360.revista de alta velocidad
número 6 - junio - 2018. Pág 225 - 237

# Impacts of station accessibility and regional heterogeneity on HSR ridership

**Kim, Junghwa**
**Li, Yeun-Touh**
**Schmöcker, Jan-Dirk**

Kyoto University[1]

**Abstract**

This paper examines how accessibility to the station impacts HSR ridership considering regional heterogeneity. Our study targeted on Taiwan High-speed rail (THSR). Monthly ridership data of THSR from 2007 to 2015 have been obtained from eight stations that are currently in operation. With a panel data set shown as two dimensions, a region *i* and time *t*, two-way error components model was applied in this study. Our results suggest that differences in the regional heterogeneity measured by population, road infrastructure supply, car ownership and business, would influence the HSR demand pattern. We further show that bus service (shuttle bus and BRT) would induce more demand than rail services (MRT/TR). In addition, our results show that the demand was also influenced by station's allocation; the one closest to city center had attracted more ridership. Under these findings, we discuss the way for pursuing long-term demand for HSR through improving accessibility to HSR stations and increasing quality of rail travel.

**Keywords**: *High speed rail; Travel demand; Access mode; Taiwan; Accessibility*

1 *Kim, Junghwa. Kyoto University. Email: junghwa.kim.trans@gmail.com*
*Li, Yeun-Touh. Kyoto University. Email: joe.liyt@trans.kuciv.kyoto-u.ac.jp*
*Schmöcker, Jan-Dirk. Kyoto University. Email: Email: schmoecker@trans.kuciv.kyoto-u.ac.jp*

## 1. Introduction

Taiwan high-speed rail (THSR) opened its operation from 2007. The system primarily relies on imported rolling stock from Japan and supplemented with European traffic management system. Through connecting the island's economic corridor north to south, serving almost 90% of the industry and the population. It had progressively reformed Taiwan into a "One-day living circle". The nearly 350 kilometers investment has significantly reduced the travel time from 4 hours into 1.5 hours, which the interregional accessibility of the Western coast Taiwan has naturally improved (Li et al. 2015).

To further illustrate this impact of intercity travel market share, traffic volumes of individual modes have been obtained from Taiwan's Ministry of Transportation and Communications (MOTC) are shown in Table 1. As a consequence of the THSR introduction, the ridership and intercity market share shifted between different travel modes between 2005 and 2015. Expressway buses, and domestic airlines experience negative trends while conventional rail demand (Taiwan railway, TR) remained stable during the first year of THSR operation and has since then been increasing. Private car though, seems have not experienced such impact from THSR but one should note that the expressway network (total length) had increased to 8.9% since 2005, and most of the extended sections were those areas that THSR could not be served. The average annual growth ratio for each mode since 2005 is 0.1% for cars, -3.86% for buses, 3.23% of Taiwan rail (conventional rail), and -5.89% of domestic airlines respectively; while THSR increased 7.53% per year on average.

Cheng (2010) investigated the initial stage operation and the aggregated demand of THSR; though he concluded that unsatisfied ridership (compared to previous forecasting) is the major concern for THSR system operator and the authorities, the ridership, service frequency, load factors (seat occupancy) are continuously increasing. As demand keeps growing, new stations opened, new access/egress mode opened/connected to stations, these impacts of station accessibility and regional heterogeneity, however, were not cleared and yet not disclosed from literature.

### Table 1. Aggregated Intercity Ridership of Travel Modes in Taiwan

| Travel Mode | Unit (market share) | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Private Vehicle | million cars | 479.1 | 480.6 | 475.5 | 453.9 | 457.1 | 464.8 | 479.6 | 482.8 | 498.9 | 449.1 | 479.2 |
| | (%) | (52.0) | (52.7) | (51.9) | (49.4) | (49.9) | (49.8) | (50.1) | (50.5) | (52.1) | (49.2) | (50.9) |
| Bus | million Pax | 252.8 | 245.2 | 242.3 | 246.4 | 237.8 | 232.8 | 220.6 | 197.1 | 173.9 | 172. 0 | 169.0 |
| | (%) | (27.5) | (26.9) | (26.5) | (26.8) | (26.0) | (24.9) | (23.0) | (20.6) | (18.2) | (18.8) | (18.0) |
| Conventional Rail | million Pax | 169.6 | 169.0 | 169.7 | 178.7 | 179.4 | 189.8 | 205.8 | 220.3 | 227.3 | 233. 0 | 232. 0 |
| | (%) | (18.4) | (18.5) | (18.5) | (19.4) | (19.6) | (20.3) | (21.5) | (23.1) | (23.7) | (25.5) | (24.7) |
| Domestic Airlines | million Pax | 19.29 | 17.36 | 12.71 | 9.85 | 9.23 | 9.73 | 10.48 | 10.68 | 10.55 | 10.55 | 10.56 |
| | (%) | (2.1) | (1.9) | (1.4) | (1.1) | (1.0) | (1.0) | (1.1) | (1.1) | (1.1) | (1.2) | (1.0) |
| THSR | million Pax | - | - | 15.56 | 30.58 | 32.35 | 36.94 | 41.63 | 44.53 | 47.49 | 48.02 | 50.56 |
| | (%) | | | (1.7) | (3.3) | (3.5) | (4.0) | (4.3) | (4.7) | (5.0) | (5.3) | (5.4) |
| **Total** | **million Pax** | **920.8** | **912.2** | **915.8** | **919.5** | **915.9** | **934.1** | **958.1** | **955.4** | **957.9** | **912.6** | **940.5** |

