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Urban Travel Mode Split Optimization Based on Travel Costs

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Abstract

With the rapid development of economy and accelerated pace of urbanization in China, the trip share of private cars has been increasing continually. This study investigates the optimal mode-split for a developing megacity and optimizes the weighted generalized travel cost per capita for one trip on an urban transport network. The main urban area of Beijing is taken as the study area of this research and the revealed preference survey method is utilized to get the trip survey data. Based on a nest-logit model, an optimization model is developed for the minimal weighted generalized travel cost per capita for one trip. The phase estimation method with the Newton-Raphson algorithm and the genetic algorithm are used to solve the optimization model. In addition, different cases are studied to assess the effect of different transport policies for the improvement of urban transport in Beijing. These policies are concerned with parking fee, taxi average fare, bus priority and rail transfer time. It is found that the bus priority policy for reducing the in-vehicle time of a bus trip has the greatest weighted generalized travel cost per capita for one trip in Beijing. Moreover, successful rail transfer time reduction is more beneficial to travellers in comparison to the effect of increasing parking fees of private cars or increasing the average fare of taxi utilization. In the future research, more comprehensive policy packages are worthy of studies in a further.

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Keywords: Urban travel mode split; Cost optimization modelling; Mode-split; Genetic algorithm; Transport policy

1. Introduction

With the rapid development of economy and urbanization, private car gains its popularity in China. However, it also leads to traffic congestion and waste of resources. In order to solve such problems, a lot of studies have been

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made from economic perspectives. Many studies trying to maximize social welfare (see, e.g. Qin and Jia, 2013; Romilly, 2004; Basso et al., 2011; Jara-Díaz et al., 2008; Lu et al., 2011; Ferrari, 2002; Chu et al., 2012; Jansson et al., 2008). Moreover, much attention has also been attached to generalized travel cost (see, e.g. Tirachini et al., 2010; Chang and Chu, 2005). This research newly develops an optimization model with the objective of minimising the weighted generalized travel cost per capita for one trip to explore the optimal management policies for the operations of different urban travel modes. The main urban area of Beijing is taken here as the study area of this research. The following sections of this paper are organised as follows. In section 2, the study area and the survey data are introduced. Section 3 explains the proposed optimization model. In section 4, different cases are analyzed to assess the effect of different policies. Finally, Section 5 shows the research conclusions.

2. Study area and survey data

As one of the representative megacities in the world, Beijing is developing rapidly in economy and urbanization. The population in Beijing has increased to 20.19 million in 2011. The ratio of car trips in 2011 is 33.00%. Moreover, the percentage of public transport trips is 42.00% in 2011. Specifically, the shares of rail and bus transports are only respectively 13.8% and 28.2% (BTRC, 2011). There are 486 congested road links whose total length is about 199.00 km during peak-hour in Beijing in 2011 and the annual congestion duration is around 70 minutes (BTRC, 2011). This study investigates the main urban area of Beijing. According to the trip survey data, the average travel time, travel cost, and so on for each travel mode are explained in Table 1.

Table 1. Average travel time, travel cost, and so on. for each travel mode

Travel mode	Fuel charge (CNY)	Parking fee (CNY)	Travel time (minutes)	Waiting time (minutes)	Fare (CNY)	in-vehicle time (minutes)	Fare (CNY)	Transfer and waiting time (minutes)
car	36.3700	6.0000	38.0000	-	-	-	-	-
taxi	-	-	-	3.0000	32.0000	40.5900	-	-
bus	-	-	-	-	-	62.1000	0.9500	14.3700
rail	-	-	-	-	-	60.5000	2.0000	8.0000

3. The model

3.1. Model Establishment

Four travel modes are considered in this research. They are car, taxi, bus and rail. A nest-logit (NL) model is used to analyze the trip shares of different travel modes. The hierarchical process of the NL model is shown in Fig. 1.

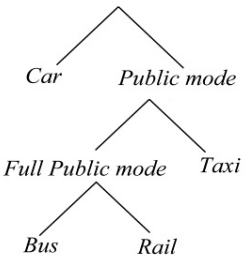

Fig. 1. Structure of the proposed nest-logit model

The generalised travel cost (GTC) defined by C_i, where i = {1, 2, 3, 4} representing car, taxi, bus and rail in turn, is explained by the sum of money and time costs, as respectively described by Eqs. (1a), (1b), (1c) and (1d). α_k, β_k and θ_k (k=1, 2, 3) are the parameters.

$$C_1 = \theta_0 + \theta_1 \times G_{car} + \theta_2 \times PA_{car} + \theta_3 \times T_{car}, \tag{1a}$$