Analysis of High Speed Rail Station Specific Demand Adaptation

高速鉄道の駅特性を考慮した需要適応性に関する分析

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出水　文章

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1. Introduction

In recent years, high speed rail (HSR) networks are rapidly expanding around the world. Further new HSR projects are being planned even in developing countries with the expectation to generate economic benefits. However, the actual number of passengers of HSR are often less than predicted before begin of construction. Doi *et al.*[1] suggest that the time-lag between start of operation and a population adapting to the new transportation mode is one of the reasons for this. Therefore, Li *et al.*[2] defined a continuous variable for months since operation starts as the "Adaptation Effect". By using this as an explanatory variable, they aimed to quantify and explain this adaptation effect. However, they focused on the effect for the whole system and did not analyze station specific effects, which is the focus of this thesis. Further different forecasting scenarios and methodologies depending on whether the forecast is made before opening or in the initial years of operation are employed.

2. Target Area

As a case study, Taiwan HSR (THSR) ridership is analyzed in this research. There is currently only one HSR line in Taiwan. It connects the two largest metropolitan, Taipei and Kaohsiung in Taiwan within travel time about 90 minutes. The target period of our research is from March 2007 to April 2015 after Taipei station began its operation. The eight HSR stations listed in Table 1 are operated in this period.

Table 1 Information and Classification of Each Station

ID	Station	Station scale		Distance from Taipei Sta.	Travel Time from Taipei Sta. (min)	Population (×1000)		Distance from CBD to THSR Sta. (Km)
		1	2			2007	2015	
1	**Taipei**	**L**	**L**	0	0	6,402	6672	-
2	**Banqiao**	**S**		7.22	8	6,402	6672	-
3	**Taoyuan**	**S**	**S**	36.38	22	1,913	2062	8.4
4	**Hsinchu**	**S**	**S**	66.28	35	883	970	9
5	**Taichung**	**M**	**M**	159.83	49	2,588	2742	11
6	**Chiayi**	**S**	**S**	245.68	89	826	795	15.5
7	**Tainan**	**S**	**S**	307.96	106	1,867	1885	13.9
8	**Zuoying**	**M**	**M**	339.28	94	2,761	2779	-

L; Large Station　M; Mid-size Station　S; Small Station

3. Basic Analysis of Demand Dynamics

In this chapter, demand dynamics of THSR for each station are analyzed by two basic methodologies. After some descriptive analysis on the demand development of stations compared to total demand, growth factor modelling is used. More specifically, a Fratar model is developed which is a well-known method for trip distribution. The model is usually utilized for a single forecast timer period. Compared with conventional model, the characteristic of our model is that parameters *r* and *s* are expanded to become time dependent parameters $r_i(t)$ and $s_j(t)$ toward the target time as shown in Eqs.1 and 2 below. The model is given by:

$$r_i(\mathrm{t}) = {P^*}_i \Big/ \textstyle\sum_j s_j(t) T_{ij}(t) \qquad (1)$$

$$s_j(t) = {A^*}_j \Big/ \textstyle\sum_i r_i(t) T_{ij}(t) \qquad (2)$$

Initialise $s_j(\mathrm{t}) = 1$ for all j

$T_{ij}(t)$ denotes the mean of trips per month from *i* to *j* in year *t*. ${P^*}_i$ is the mean generated traffic volume per month in the target year 2015 at station *i*. ${A^*}_j$ is the mean attracted traffic volume per month in the target year. $r_i(\mathrm{t})$ is defined as growth rate of the mean traffic volume per month from *t* until the target year, which we set as 2015. Similarly $s_j(t)$ is defined as growth rate of the mean of attracted traffic volume per month from t until the target year. Then the interdepending Eqs. (1) and (2) are repeatedly calculated until convergence is obtained. After convergence we obtain the growth factor matrix **G** as product of **r** and **s** as in Eq (3).

$$G_{ij}(t) = r_i(t) \times s_j(t) \qquad (3)$$

where $G_{ij}(t)$ is defined as the growth factor from origin *i* to destination *j*, from year *t* to the target year. Utilizing the station scaling 1 shown in Table 1 the results of the mean of $G_{ij}(t)$ for each station scale are summarized in Fig. 1. The figure shows that by 2013 the demand has almost stabilized for all station types but that there are some differences between the station types.

Firstly we observe that the largest demand growth occurs during the initial year of operation independent of station scale. The figure further indicates that the immediate increase effect of the small station is largest of the three. Moreover, the gradual increase effect lasts longer. **G** for the large scale station (Taipei) is lower than that of small stations but larger than for small stations indicating that medium scale station adapt fastest.