*Source: Ministry of Transportation and Communications (MOTC)*

Taken the perspective from a regional point of view, this paper examines how access transportation affects the local demand of THSR. It is a suitable case study for researchers to investigate the impact of a single HSR route for the country and to understand the passenger's travel behavior. Especially the differences among region's economic developments and city characteristics, how it would influence HSR demand over time.

## 2. Literature Reviews

Accessibility is quite an important topic, especially for transit system as already confirmed by many studies. Murray (2003) noted that accessible and efficient service is vital features, especially for well-utilized public transit systems. Mitra and Saphores (2016) investigated the recently published studies which identify the impacts of accessibility on property value of transit. They also argued that a positive relationship between accessibly improvements and property values has been verified by a number of literatures ((e.g., Cervero and Kang (2011) for Seoul's Bus Rapid Transit; Debrezion et al. (2011) for road accessibility on office prices in the Netherlands; or Dubé et al. (2013) for commuter rail accessibility in Montreal).

Accessibility to rail station becomes more important factor for rail transit in particular. The accessibility of the railway station can be a factor in determining if rail is chosen as a travel alternative (Hine and Scott, 2000; Krygsman et al., 2004; Wardman and Hine, 2000; Wardman and Tyler, 2000; Brons et al., 2009). In order to provide highest quality se1vices to its users, railways need to pay attention not only to the standard qualitative and quantitative indicators, but also to the accessibility of the railway station (Bogovic et al, 2003). Brons et al. (2009) indicated that rail operators aiming at increasing rail use must consider the aspect of satisfaction with its level. Here, they argued that access-to-the station is an important part in passengers' overall satisfaction with rail journey. Many past studies have also confirmed the importance of accessibility to the station. Keijer and Rietveld (2000), Rietveld (2000) and Givoni and Rietveld (2007) investigated the accessibility of rail travelers to the railway stations focusing on their mode choice (Brons et al., 2009).

The high-speed rail (HSR) is becoming more and more popular as a representative transport mode of railway in recent years. Therefore, based on the above literatures, access-to-the station is also one of the major factors which should be considered carefully in the case of HSR. According to the report of California High-Speed Rail Authority, it should be important to prioritize and obtain a balancing of many transport modes for station accessibility so that all users will be safe and comfortable moving to and from the HSR station and surrounding areas. Moreover, Eidlin (2015) argued that "high speeds (HSR) should be prioritized in sparsely populated places, while maximizing connections should be the primary consideration in densely populated places". Referring to these, intraregional station accessibility might be one of the issues at stake in the problem of securing sustained HSR demand

This paper continues the line of research on access to railway stations as an extension study of Li and Schmöcker (2014) and it has two broad aims as follow. First, to demonstrate that factors of access-to the station serves as a key element in explaining passenger demand of HSR with regional heterogeneity such as socioeconomic characteristics. Secondly, to investigate which public transport between bus and urban rail system is the most influential on increasing HSR ridership. This would also show the degree of influence by access transport modes on increase of accessibility to HSR station. The Taiwan HSR network is used as a case study as mentioned earlier.

# 3. Data

## 3.1 Station Accessibility by Region

One of the issues at stake would be intraregional station accessibility; Su et al. (2012) discusses that five out of eight stations are located in suburbs and far away from the CBD (central business district) area (except Taipei, Banciao, and Zuoying); where they found intercity travelers from around these stations are less willing to use THSR. In terms of this, the THSR stations which located in a peripheral location did not have a direct transit connection with its corresponding CBD at the beginning. This has reduced the travel time benefits in many cases compared to conventional rail. For example, the traveling time from Taipei to Tainan is 110 min, but from Tainan HSR station to downtown requires a traveling time around 35-40 min. Therefore, the lack of access to these HSR stations needs to be solved; THSR operators realized that creating a seamless journey for their travels is essential.

