evaluation: the Entropy Weight Method (EWM) will be used to calculate the weight of each sub-indicator; the product of the corresponding probability and weight will be used to formulate the performance from operator's, passenger's and government's perspectives; the TOPSIS will be used to calculate the comprehensive evaluation values and rankings of performance for each month. Third, the Chengdu subway with 34 months initial data will be chosen as the case study to test our new approach, the related suggestions to the government, to the passengers as well as the operators and managers will also be given.

1. Introduction

Over the last decade, urban rail transit system (including subway system, light rail system, suburban railway, monorail system, tram system and magnetic levitation system) development has been booming in China. The reliable and energy-efficient public passenger transport mode has come to be regarded as the best transportation system to alleviate road congestion, thus it plays an increasingly important role in many large Chinese cities (Kang et al., 2015; Sun et al., 2016). As a basic assessment, urban rail transit system operation performance evaluation (in this paper we abbreviate it as: URTSOPE) results are important operation data for the related government department, transit operators and passengers.

From the government's perspective, URTSOPE is very important because it is the basis of governmental subsidies at present due to their public nature, the differences in URTSOPE results among different evaluation periods present a powerful justification for governments financial subsidies (Cervero, 1984; Oum and Yu, 1994; Karlaftis and McCarthy, 1997; Cantos et al., 1999; Tsamboulas, 2006; Graham, 2008). Also, the URTSOPE results provide crucial references to government on how to optimize the urban transport structures and improve the cities' competiveness. Now in China, the average passenger transport share of rail transit system in major

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cities is less than 20%, and in some small and medium-sized cities, the data is less than 10%, which is lower than the data in most developed countries (Zhang et al., 2016). Furthermore, as urban rail transit networks are continuously expanding in Chinese cities, the evaluation results are very vital for related government departments to control the network expansion rate and financial budget allocation. The government departments want a comprehensive calculation value to evaluate the operation performance about the whole urban transit network.

From the operators' perspective, they typically aim at minimizing the operational costs conditional and meeting the daily passengers travel demand. The URTSOPE can be regarded as efficiency evaluation which focuses on whether the operators achieve the pre-set goals, and what jobs they have done in order to get the goals. The evaluation results describe the relationship between resource inputs and produced outputs, include indicators of the overall cost efficiency, labor utilization, and vehicle utilization (Fielding et al., 1985). Adopting the final results of the URTSOPE as a reference, operators can improve their operation mode to be more market-oriented and safe, make the management mode more cost-saving, and find a more passenger-oriented service mode.

From the passengers' perspective, the URTSOPE can be regarded as effectiveness evaluation. Passengers should feel that urban transit systems are available to meet their daily travel requirements at lower costs, safe, time-saving and environmentally-friendly, so the effectiveness can be measured by the service utilization, service quality, and service satisfaction (Fielding et al., 1985).

In this paper, we focus on the approach and application of URTSOPE which can be applied in China, by considering the operator's, passenger's and government's perspectives. The remainder of this paper is organized as follows. Section 2 is devoted to the literature review about the public urban transit system performance evaluation, we analyze the related evaluation indicators as well as the evaluation approaches about the existing papers. In Section 3, we establish the URTSOPE indexes system based on the basic national policy (Guiding Opinions on Priority Urban Development of Public Transport by the State Council of the People's Republic of China, 2012, Number 64) and China's urban rail transit enterprises operation and management standard (Metro Operational Performance Evaluation System: MOPES 2.0). Section 4 is devoted to the description of the evaluation method which is based on Entropy-TOPSIS Method. In Section 5, a case study will be carried out by taking the Chengdu subway system in China as a background in order to test the performance of the methodology presented in this paper. The evaluation analysis results will be presented and the related suggestions for Chinese government departments and Chengdu subway operation enterprises would be given. In Section 6, we present the major conclusions and give an outline of future research tasks.

2. Literature review

In recent years, a lot of researches have been devoted to the public transit performance evaluation. Usually, the researchers use Technical Efficiency, Total Factor Productivity, Service Satisfaction and Hensher Performance Model to evaluate the performance of public transit (Chu et al., 1992; Fielding et al., 1985; Hensher, 1987; Hensher, 2001; Graham, 2008; Boitani et al., 2010). Many researchers adopt a concept of assuming public transit services as production because the public transit operators provide public transit services, such as passenger-kilometers and vehicle-kilometers, using number of vehicles, fuel, employees, and other inputs such as oil and tires. The public transit performance evaluation always been analyzed by comparing multiple inputs and outputs (Shalaby, 1999; Khasnabis et al., 2002; Roy and Yvrande-Billon, 2007; Ottoz et al., 2009; Boitani et al., 2010). This implies the final performance evaluation results are highly dependent on the selection of inputs and outputs. There are many indicators influencing the performance of public transit operators and any variable related to public transit systems can be taken as a potential indicator to evaluate the performance. Usually, the inputs of public transit systems are capital, labor and energy (Kerstens, 1996; De Borger and Kerstens, 2000; Odeck, 2006; Barnum et al., 2008; Sahoo et al., 2014). The outputs used to evaluate the performance are usually vehicle-kilometers, seat-kilometers, passenger- kilometers, passengers and operating revenue (Cowie and Asenova, 1999; De Borger et al., 2002; Karlaftis, 2004; Odeck, 2008; Sahoo et al., 2014).

There are several approaches to measure and evaluate the performance of public transit systems. Generally, the approaches can be classified as parametric and non-parametric. The parametric approaches are seldom used because they need certain assumptions to establish the production function or cost function, so researchers prefer to use non-parametric approaches that entail fewer assumptions (Sánchez, 2009). The non-parametric approach such as Data Envelopment Analysis (DEA) has been widely used to evaluate public transit performance. DEA was firstly introduced by Farrell (1957) and popularized by Charnes et al. (1978) and Banker and Cooper. (1984). The DEA is a data analytical technique for measuring the relative efficiency of organizational or production units. It has been widely used for its strength of (i) capturing multiple inputs and outputs, (ii) combining multiple performance dimensions, and (iii) computing performance measurements that integrate data/information across multiple dimensions and input/output resources (Gattoufi and Oral, 2004; Karlaftis, 2004). Jain et al. (2008) used DEA to conduct a comparative analysis of 15 urban rail transit systems from 1992 to 2002 across the world (not including U.S. rail systems), and to analyze the relationship between ownership structure and technical efficiency. However, the basic DEA model can't describe the distinction between some of the efficient decision-making units that have identical efficiency scores equal to one. In order to solve the problem, Zhang et al. (2016) applied the integrating information entropy and the super efficiency data envelopment analysis (SE-DEA) model (firstly introduced by Seiford and Zhu, 1998) to measure the public transit service performance. Chu et al. (1992) proposed three single-ratio DEA models to measure efficiency of U.S. public multimodal transit systems. Cantos et al. (1999) used the Malmquist productivity index along with DEA to compute the efficiency of European railways from 1970 to 1995. Graham (2008) formulated and compared the efficiency results of 200 urban railways throughout the world by using DEA and Total Factor Productivity (TFP). Yu (2008) explored efficiency and effectiveness scores for a group of 40 global rail systems (passenger and freight) in 2002. Yu used a two-stage network DEA model along with a one-stage DEA model to compute the efficiency scores and compared them, and concluded that the network DEA model provides deeper insight into sources of inefficiencies than does the one-stage DEA model. Yu and Lin (1996)