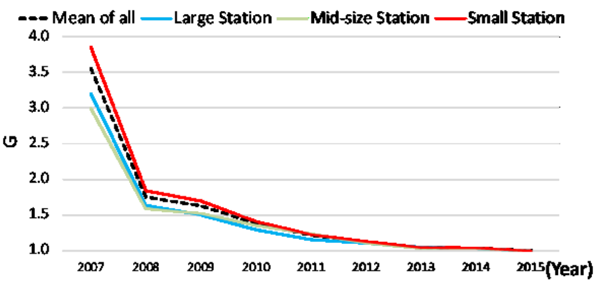

Fig. 1 $G_{ij}(t)$ per Each Station Scale (Scale 2 in Table 3.1)

4. Gravity Model

Demand dynamics is analyzed in more detail utilizing the gravity model. This chapter also aim to estimate the O-D trip by the observed trip data in one year before, a scenario common to estimate demand in the initial years of the project when information of total demand are given and an OD matrix has to be predicted. Different model formulations are tested. Firstly, by a standard gravity model then by including a modified cost function and finally by including an adaptation effect. The model formulation and result of the final gravity model is summarized below.

$$\hat{T}_{ij}(t) = P_i(t)^{\alpha} \cdot A_j(t)^{\alpha} \Big/ \left\{\frac{\beta \cdot C_{ij,} + \gamma \cdot F_{ij}(t)}{d_{ij}} + \delta \cdot C_{ij,}\right\} \quad (6)$$

$$\hat{T}_{ij,t} = (\text{Adap}) \cdot \left[P_i(t-1)^{\alpha} \cdot A_j(t-1)^{\alpha} \Big/ \left\{\frac{\beta \cdot C_{ij,} + \gamma \cdot F_{ij}(t-1)}{d_{ij}} + \delta \cdot C_{ij,}\right\} \right] \quad (7)$$

Where

$$\text{Adap} = \begin{cases} 1 + \theta_1 \cdot e^{-\mu_1 (t-1)} + m \ (1 \le t \le 12) & \text{; Immediate effect} \\ 1 + \theta_2 \cdot e^{-\mu_2 (t-1)} + m \ (13 \le t \le M) & \text{; Gradual effect} \\ 1 + m \ (M \le t \le 97) & \text{; after the demand adapted} \end{cases}$$

t ; Month since THSR started its operation.

$P_{i,(t)}$; Production trip from *i* in month t. $A_{i,(t)}$; Attraction trip to *j* in month t.

C_{ij} ; Travel time from *i* to j $F_{ij,(t)}$; THSR fare from *i* to j in month t

d_{ij}; Distance from *i* to j m; Monthly dummy

M; the month since THSR starts its operation and when the demand adaptation stops with ($25 \le \text{M} \le 85$)

The adaptation effect consists of three parts; immediate effect, gradual effect and the variable after the demand adapted. The adaptation effect is calculated for three O-D trip groups; where L ⇔ (M, S) stands for trips between large stations and medium or small stations and so on. The model fit is shown in Table 2 and the adaptation effect for each O-D trip group is illustrated in Fig.2.

Table 2 Model Fit of Gravity Model

	L⇔(M, S)	M⇔(M, S)	S⇔S
R^2	0.889	0.551	0.612
MAPE	24	51	57

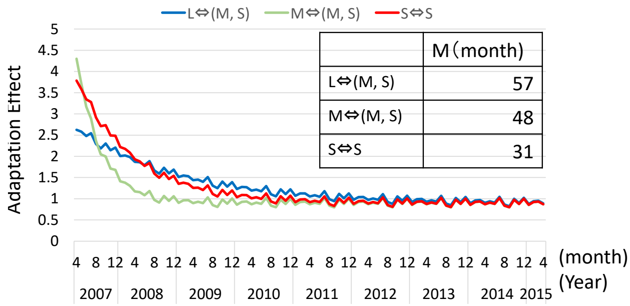

Fig. 2 Immediate and Gradual Demand Dynamics

Both L⇔(M, S) and S⇔S show almost the same change except for the time when demand adaptation is assumed to have stopped. Both immediate and gradual effect are larger than that of M⇔(M, S). Moreover L⇔(M, S) required longest time for demand adaptation of the three.

5. Conclusion

The findings are summarized in the Table 3. The relative attraction of mid-size stations decreases over time. For small cities, HSR might gradually give benefits such as increasing tourists or the demand of business trip. However, along with the increase in exchange between large and small cities, the population might move towards large cities providing some evidence for the existence of a “straw effect”. This is confirmed in the last part of the thesis where demand forecasting based on the assumption that total demand and population developments are uncertain is further explored. Under such scenarios demand forecasting remains difficult.

Table 3 Adaptation Effect for Each Station Scale

Station Scale	Adaptation Effect		
	Immediate increase effect	Gradual increase effect	Time to passenger increase stop
L⇔(M, S)	Large	Large	long
M⇔(M, S)	Smallest	Smallest	short
S⇔S	Large	Large	middle

参考文献

1) Doi Toshiaki, Shibata Yozo : STUDY ON EFFECTIVENESS OF DEMAND FORECASTING METHODS APPLIED TO TOKAIDO SHINKANSEN, 土木学会論文集,1997, vol.562/IV-35, p.p121-131

2) Li Yeun-Touh, Schmöcker Jan-Dirk, Fujii Satoshi : Demand adaptation towards new transport modes: the case of high-speed rail in Taiwan, Transportmetrica B: Transport Dynamics,2015, p.p27-43

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