To this end, THSR has been working on improving its station accessibility since the operation. By cooperating with other stakeholders, THSR increased the level of service of access links and implemented new feeder lines. The reduced access/egress time to stations enhanced station accessibility. Table 2 indicates the time and types of access links to THSR. Four categories of access mode could be distinguished, MRT (mass rapid transit), TR (Taiwan Railway), BRT (bus rapid transit), and free shuttle buses offered by THSR. Considering the low cost and efficiency of deployment, THSR attempted to use BRT and shuttle buses which delivered a direct connection between THSR station and its corresponding CBD at the beginning years of 2007 and 2008. MRT and new feeder line constructed by TR takes longer construction time/cost, but expects higher capacity and frequency. We note that in a few stations, the shuttle bus had been suspended soon after the railway links (MRT and TR) began their operation.

**Table 2. Access Modes for THSR station**

| Station \ Access Modes | MRT | Taiwan Railway | BRT | THSR Shuttle Bus |
|---|---|---|---|---|
| Taipei and Banciao¹ | ● | ● | | |
| Taoyuan² | ◎ (2017.02) | | | ◎ (2008.02) |
| Hsinchu² | | ◎ (2011.11) | | ◎ (2008.02-2012.05)* |
| Taichung² | ○ (2019) | ◎ (2007.11) | | ◎ (2007.11) |
| Chiayi² | | | ◎ (2008.02) | |
| Tainan² | | ◎ (2010.11) | | ◎ (2008.02) |
| Zuoying¹ | ◎ (2008.03) | ● | | ◎ (2007.11-2008.04)* |

Note:

- Superscript¹ denotes stations which located within / close to CBD
- Superscript² denotes stations located in suburb areas
- Number within parentheses indicates actual or scheduled year/month of opening, where superscript* denotes links suspended after a new link connects to stations
- ●: Links implemented / exist before THSR
- ◎: New links after THSR opened
- ○: Links currently under construction

For the stations close to the CBD, access links had been integrated with THSR before opening. Taipei and Banciao station are both located within the Taipei metropolitan area and are integrated nodes in the TR and MRT networks, the MRT network extended the network length from 74.4km in 2007 to 112.8km in 2012. While Zuoying station was constructed with Xinzuoying station (TR) at the beginning of the operation, the number of TR services increased from 117 per day to 159 at the end of 2012. On the other side, Taichung HSR station later constructed pedestrian flyovers to nearby Xinwuri stations (TR) in late 2007. Smaller metropolitan areas such as Hsinchu and Tainan instead implemented new TR feeder lines (Luijia line and Shalun line) to its HSR station in 2010 and 2011. These improvements induced THSR ridership demand as well as reduced HSR station access/egress by private vehicles from 59.5% in 2008 to 51.5% in 2010 (Su *et al.*, 2012). Furthermore, Taoyuan has an MRT project that connects to its CBD, THSR station, and Taoyuan International Airport was opened in 2017. Based on the aforementioned effort improved by THSR, the impact of intraregional accessibility to THSR station ridership need to be further examined. (See Figure 1)

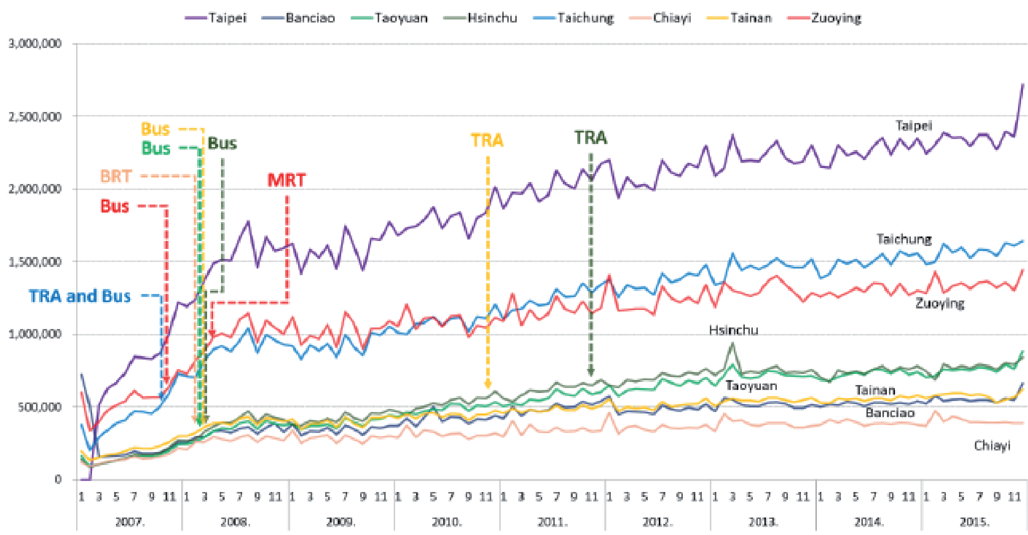


*Figure 1 .THSR monthly ridership and opening time of access transport to the station*

