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RESEARCH PAPER

An Evaluation on Coordinated Relationship between Urban Rail Transit and Land-use under TOD Mode

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Abstract: This paper establishes an evaluation index system of coordinated relationship between urban rail transit and land use under TOD mode. The evaluation results and rank are generated by the improved DEA model. Different input/output indexes are standardized through further analysis of different indexes' slack variables and surplus variables. The influencing degrees of different index factors to the coordinated relationship are examined. The improved directions of DEA invalid decision making units (DMU) are also analyzed through the DEA projection theory, which provides an improved reference to the invalid DMU. A case of Allegheny country in U.S. is conducted to verify the evaluation method, and the results show that the evaluations match well with the real situations. It is an effective way to evaluate the coordinated relationship between urban rail transit and land use under TOD mode.

Key Words: urban traffic; rail transit; coordinated relationship; land use; DEA model; TOD mode

1 Introduction

Complex interactions exist between urban transportation and land use. Urban transportation improves the accessibility in different regions and significantly affects land use. Meanwhile land use is derived from the transportation generation, total transportation demand with distribution of main traffic direction can be determined by land use pattern and function layout[1,2].

Large-capacity, rapid-speed and low-pollution rail transit not only meets urban traffic demand but also strengthens commerce and employment activities in the city centre. It therefore stimulates the formation of outskirts along the rail corridor. Chu[3] established the macro evaluation index system considering the characteristics of Beijing, where indexes were selected from three aspects: degree of land use intensity, efficiency and service level of transport system, and environmental quality. Yang[4] analyzed coordination of urban transportation and land use in 16 typical cities in China, and proposed a simple evaluation index based on transit orientated development (TOD). However, the index system took transportation and land use as the inputs and outputs of the system respectively, and thus failed to capture the interactive relationship between them. Researchers at the University of North Carolina[5,6] established an evaluation system on the coordinated relationship between transportation and land use with regard to the decentralized and low-density development mode in some large cities in the United States of America. In summary, previous studies have used the qualitative analysis method to evaluate the relationship between urban transport and land use at the macroscopic level.

In practice, TOD programs may not strictly follow the standard planning process. TOD programs may be deviated from the coordinated planning of rail transportation and land use due to diverse stipulations of government, real estate developers and other departments. In fact, it turns out to be transit related development (TRD), rather than TOD. Thus, tracking the implementation effects is necessary for coordination evaluation during the different stages of construction. Then, it is possible to identify the key attributes affecting the coordinated development between urban rail and land use. The results play an important role for the next phase of urban rail transit and TOD land use planning.

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2 Evaluation index system for coordinated development between urban rail transit and land use under TOD mode

2.1 Evaluation methods analysis

A data envelopment analysis (DEA) model is suitable for the evaluation due to the fact that it has multiple inputs and outputs. It is particularly suited for the evaluation, because the dimensions of the input and output data are not required. Consequently, it cannot be affected by the different units of measurement in the indexes. Furthermore, it does not require a weight for the input and output indexes, and excludes many subjective factors. The DEA method can be used to evaluate the validity of the decision making units (DMU), in addition to analyzing the reasons why the DMU is invalid. This practice allows measures to be obtained to improve the system.

2.2 Principles of establishing an evaluation index system

Evaluation indexes should reflect the characteristics of the land use under the TOD mode. They are used to determine whether the land use of the TOD communities are adapted to the rail transit system, and whether the development coordination can be achieved. Rail transport resources should neither be wasted due to inadequate land use development, nor over used through excessive land use development. Diversity within the evaluation indexes is encouraged, however strong correlations among the indexes should be avoided. Additionally there must be available and quantifiable data for the index.

2.3 Evaluation index system

The evaluation index system for the relationship between the urban rail transit and land use under the TOD mode is shown in Table 1.

3 Evaluation for model of coordinated development between urban rail transit and land use under TOD mode

3.1 Modified DEA model with sequencing

The basic DEA model can only be used to evaluate the validity of the DMU. The invalidity of the DMU can be ranked according to their relative validity values. However the relative validity values are only determined for the effective DMUs. The scheduling problem of a valid DMU can be solved using the ideal point method or worst element method. The ideal point element method is used because the ranking can be attained for all valid DMU. Furthermore the amount of computing needed is trivial. The steps are as follows[7]: first, construct a new DMU* as a reference in order to ensure that valid minimum and maximum values for the input index were used in the input and output. Then the referenced DMU* can be added into the production possibility set, and the linear C^2R model is applied to determine the weight coefficients; ω and μ for the DMU*. The model is shown in Eq. (1).

$$\max \sum_{r=1}^{s} \mu_r \gamma^{r}_{\max}$$
$$\text{s.t.}\begin{cases} \sum_{i=1}^{m} \omega_i x_{ij} - \sum_{r=1}^{s} \mu_r \gamma_{rj} \ge 0 \quad (1 \le j \le n) \\ \sum_{i=1}^{m} \omega_i x^{i}_{\min} - \sum_{r=1}^{s} \mu_r \gamma^{r}_{\max} \ge 0 \\ \sum_{i=1}^{m} \omega_i x^{i}_{\min} = 1 \\ \omega_i \ge \varepsilon \quad (1 \le i \le m) \\ \mu_r \ge \varepsilon \quad (1 \le r \le s) \end{cases} \tag{1}$$

Then, the linear programming must be solved to obtain the optimum solution for ω^* and μ^* for the sequencing efficiency index of DMU_j:

Table 1 Evaluation index system between urban rail transit and land use under TOD mode

System	Coordinated performance	Variables	Index definitions
Urban rail transit	Convenient path from home to transit station in TOD community	A_1	Average time from houses to stations (min)
	Efficient transfer between rail transit and buses	A_2	Average transfer time (min)
	No waste of public transport resources and passengers should not exceed the capacity of transit station	A_3	Utilization rate of the transit station capacity (%)
	Encourage public transit ridership	A_4	Split ratio of bus trips (%)
	Reduce emissions from cars to protect the environment	A_5	Vehicle kilometers travelled per capita (km per capita)
	Reduce unnecessary trips to control the total traffic demand	A_6	Trip distance per capita (km per capita)
Land use	Make full use of land resources to prevent low density spread	B_1	Population density (people per square kilometer)
	Employment-Housing balance	B_2	Employment-housing ratio (%)
	High density development	B_3	FAR (floor area ratio)
	Comfortable environment for walking and using bicycle	B_4	Non-motor lane area ratio (%)
	Mixed land use incorporating different land use functions	B_5	Non-residential land use area ratio (%)