Impact of Fare System and Distance on Metro OD Demand

料金制度と移動距離が鉄道 OD 需要に与えるインパクトに関する研究

Masahiro TOMINAGA*

冨永　真裕

*Division of Transportation Engineering and Management　Intelligent Transport Systems

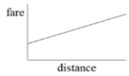
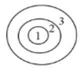
1. Introduction

The main purpose of this thesis is to estimate an impedance function for a mode specific trip distribution model, in this case for metro. For our study metro or "tube" Oyster card records from London are used. Using London data allows us to estimate the impact of a fairly complex zone-based fare system. After calibrating the model, it is applied to three scenarios. The first scenario is a fare decrease in the same fare system. The second scenario is changing the fare system from zonal to flat fare. The third scenario is changing the fare system from zone to distance-based.

2. Fare Systems

Following Smith[1] Table 1 illustrates the three common fare systems and their advantages and disadvantages. Whereas there is much research about fare levels, the literature on the impact of fare systems on trip distribution is scarce.

Table 1　Feature of Fare System

	Flat fare	**Distance-based**	**Zonal fare**
			
Advantage	• Simplicity • Cheapest cost to implement • Lowest level of fare abuse	• Potential to produce more revenue • Equitable; longer trip carries higher fare	• Simplicity • More equitable than flat fare
Disadvantage	• Fare increase will cause greatest loss of passenger • Discourages shorter-distance trips	• Calculation of fare for irregular trips difficult • Difficult to implement and administer	• Places inequitable burden in those making shortest trips
Operators	• Kyoto city bus • London Buses	• Japan railway • Kyoto city bus (mixture of flat fare and distance based)	• London Underground • VAG Freiburg

3. Methodology

We firstly propose a Public Transport (PT) specific gravity model. This model considers not only travel cost but also existence of other traffic mode.

The concept of impedance introduced in this thesis is that of travel impedance for metro. Surely, the higher the travel cost, the less passenger demand. In the case of metro, the impedance function needs to consider factors that explain the resistance to travel between two stations that might be in different zones. For example, travelers might not prefer to use metro for short trips because walking or cycling are more convenient. Also, using metro requires access time as well as fees to enter. Thus, even if the distance between two stations is short, the passenger demand might be relatively in case of metro. Figure 1 shows hypothesis made for this type of model.

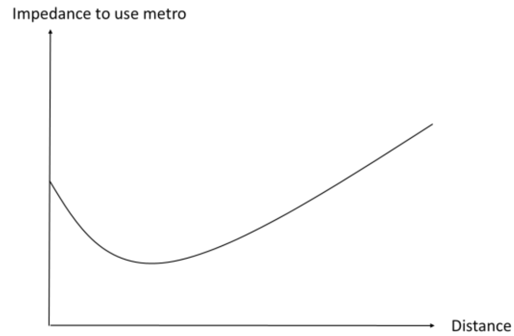


Figure 1　PT Specific Gravity Model

Considering access and egress costs as well as general resistance to travel long distances, we propose that the impedance function consists of two parts:

- A decreasing function with distance to reflect that the metro is becoming more attractive with distance.
- An increasing function with distance to reflect that generally, all else being equal, nearby destinations are preferred.

Theoretically one might explain this function also as follows. We estimate a combined destination and mode choice model, where alternative modes (e.g. walking) are more attractive for nearby destinations but in general travelers prefer close destinations. We express this impedance function g as follows:

$$g_{ij} = \frac{\alpha \cdot c_{ij} + \beta \cdot f_{ij}}{d_{ij}} + \gamma \cdot c_{ij} + \delta \cdot f_{ij} \qquad (1)$$

Where,

g_{ij}	:	PT specific impedance function
c_{ij}	:	Travel time from station i to station j
f_{ij}	:	Fare from station i to station j
d_{ij}	:	Distance from station i to station j
$\alpha, \beta, \gamma, \delta$	:	Parameters are to be estimated

Four input matrices are hence needed to estimate parameters that determine the impedance function. These are: trip matrix, fare matrix, travel cost matrix and distance matrix. This travel cost includes walking time as well as waiting time. Since in addition to these parameters we require origin and destination specific balancing factors, we use the Furness procedure in combination with a heuristic optimization approach to calibrate the impedance function. We test the goodness of fit by minimizing the chi-square value.

4.　Estimation Result and Scenarios

Figure 2 shows the calibrated proposed impedance function in the London Underground after convergence of the optimization. Total number of stations is 253 and trip is 50631.