As representing , three types of parameters were considered to THSR station location in terms of accessibility measurement: a) direct distance away from its corresponding downtown b) access mode via road infrastructure such as bus service (BRT, shuttle bus), and c) access mode via rail service (MRT, TR). First one is measured by distance from city center to the station as shortest path (km). Here we assumed that shorter distances represent better accessibility. For the other two variables, the access link could be considered as binary dummy variable, i.e. if bus/rail is connected to the station 1, or not 0. This is one of the limitations of this paper have been that access link measures for all THSR station are complex and may result in difficulty of comparing their impact across different stations. These two dummy variables also indicate the specific month when access links connected to THSR stations as panel data which has a double subscript, region *i* and time *t*.

### 3.2 Variables for Region Heterogeneity

Based on previous studies, parameters that significantly influence aggregated THSR ridership had been specified as found by Li and Schmöcker (2014). Taipei is the capital and largest city of

Taiwan with a population of around 6.6 million at the end of 2012. The station was dominated by all kinds of travelers, including business travelers as well as local and some foreign tourists. Zuoying (located in Kaohsiung city) and Taichung station represent the 2nd and 3rd largest metropolitan areas located in the south and middle of Taiwan's west coast respectively. The rest of the stations listed in order of ridership are Hsinchu, Taoyuan, Tainan, and Chiayi, which are considered as second or third-tier city, from the 3rd group. Note that Banciao is located in the Taipei metropolitan area as a satellite station dispersing the mass demand from Taipei. Therefore two cities, Taipei and Banciao were considered together as one region in this study.

We consider regional heterogeneity mentioned briefly in above and assumed that regional heterogeneity would measured by some socioeconomic variables such as population, car ownership (%), total length of road (km), fuel price and business scale by city as underlying independent variables *($X_{itk}$)* (. These were obtained and calibrated into the regional scale of monthly data from 2007 to 2015. For brevity we omit descriptive statistics as shown in Figure 2.

The region of Taipei and Banciao shows the highest value of population and business scale while the lowest ratio of car ownership compared to other cities. This might come from Taipei being the capital of Taiwan. The highest road supply rate is shown in Taichung with a high ration of car ownership. This implies that better mobility by car use would be in case of Taichung even this is located in the middle of Taiwan. In addition, regarding explanatory variables which explain THSR station demand, Li et al. (2015) we also considered two time specific factors, including a variable for years ($X_y$), which shows time since operation after THSR opening, in order to reflect the trend of increased demand over time and a dummy variable for summer vacation ($D_s$), to reflect some induced demand such as leisure trips. Thus the variables for regional heterogeneity also have a form of panel data which has a double subscript, index *i* and time *t* as same as variables of accessibility.

