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Impact evaluation of a mass transit fare change on demand and revenue utilizing smart card data

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ABSTRACT

Transit fares are an effective tool for demand management. Transit agencies can raise revenue or relieve overcrowding via fare increases, but they are always confronted with the possibility of heavy ridership losses. Therefore, the outcome of fare changes should be evaluated before implementation. In this work, a methodology was formulated based on elasticity and exhaustive transit card data, and a network approach was proposed to assess the influence of distance-based fare increases on ridership and revenue. The approach was applied to a fare change plan for Beijing Metro. The price elasticities of demand for Beijing Metro at various fare levels and trip distances were tabulated from a stated preference survey. Trip data recorded by an automatic fare collection system was used alongside the topology of the Beijing Metro system to calculate the shortest path lengths between all station pairs, the origin–destination matrix, and trip lengths. Finally, three fare increase alternatives (high, medium, and low) were evaluated in terms of their impact on ridership and revenue. The results demonstrated that smart card data have great potential with regard to fare change evaluation. According to smart card data for a large transit network, the statistical frequency of trip lengths is more highly concentrated than that of the shortest path length. Moreover, the majority of the total trips have a length of around 15 km, and these are the most sensitive to fare increases. Specific attention should be paid to this characteristic when developing fare change plans to manage demand or raise revenue.

1. Introduction

Public transit fares not only affect the revenue of operating agencies but also travel demand due to passengers' trip decisions in response to fare changes (Webster and Bly, 1980). Therefore, urban transport agencies are able to manage travel demand through fare policy, as has been observed in the cases of London Transport, Atlanta Rapid Transit, Los Angeles and other metropolitan cities in developed countries (Evans, 2004; Zureiqat, 2008).

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As the capital of the largest developing country, Beijing's public transit system provides significant numbers of daily residential trips and is approaching its capacity. However, its financial performance is deteriorating concurrent with the rapid growth of newly built lines. It is ascribed to the extraordinarily low fare charges and unsustainable government subsidies. This is particularly true for the metro. By the end of May 2015, the metro system consists of 17 lines and 277 stations (transfer stations being counted more than once) and the total network length is 465 km. The ridership of Beijing Metro reached 3.209 billion trips in 2013 (based on the count of unlinked trips as every transfer in the system is counted as an additional trip). This represents a daily Demand of more than 10 million trips on a busy weekday. The stations and trains are heavily crowded during rush hours, reaching 8 persons per m^2, as shown in Fig. 1. Congestion management measures such as holding incoming passengers at the entrance are applied to 40 stations during peak hours.

Given such a large system, the fare structure is simple: a flat fare of 2 RMB for the entire network except the Capital Airport Line, which charges 25 RMB. The fare is roughly a third of that in Shanghai or Guangzhou, China. The fare revenue of Beijing Metro cannot cover its operating costs, not to mention construction costs, and a 20 billion RMB subsidy was provided by the government for the bus and rail operation company in 2013 (FBB, 2014). The subsidy is expected to increase in order to pay for and maintain more newly built lines every year. Based on the long-term planning of Beijing Metro, estimated investment will rise to 297.8 billion RMB by 2020 (Zhang et al., 2012). Currently, Beijing government can provide only 10 billion RMB per year as a special fiscal budget.

Although various financing modes have been investigated and implemented, including a public–private partnership with Hong Kong MTR for Line 4 and a build-transfer mode for the Olympic Line, the financing gap for Beijing Metro's construction and operation is still extremely large. Mass public transit is regarded as a quasi-public good, and welfare policies are irreversible, so fare increase proposals have been opposed intensely by the public and several fare change plans have deadlocked.

However, the current fare policy has threatened the level of service and the sustainable development of Beijing Metro significantly, and fare change is imperative. The initial proposal is to increase the base fare and charge for a linked trip according to its length. Before the new fare policy is implemented, passengers' responses should be investigated; that is, the impact on travel demand, and the revenue after fare increases should be assessed (Chen and Lin, 2005; Kremers et al., 2002).

The objective of this study is to develop a method to evaluate the impact of fare increases on the demand and revenue for a transit network using a large amount of smart card data. To this end, this contribution first establishes an estimation model of revenue pertaining to fare increases. The model is formulated with price elasticity, current metro demand, and shortest paths between any stations in metro network. For the data needed in the model, the price elasticities are collected by a stated preference (SP) survey. Current demand is extracted from an automatic fee collection (AFC) system by assigning each record to an origin–destination (OD) pair according to its entry and exit station. And shortest paths between any stations are obtained by a network approach. Finally, using this model, the impacts on demand and revenue are estimated for each fare increase alternative, and corresponding discussion and conclusions are provided.

Fig. 1. Overcrowding problem in stations and trains of Beijing Metro. *Source:* Taken in the field study.