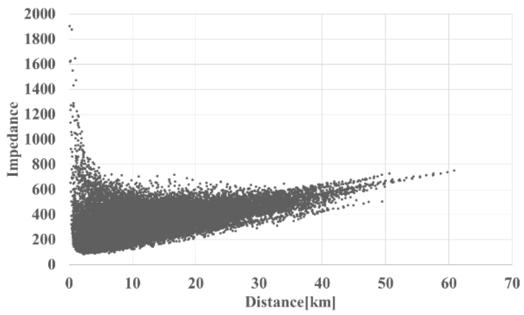


Figure 2　Impedance Function in Zonal Fare

Where,

α	:	120100
β	:	140140
γ	:	45.8201
δ	:	1.5106
Chi-square value	:	13731.930

Its vertical axis is for the impedance defined by PT specific gravity model and the horizontal axis is for the distance between each stations. Basically, impedance is proportional to distance. In near distance, impedance is inversely proportional. As distance is longer, impedance is increasing. This implies that second term of impedance function is effective. That is, the longer the distance between the stations is, the more passenger hesitate to travel. Also, passenger is unwilling to travel by metro if the destinations are too close, because other transport modes are more attractive.

Then, we introduce 3 scenarios to gain result of fare or fare system change. Figures 3 to 5 show relation of impedance in each scenarios. We found that near stations gain passengers by changing fare system from zone to distance-based.

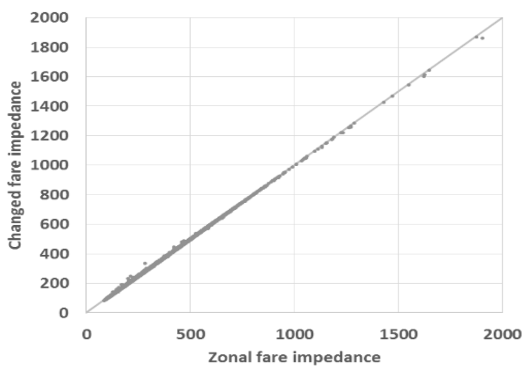


Figure 3　Relation of Impedance in Fare Change

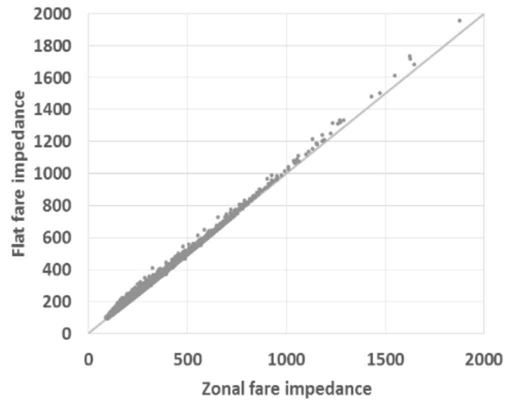


Figure 4　Relation of Impedance in Fare System Change (From Zone to Flat)

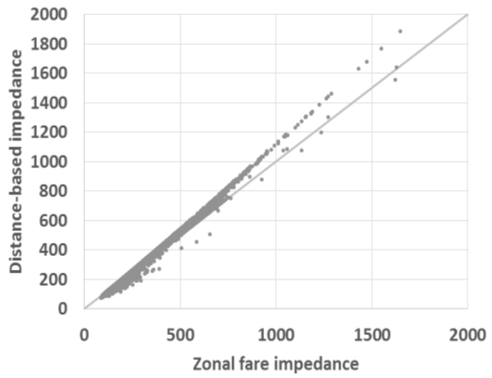


Figure 5　Relation of Impedance in Fare System Change (From Zone to Distance-based)

5.　Conclusion

This thesis provided trip distribution model that is estimating impedance function in a mode specific gravity model, in this case for metro. We analyzed the impact of fare system and distance on metro OD demand. The past passenger behavior data from Oyster card data can be used to predict their future trip pattern. We could confirm a decreasing function with distance to reflect that the metro is becoming more attractive with distance.

We find that small fare changes within the same fare system hardly affect passenger behavior. This can be expected since small fare changes will hardly change one's choice of origin or destination. However, we illustrate that changing the fare system might affect passenger trip patterns more significantly. For example, near stations gain more passengers when fare system is changed from zone to distance-based.

Reference

1)　Matthew Justin Smith : Public Transit and the Time-Based Fare Structure –Examining the Merits of Peak Pricing for Transit, Transport Chicago, 2009

修士論文指導教員

Jan-Dirk Schmöcker 准教授，宇野伸宏准教授，中村俊之助教，山崎浩気助教