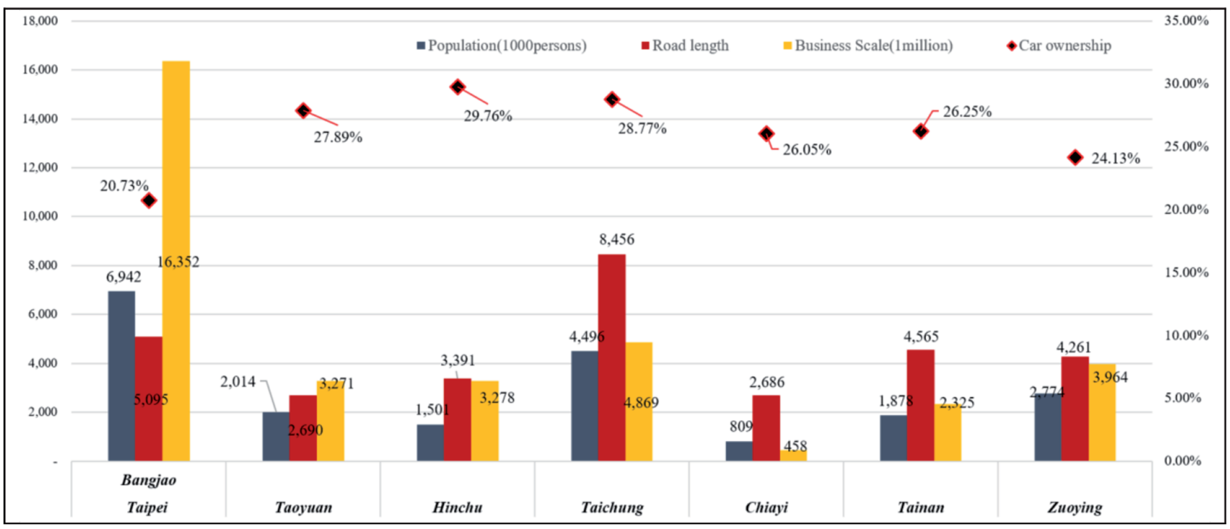


*Figure 2. Descriptive statistic of socioeconomic variables by major city*

## 4. Methodology

This study uses a two-way error component model, a kind of panel model, to mitigate the errors occurred from unobserved heterogeneity in terms of location regions and time. A two-way error component random effect model was applied in this study where we control the unobserved effects, presented by month and city as random variables. Baltagi (*2013*) noted that a panel data model differs from a regular time-series or cross-sectional regression in that it has a double subscript on its variables, i.e.

$$y_{it} = \alpha + X'_{it}\beta + \varepsilon_{it},\ (i = 1, \ldots, I;\ t = 1, \ldots, T), \qquad (1)$$

where $i$ represents location and $t$ represents time. The $i$ subscript therefore denotes the cross-section dimension, whereas $t$ denotes the time-series dimension. Here is a scalar, β is a $K$x1

$$\varepsilon_{it} = u_i + \mu_t + v_{it},\ (i = 1, \ldots, I;\ t = 1, \ldots, T), \qquad (2)$$

$$y_{it} = \alpha + X'_{it}\beta + u_i + \mu_t + v_{it},\ (i = 1, \ldots, I;\ t = 1, \ldots, T), \qquad (3)$$

where $u_i$ denotes the unobserved regional effects, $\mu_t$ denotes the unobservable time effect, and $v_{it}$ is the remainder stochastic disturbance term. Here, $u_i \sim IID(0,\sigma_u^2)$ and/or $\mu_t \sim IID(0,\sigma_u^2)$ and $v_{it} \sim IID(0,\sigma_u^2)$ independent of each other, it is possible to obtain the two-way random effect error component model. In addition, $X_{it}$ is independent of $u_i$, $\mu_t$ and $v_{it}$ for all $i$ and $t$ . Inference, in this case, pertains to the large population, which the sample was randomly drawn from.

In this study, we estimate two models. First model only includes socioeconomic variables and then transport accessibility variables would be considered as an additional factor in the second model. We are going to identify whether accessibility variables are important as much as socioeconomic factors to the model which explains HSR ridership. Our hypothesized model could be expressed as follows;

$$y_{it} = \beta_0 \cdot \beta_k X_{itk} \cdot \beta_y e^{X_y} \cdot \beta_s e^{Ds} \cdot e^{\varepsilon_{it}}, \qquad (4)$$

Here, taking a log to equation (4)

$$\ln(y_{it}) = \ln(\beta_0) + \textstyle\sum_k^K \beta_k \ln(X_{itk}) + \beta_y X_y + \beta_s Ds + \varepsilon_{it},\ \varepsilon_{it}{=}u_i + \mu_t + v_{it}, \qquad (5)$$

Where, $i$=city (region) and $t$=month, $X_k$=socioeconomic factors(population fuel price, business scale, road supply, car ownership), $X_y$ =year, $Ds$=dummy for summer, Then, our hypothesized second model with transport accessibility variables is presented as follows:

$$\ln(y_{it}) = \ln(\beta_0) + \textstyle\sum_k^K \beta_k \ln(X_{itk}) + \beta_y X_y + \beta_s Ds + \sum_n^N \beta_n \ln(A_{itn}) + \sum_{n*}^{N*} \beta_{n*} \delta_i A_{itn*} + \varepsilon_{it} \qquad (6)$$

Where, $A_n$=station location (distance from CBD to (HSR station(km)) and $A_{n*}$=Rail and bus transit (dummy variable) are added as transport accessibility variables.

