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A quantitative transportation project investment evaluation approach with both equity and efficiency aspects

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ABSTRACT

The motivation of this study is to develop a method for evaluating transportation investment quantitatively with consideration of both efficiency and equity.

The current evaluation methods, predominantly cost–benefit analysis (CBA), concentrate mainly on the economic efficiency. Lacking equity considerations, these evaluation methods may result in an inappropriate investment. China is now a typical country with such a problem. With the huge investment in transportation infrastructure flooded in eastern provinces decades ago, these areas are benefitting the high GDP growth rate which is supported by these infrastructure, while the western provinces are suffering from the poor transportation system.

Developing countries tend to invest more in comparatively developed areas for a higher return rate, leaving diversity between areas become more and more huge.

This study introduced equity impacts into transportation investment evaluation methods after the concepts of various types of equity have been reviewed. Four quantitative models are proposed corresponding to 4 types of equity. Hereafter, an evaluation model from both equity and efficiency aspects for highway infrastructure investment appraisement is developed based on the theory of Wilson's entropy. The Lagrangian method is used to testify the model and to prove the result possesses optimal benefit distribution. This model takes account of the differences among different areas and social groups. Sensitivity analysis is conducted before twelve highway investment projects in China are studied with the method. The evaluation result is observably different from the one derived from the CBA.

This fundamental consideration of transportation equity as well as the quantitative models may be helpful to developing countries or areas. However, further studies on transportation equity still need and the model still needs to be improved.

1. Introduction

Transportation infrastructures have great impacts on both social and economic development. The investment on transportation system, like new transportation infrastructures plans, is huge. However, uncharged transportation facilities could hardly cover the construction cost. Thus sequentially spending limited financial funds on transportation projects according to their rewards is advisable. Therefore, various evaluation techniques and manuals are put forward and the longstanding most widespread method is cost–benefit analysis (CBA). The CBA method is widely used in different countries such as UK (Vickerman, 2000), France (Quinet, 2000), USA (Lee, 2000), Japan (Morisugi, 2000), and many other developing countries (Talvitie, 2000). The CBA method is efficient in dealing with the economic efficiency of project investment. But its drawback of neglecting social equity impacts, another significant aspect of social welfare is also noticeable (Guo, 2001).

Sustainable transportation and Green Transportation put forward last century also calls for transportation equity. Sustainable transportation development indicates that some groups or individuals should not benefit at the expense of others, especially the disadvantaged groups or individuals (Sanchez, Stolz, & Ma, 2003). And transportation equity is surely one big issue when considering distributing the welfare gained from economic development through the entire society fairly. Moreover, harmonious development among regions is a Chinese official policy, which takes transportation equity among regions as an important aspect. Therefore, this study aims at probing into modeling the

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transportation equity quantitatively and developing a comprehensive evaluating approach for transportation investment with consideration of both efficiency and equity aspects is significant.

2. Literature review

It seems not easy for people to judge whether something is fair, not to mention the degree of fairness or justice due to the complexity of equity analysis. There are no universal definitions of equity and fairness. This well explains why few researches were conducted on social equity in the past. However, unfairness was found by a growing number of researchers in recent years. Litman (2003) stated that nearly one third of Canadian families are transportation disadvantaged, and inadequate transport sometimes leads to social exclusion. This is particularly true for people who cannot afford or drive automobiles but living in automobile-dependent communities. High-income class people who own private car (only 20% in Beijing) unfairly enjoy the greatest share of benefits from transportation projects at the expense of the low quality of other transportation modes, such as transit service and facilities for walking and cycling (Zhu & Li, 2003). According to the principle of diminishing marginal utility, 100 dollars has a higher value for low-income groups than high-income ones. Thus, most people would prefer public policies promoting the economic status of the low-income class rather than the high-income class (Almeida, Haddad, & Hewings, 2004). Álvarez, Cantos, and García (2007) found that people of different income levels have different sensitivities on the transportation toll. And Rune Elvik (2009) similarly pointed out that transportation infrastructure would affect people's safety in different regions in different degrees.

