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Integrated weight-based multi-criteria evaluation on transfer in large transport terminals: A case study of the Beijing South Railway Station

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ABSTRACT

Stringent evaluation on passenger transfer capacity is one of the fundamental requirements to validate designs and ensure efficient operations at large transport terminals as effective transfer service is always the prime concern of the operators. This study focuses on the transport terminals at major cities where a number of transport services connecting local and inter-city traffic convert. It is rather arduous to evaluate the overall performance of passenger transfer when the performance is attributed by both quantifiable factors and subjective perceptions which are on different scales and bounds of evaluation. In this paper, multi-criteria evaluation on transfer alternatives is developed by formulation of criteria systems and integration of performance factors. Multilevel grey evaluation (MGE) and technique for order preference by similarity to ideal solution (TOPSIS) are employed to devise the overall evaluation results and produce ranking for alternatives. The merits of the proposed methodology are illustrated through a case study on the Beijing South Railway Station in China. This study is particularly useful for the designers and operators to assess transfer performance and level of service in large transport terminals amid the increasing demands of the modern transportation.

1. Introduction

Many transport terminals at major cities, such as the Transbay Center in San Francisco, the La Defense station in Paris and the Lehrte station in Berlin, are regarded as world class as they provide efficient, convenient, comfortable and secure transfer service for passengers. A number of large transport terminals in China have been put into operation in recent years because of rapid economy growth and the drastic increase of travel demand. The terminals, such as the Beijing South Railway Station, Shanghai Hongqiao Terminal and Guangzhou South Railway Station listed in Table 1, occupy hundreds of thousand square meters and usually connect a large amount of inter-city and local traffic volume while serving more than tens of million passengers every year with high expectation on service quality. The transfer process often imposes significant time or cost expenses on individual

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Table 1
Three major integrated transport terminals in China.

Title	Year into operation	Floor area (m^2)	External transportation	Capacity	Major local transportation
Beijing South Railway Station	2008(1897)	420,000	Railway, intercity railway (Beijing–Tianjin), high speed railway (Beijing–Shanghai, Beijing–Qingdao),	150 million per year (in 2015), 190 million per year (in 2020)	Car (taxi), bus, metro, etc.
Shanghai Hongqiao Terminal	2010	1,500,000	Freeway, intercity railway, high-speed railway (Shanghai–Beijing, Shanghai–Hangzhou, Shanghai–Nanjing, etc.), civil aviation	90 million per year (in 2020)	Car (taxi), bus, metro, maglev railway, etc.
Guangzhou South Railway Station	2010(1901)	370,000	Railway, intercity railway, high-speed railway (Beijing–Hong Kong, Guizhou–Guangzhou, Nanning–Guangzhou, etc.)	80 million per year (in 2020)	Car (taxi), bus, metro, etc.

passengers (Guo and Wilson, 2011). Thus, passenger transfer capacity and the corresponding level of service is a crucial element in the evaluation on their design quality and operation efficiency (Correia et al., 2008).

Previous studies on passenger transfer emphasize on the estimation of transfer probability and demand from one transportation mode to another (Sun et al., 2012), transfer waiting time and its effects (Hsu, 2010; Guo et al., 2011), and transfer optimization through scheduling models (Shafahi and Khani, 2010). They tend to investigate the optimal control and management policies for daily operation of transport terminals (Sun et al., 2012), such as reducing passenger flow conflicts, improving scheduling and headways of the connecting and feeder transport services (Hsu, 2010). The evaluation of passengers through transfer facilities (de Barros et al., 2007) is however one of important drive to improve the transfer performance at the transport terminals. For example, as one component of transfer cost, walking time is closely related to the walking distance of passengers in terminals (Zhao and Zeng, 2008; Guo and Wilson, 2011), which is usually affected by the layouts and capacities of corridors, stairs and escalators. Mismatched supply–demand from mass transit modes to small ones is often critical because large transport terminals are almost hub-and-spoke systems combining local transportation modes with external ones (Jara-Diaz et al., 2012). With the rising concern on environment, the emission reduction and energy consumption also attracted more attention (Bastani et al., 2012; Nealer et al., 2012).

Evaluation on the performance of transfer facilities in a railway station can be treated as a process of multi-criteria decision analysis (MCDA) based on multi-attribute utility theory (MAUT) and multi-attribute value theory (MAVT) (Gass, 2005). The common methods for MCDA in transportation applications include the preference ranking organization method for enrichment evaluations (PROMETHEE) (Kumar et al., 2006; Safaei Mohamadabadi et al., 2009), technique for order preferences by similarity to ideal solutions (TOPSIS) (Teodorović, 1985; Sheu, 2010), analytic hierarchy process (AHP) (Tudela et al., 2006; Zubaryeva et al., 2012) and grey evaluation method (GE) (Li et al., 2004; Pai et al., 2007). Moreover, a key prerequisite to MCDA is to establish the relative importance or weights of different performance criteria in terms of subjective perception by decision makers (Sinha et al., 2009) or objective mathematical computation from facilities attributes (Wang and Lee, 2009).

From the previous studies, few research work on the overall evaluation of passenger transfer performance at large transport terminals can be found because it is very difficult to collect field data, coordinate the conflicts among different criteria (Correia et al., 2008) and integrate subjective and objective perspectives (Guo and Wilson, 2011). To challenge the above difficulties, an integrated weight-based multi-criteria evaluation on transfer performance at large integrated transport terminals is proposed as a robust and flexible method in this paper. Moreover, to meet the requirement of extending the scales of research, lowing computational demand, reflecting the relative contrast intensities of evaluation criteria, incorporating sample data without being subjected to any distribution and coordinating those criteria which are conflicting and incommensurable, order relation analysis, entropy method, multi-level grey evaluation and TOPSIS methods are also employed in this study. The Beijing South Railway Station in China is selected to carry out for verifying the feasibility and effectiveness of the proposed method.

2. Criteria system for evaluation

The common criteria system for comprehensive evaluation of transfer services for passengers at large integrated transport terminals involves transfer efficiency, facilities, continuity and even sustainable development (Mateus et al., 2008). Ten specific attributes are selected here to construct a hierarchical evaluation criteria system as shown in Fig. 1. The letter L in the round brackets represents that the evaluation results are good when the attribute values reach low while the letter H does the opposite.

The definitions of these evaluation attributes are given as below.

- C_1: transfer distance (unit: m), $D_{transfer}$, is the average walking distance of passengers from one transport mode to another and it is calculated as below.