## 5. Model Estimation

The estimated time-random/region-random effects two-way error component models' results are shown in Table 3. By the model 1, we examine how socioeconomic indicators and time/seasonal factors which have been verified variously in previous studies, explain THSR ridership considering regional heterogeneity. Additionally, this study also examines how the factors of access-tothe station enhances model fits towards THSR ridership. Thus, Model 2 contains all socioeconomic elements of the Model 1 as well as accessibility factors. Both models are statistically significant, supported by the Chi2 statistic of 0.000, moreover all coefficients of explanatory variables are significant at the 5% level; (coefficients significant at the 1% level are shown in bold)

From our finding, regional specific socio-demographics (i.e. population, car ownership, length of road network, business scale), fuel price by year as well as time dummy variables are always being significant generally explain THSR demand. Population and car ownership are most influential variables to explain THSR ridership by region, since population may represent the market size of the travel demand and HSR works as an alternative transportation mode instead of car use. Therefore, this indicates that higher number of HSR users can be shown in the cities with high population and low car ownership ration. Furthermore, the length of road network, fuel price, business scale that shows the revenue per company, is found positive to local THSR ridership. In addition, the seasonal factors, the summer vacation and the element which shows how long after the opening of THSR, performed well to explain the local demand as well. The demand is found positive significant in the summer suggests that vacation activities has induced HSR demand. Moreover, the number of THSR users increases as time passes after system opening. This result shows the "mass effects" which argued by Schmöcker et al. (2014) and "adaptation effects" suggested by Lit et al. (2015). According to Li and Schmöcker (2014), the negative perception of the traveler at the beginning of operation has been observed, such as safety concerns, unreliable ticketing, or the reservation system that prohibited some potential users to taking rides (Cheng, 2010). However, this general perception might possibly have been changed over time, where more travelers recognized the advantages of HSR, travel time saving, level of services, easier to access than before and other advantages related with perception. These conversions of perceptions would enlarge HSR travelers from a small number of population group penetrates into the majority. This was resonated by Schmöcker et al. (2014) who discussed that "mass effects" can be significant determinants of long term demand adaptation. One persuades a few to change their behavior initially in order to encourage a large number of people to follow later. There is then a potential of enduring significant demand increases as the new service might increase its attractiveness over time if more start to join it. Li et al. (2015) proposed an econometric time-series model to predict aggregated THSR ridership on long-term demand. This study takes into account on THSR local demand to understand the impact of "adaptation effects" as well as access link regarding other general explanatory variables.

The result of Model 2 is also quite similar results with those of the Model 1 in the case of a socioeconomic variable by region. However, we considered three of accessibility variables here additionally. All are significant but has different sign in the coefficients. Especially the station location has negative value, unlike the other two accessibility variables. It implies that the number of passengers is smaller as the station of the HSR is located far from the city center. On the other hand, the ridership demand would be induced if buses or railway public transportation is connected to the HSR station. In addition, when we compared to the transit system in an aspect of access-to-the station, bus system (BRT and shuttle bus) has a larger influence than rail transit (MRT and TR). From the result of the Model 2, we identified that accessibility to HSR station is also an important factor in explaining the demand for HSR as much as socioeconomic indicators.

### Table 3. Results of model estimation

| Variables | | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|---|
| $Y_{it}$:Ridership | | Coef. | Std. Err. | pvalue | Coef. | Std. Err. | pvalue |
| Socioeconomic variable by region | population | **2.714** | 0.503 | 0.000 | **4.280** | 0.499 | 0.000 |
| | Car ownership | **-6.651** | 0.439 | 0.000 | **-4.817** | 0.389 | 0.000 |
| | Road length | **-0.756** | 0.149 | 0.000 | **-0.359** | 0.128 | 0.005 |
| | Fuel price | **0.199** | 0.058 | 0.001 | **0.186** | 0.049 | 0.000 |
| | Business scale | 0.235 | 0.109 | 0.031 | **0.295** | 0.091 | 0.001 |
| Time dummy variable | year | **0.224** | 0.008 | 0.000 | **0.174** | 0.007 | 0.000 |
| | Summer season | 0.060 | 0.234 | 0.012 | **0.061** | 0.021 | 0.004 |
| HSR station accessibility variable | Station location | - | | | -2.734 | 1.191 | 0.022 |
| | Bus accessibility | - | | | **0.296** | 0.018 | 0.000 |
| | Rail accessibility | - | | | **0.053** | 0.019 | 0.005 |
| Constant | | 472.113 | 15.575 | 0.000 | 385.896 | 14.035 | 0.000 |
| Random effects parameters | Region identity | 1.610 | 0.598 | - | 1.921 | 0.607 | - |
| | Time identity | 0.053 | 0.101 | - | 0.051 | 0.009 | - |
| | sd(Residual) | 0.182 | 0.005 | - | 0.152 | 0.004 | - |
| Log likelihood | | 160.829 | | | 289.798 | | |
| Wald chi square | | 2771.64 | | | 4307.17 | | |
| Prob>Chi2 | | 0.000 | | | 0.000 | | |