John Rawls (1971) set up the widely accepted theory of justice which is called "justice as fairness." The theory is composed of two principles of justice. The first principle—principle of equal basic liberties—expresses an egalitarian concept of justice. And the second principle—difference principle—states that people who are equally talented and motivated must have equal opportunities to attain desirable positions, which means people's lives should depend on neither their birth nor upbringing. John Rawls's theory is used to test whether the constitution, laws, elementary social rights etc are fair. Since transportation is treated as people's basic rights in contemporary society, John Rawls's theory can be introduced into the transportation area. Initially, the recognition of equity is limited in the judgment of income distribution. Classical ways of judging are the Lorentz Curve and the Geordie Coefficient.

With the extension of the research area, the concept of equity permeates through various disciplines and social problems. The European Union Transport Research Fourth Framework Program invokes two dimensions of equity, horizontal equity associated with the principle of equality of opportunities, and longitudinal equity associated with the comparison of conditions between present and past, for each individual citizen, and social groups. The National Cooperative Highway Research Project held in 1994 defines equity as the distribution of cost and benefit among people of different incomes (Viegas, 2001). Jones (2004) defined transportation equity as comprised of spatial equity and social equity. Raux and Souche (2004) review these issues of equity, and propose the three dimensions of territorial, horizontal and vertical equity in a study implemented in Lyon. Litman (2005) classified transportation equity into horizontal and vertical types. These concepts of equity refer to a reasonable allocation of benefits among various social groups or individuals, but do not consider the problem of distribution of opportunities. The Intermodal Surface Transportation Efficiency Act (ISTEA) of USA advocates that transportation infrastructure decisions should involve public participation. This is because the traditional planning system merely includes experts and governors in the decision-making process and excludes the public. Shi, Yang, Huang, and Ying (2009) define transportation equity mainly in four aspects according to China's situation: equity among diverse traffic mode users, different social groups, different regions, and different generations.

When it comes to the evaluation model of transportation equity, Silva and Tatam (1996) made some modifications to the Multi-Criteria Assessment models and selected the criteria to represent regional and community groups' interests. The evaluation results can address both efficiency and equity issues, but the whole procedure is too complex and relies on a large-scale investigation of personal intent.

The purpose of this study is to establish an evaluation model for transportation projects investment considering equity quantitatively. Parameters reflecting social compensation on disadvantaged groups are introduced and different kinds of equity and various equity impacts of transportation investments are considered in the model. The evaluation example in the latter part of this article could be useful reference for decision makers.

3. Classification and quantitatively measure of transportation equity

In this part, four quantitative evaluation models corresponding to four kinds of equity are described.

3.1. The equity among different traffic modes users

From the view of equity among different transportation mode users, one should cover the social costs he causes. One normal case of unequal is that road users like walkers have to bear the extra cost such as noise, air pollution, brought by automobile users.

A model measuring the difference of the cost can be used to evaluate the equity among different traffic modes. The model can be expressed as follow:

$$\begin{aligned}\min \mathrm{SV} &= \sum_i \int SV_i(t)\mathrm{d}t \quad \forall i,t \\ &= \sum_i \int \left| \sum_j CS_{ij}(t) - \sum_j CR_{ij}(t) \right| \mathrm{d}t \end{aligned} \tag{1}$$

Subject to

$$CS_{ij}(t)>0, \quad CR_{ij}(t)>0$$
$$i = 1,2,\ldots,I \quad j = 1,2,\ldots,J$$

where:

$SV_i(t)$—the difference between what the users of traffic mode i should pay and what he pays indeed in a given time period t;
$CS_{ij}(t)$—the social cost j that the users of traffic mode i should pay in a given time period t;
$CR_{ij}(t)$—the personal cost j that the users of traffic mode i pays in a given time period t;
I—the number of kinds of traffic modes;
J—the number of kinds of social cost.

Payment and gain in this model can be supplemented according to the time and budget of the evaluation work. For example, tax could be considered while money directly spent is included if it is needed in certain research.

If the difference between $CS_{ij}(t)$ and $CR_{ij}(t)$ is larger, it means other road users pay more extra costs caused by users i. Social equity would be worsen. So the smaller SV represents a fairer state.