In order to re-verify that the elements of accessibility are important and to find out which model is more appropriate to explain HSR ridership, we tried to compare Model 1 and 2 by statistical method. Burnham and Anderson (2004) note that the first step for model selection would be to establish a selection criterion, such as the Akaike information criterion (AIC) or the Bayesian information criterion (BIC). AIC is an usual selection criteria which were well adopted in past studies, however BIC also has been suggested in recent studies. One advantage of the BIC over traditional hypothesis testing is that it has good properties under conditions of weaker regularity compared with the likelihood ratio test (Roeder et al., 1999; Kim et al. 2013). In addition Keribin (1998) demonstrated that under certain conditions, the BIC consistently determines the right number of components in the mixture model (Lee and Timmermans, 2007; Kim et al. 2013). In this study, we are going to confirm which model has a high model fit and then to select more appropriate models between the two based on BIC with consideration of AIC. Those formulas are:

$$AIC = -2LL + 2K$$

$$BIC = -2LL + \frac{\ln N}{K}, \quad (7)$$

where *LL* is the value of the log-likelihood function at convergence and means the level of model fit, *K* is the number of parameters in the model, and *N* is the total sample size (Wen and Lai 2010; Kim et al. 2013). Through BIC and AIC values reported in Table 4, it could be an appropriate way to check which model is better. Since *LL* indicates the level of model fit, the model which has a lower value of AIC and BIC could be selected. A comparison of BIC and AIC values indicated that model 2 which considered THSR station accessibility could be identified the proper model than model 1 in order to explain THSR ridership.

**Table 4. AIC and BIC analyses for model selection**

| Model | df | Log-likelihood at convergence | AIC | BIC |
|---|---|---|---|---|
| Model 1 | 11 | 160.829 | -299.6584 | -248.8523 |
| Model 2 | 14 | 289.798 | -551.5967 | -486.9344 |

## 6. Discussion and Conclusion

Our analysis suggests that differences in regions economic developments and city characteristics would influence HSR demand pattern. Furthermore, in discussion on the demand impact from THSR access links, our result shows analysis that improvement of access links does seem to affect ridership. It also suggests that access links of public transportation appear to be important factors to induce HSR ridership. The result also indicates bus service (shuttle bus and BRT) would induce more demand than rail services (MRT/TR). The THSR accessibility improvement is essential from our observation, once the link connects to those which located in peripheral locations, it generally induces THSR station demand. In addition, especially our findings illustrate the demand influenced by station's allocation, the one closed to city center had attracted more ridership. Our models capture the effect of accessibility to the station as well as socioeconomic variables which show regional heterogeneity on HSR demand by using panel data. Clearly this finding would support our hypothesis to model estimation.

Providing sufficient station accessibility is essential for THSR due to the remote location of stations. Obviously stations located in the CBD provide more access links than rural area. In this paper, the access quality was measured as binary variables (e.g. If connected with transit network, 1, or 0); For stations located within CBD's we show that service improvements to metro and local rail links that existed prior to THSR opening do not appear to have an influence on THSR demand. However, for most of the THSR stations located in peripheral locations and without any public transport access at the beginning of HSR operation, the first access link connected would stimulate the station demand, i.e. THSR shuttle buses (Hsinchu and Tainan) and BRT (Chiayi);. This is why the influence of connectivity in case of bus system was derived more strongly than that of the rail transit. This is the result in the same line with Li and Schmöcker (2014).

We argued that station accessibility affects on quality of rail travel in the beginning of this paper. Nevertheless a lot of rail operators still have underestimated its impact. Tentatively, we suggest that general accessibility through public transport is important, but further improvements do not necessarily generate additional journeys. Further work for this analysis could be much improved if panel data on modal split of how people access HSR would be available as well as how much time to access to the station by mode. From another point of view, as it is rapidly entering a super aging society, explanatory variables capable of responding to changes in household structure and average age users should also be considered in the model which explains the long-term demand of HSR.

## 7. References


- Li, Y.-T., Schmöcker, J.-D., and S. Fujii. (2015). Demand adaptation towards new transport modes: the case of high-speed rail in Taiwan. *Tansportmetrica B: Transport Dynamics*, 3(1), pp.27-43. DOI: 10.1080/21680566.2014.946456.

- Cheng, Y.-H. (2010). High-speed rail in Taiwan: New experience and issues for future development. *Transport Policy*, 17, pp.51-63.

- Murray A.T. (2003). A Coverage Model for Improving Public Transit System Accessibility and Expanding Access. *Annals of Operations Research*, 123, pp.143–156.

- Mitra, S. K., Saphores, J-D. M., (2016). The value of transportation accessibility in a least developed country city – The case of Rajshahi City, Bangladesh. *Transportation Research Part A: Policy Practice*, 89, pp.184-200.

- Cervero, R., Kang, C.D. (2011). Bus rapid transit impacts on land uses and land values in Seoul, Korea. *Transportation Policy*, 18 (1), pp.102-116.

- Debrezion, G., de Graaff, T., Rietveld, P., (2011). The impact of accessibility on the value of offices. In: Transitions Towards Sustainable Mobility. Springer, Berlin, Heidelberg, pp.41-57

- Dubé, J., Thériault, M., Des Rosiers, F., (2013). Commuter rail accessibility and house values: the case of the Montreal South Shore, Canada, 1992–2009. Transportation Research Part A: Policy Practice, 54, pp.49–66.

- Hine, J., Scott, J., (2000). Seamless, accessible travel: users' views of the public transport journey and interchange. Transport Policy, 7, pp.217–226.

- Krygsman, S., Dijst, M., Arentze, T., (2004). Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transport Policy*, 11, pp.265–275.
- Wardman, M., Hine, J.P., (2000). Costs of interchange: a review of the literature. Working paper 546, *Institute for Transport Studies, University of Leeds*.
- Wardman, M., Tyler, J., (2000). Rail network accessibility and the demand for interurban rail travel. *Transport Reviews*, 20 (1), pp.3–24.
- Brons, M., Givioni, M. & Rietveld, P. (2009). Access to railway stations and its potential in increasing rail use. *Transportation Research Part A: Policy and Practice*, 43, pp.136-49.
- Bogovic, B., Kovacic, B., Jenic, V. (2003). Coefficient of Railway Station Accessibility. *Science in Traffic*, 15(1), pp.7-11.
- Keijer, M.J.N., Rietveld, P., (2000). How do people get to the railway station? The Dutch experience. *Transportation Planning and Technology*, 23, pp.215–235.
- Rietveld, P. (2000) The accessibility of railway stations: the role of the bicycle in the Netherlands. *Transportation Research Part D*, 9(2), pp.151-173.
- Givoni, M., Rietveld, P., (2007). The access journey to the railway station and its role in passengers' satisfaction with rail travel. *Transport Policy*, 14, pp.357–365.
- Eidlin, E. (2015). Making the Most of High-Speed Rail in California Lessons from France and Germany. *Project Report of the German Marshall Fund of the United States*. http://www.gmfus.org/listings/research
- Li, Y.-T., & Schmöcker, J.-D. (2014). Demand Impact of Access Links to Taiwan High Speed Rail. *Proceeding of the 19th International Conference of Hong Kong Society for Transportation Studies*, pp.103-110. Hong Kong, China. ISBN: 978988-15814-3-3
- Su, C-W., C-W., Chang, Y-C., Lu, and J-R. Liu. (2012). A Study on Selecting a Feasible Mode for Seamlessly Transferring between HSR and TR Stations. *Ministry of Transportation and Communications, Taipei*. (in Chinese), ISBN 978-986-033263-6.
- Baltagi, B. H. (2013). Econometric analysis of panel data. Fifth Edition. Chichester, *West Sussex: John Wiley & Sons*, Inc. ISBN: 978-1-118-67232-7.
- Schmöcker, J.-D., Hatori, T., and Walting, D. (2014). Dynamic process model of mass effects on travel demand. *Transportation*, 41(2), pp.279-304.
- Burnham, K. P. and Anderson, D. R. (2004). Multimodel Inference Understanding AIC and BIC in Model Selection. *Sociological Method and Research*, 33(2), pp.261304.
- Roeder, K, Lynch, K.G., and Nagin, D.S. (1999). Modeling uncertainty in latent class membership: a case study in criminology. *Journal of the American Statistical Association*. 94(447), pp.766–776.

- Kim, J., Fujii, S., Lee, B. (2013). Strategies to Promote Sustainable Mobility management Incorporating Heterogeneity. *International Journal of Sustainable Transportation*, 7(2), pp.107-124.

- Keribin, C. (1998). Consistent estimate of the order of mixture models. *Comptes Rendus de l'Acamdémie des Sciences, Série I-Mathématiques*, 326, pp.243– 248.

- Lee, B., and Timmermans, H. (2007). A latent class accelerated hazard model of activity episode durations. *Transportation Research Part B*, 41, pp.426 – 447.

- Wen, C., and Lai, S. (2010). Latent class models of international air carrier choice. *Transportation Research Part E*, 46, pp.211 – 221.