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# Urbanisation Through the Benefits of High-Speed Rail System

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**Abstract.** High-speed rail (HSR) acts as a prominent role in society, particularly in urban areas. It implied on socio-economic dynamics and economic growth due to the connectivity. This study conducts the successful case studies of HSR service to analysis on the accessibility of a region and, its effects on urbanisation. Based on the positive impacts of HSR, the land pricing and population dynamic are concerned with primary factors. This research aims to examine the significance of HSR impacts and its roles in reforming urban areas. Therefore, the study brings out a case study of HSR in China (Shanghai and Minhang district) to analysis via the analysis of variance (ANOVA) methods to find a correlation of HSR services with population dynamics and property prices. The Durbin-Watson statistic and Remedial measurement method are also applied to eliminate the disturbance of auto-correlation. As a result, the research found that HSR significantly increased an employment rate and it also leads to enhancing property prices especially within 5 km radius from HSR stations.

## 1. Introduction

High-speed rail (HSR) acts as a prominent role in transport infrastructure of urban area, which provokes intense socio-economic dynamics and stimulates the fundamental aspects of economic growth by its connectivity [1]. Since Tokaido Shinkansen, the world's first HSR, started operation in Japan 1964, Shinkansen line project linking Tokyo and Osaka made a huge success both in economic and society, and then HSR was introduced to worldwide including France, Spain, German, USA and China. Relatively researches revealed the benefits HSR conferred in commercial and regional growth, such as increase in employment, income, production, and land value [2, 3, 4]. Regarding global impact, there was up to 34% of CO<sub>2</sub> emission reduction than other mode of transportations. Thus, HSR network has become an attitude to generate sustainability impacts on society.

Urban spatial structure is a description of certain urban elements in the spatial extent of heterogeneity distribution [5]. The drastic changes of the spatial accessibility (HSR) in cities result in the changes of the distribution on various elements i.e., labour, capital, transport, raw materials and other resources to gather status on different geographical space.

## 2. A Case Study of HSR

Previous research pointed out that the HSR generate accessibility area that directly stimulate urban dynamics, population dynamics, and land pricing, which can be measured by statistically analysis. The future expected impact of HSR service is the result of the development of regional accessibility; nevertheless, the development was not directly contributed from the impact of HSR [4]. The higher



accessibility of the area like investment on public transportation made competitiveness of the region regarding local resources, goods, and economics [6].

Accessibility of a region is defined as the accessibility brought from public transportation and development of the road network [4]. HSR can serve the huge volume of passenger and productions. It can be believed as a production of transport system determining the optimal location for developing in one region; therefore, the accessibility factor relates with the society and economics developments. The analysis of accessibility was widely interested that Chen (2013) mentioned there are two elements should be conducted to measure accessibility, which is the attractiveness of potential destination and, the travel cost to destination [7]. The weighted average travel time method was conducted to evaluate the accessibility of impact of future European HSR service [8]. An idea to compare various indicators by weighting travel time, economics potential and daily accessibility is provided for measuring regional accessibility [9, 10, 11]; however, these methods were suitable for the less sample set preparation and reliable result interpretation, it still excludes some competition factors. The method using the inverse balancing factors is provided to reflect the spatial effect of the HSR line in Italy and, the result shows that the service could spread off spatial effect with satisfied feedback from local population [12].

Hägerstrand firstly used the activity-based approach for developing the concept of the space-time prism [13]. The model considered the journey time to various destinations. The activity based approach model is applied to measure travel behaviour [14]. Besides, the measurement for individual accessibility could be based on utility. The log-sum model represents the desirability of the full choice [15]. This approach is less data preparation and result reasonable compare to other methods but it still need improvement on spatial-temporal constraints.

## **2.1. Effect of High-speed rail on land pricing**

The land pricing can be effected from property pricing and urbanisation. The property pricing, firstly, relies on the supply and demand of real estate market and hedonic price. Moreover, the urbanisation was caused by relocating of population and increasing of land use.

### *2.1.1. Property Pricing*

The hedonic price model has been widely applied to analyse the effect of railway accessibility on house and commercial building prices. Debrezion's research pointed out that the variousness on railway services generates different outcomes; for example, the commuting railway had significant increased on property values than long distances station [16]. In addition, the impacts of railway stations show different effect on residential and commercial properties; moreover, the impact of railway stations exists difference impacts rely on the region.

The study on urban analysis in Spain showed that increase of 1.8% for each additional transit line presenting in the areas of housing, as well as a reduction of 1.1% in their prices for single additional minute in journey time to city centre [17]. Similarly, the new project named "rail plus property development" in Hong Kong showed that more than 50% of total income of the West Kowloon railway station came from direct impact from commuting rail. Besides, almost half of workers lived within five kilometres from the station, which increased the property demand caused by the property price around station has risen up [18].

### *2.1.2. Urbanisation*

Urbanisation is another factor affecting on land pricing. The transportation is an important factor for household and firms when relocation happens in long term, which directly stimulated urbanisation [19]. The research also mentioned better transportation infrastructure reduces congestion cost, raises the investment returns, attracts new economic activities, and generates agglomerations.

Previous research mostly focus on finding empirical evidence of relocation between HSR station and urban development. Based on a theory to relocate, the choice of household location is a maximizing

utility issue, where options are primarily driven by the land price, transportation cost, public services, and local amenity, given the budget constraints. The relationship between HSR and population during 1980-1985 among 104 major regions was studied by Nakamura and Ueda and, the result found that the population and employment rates have growth in the area with HSR station more than the area without HSR [20]. Also, people willing to move closer to the HSR station [21].

The model for choosing the location of house that combined individual discrete choices model and the characteristic of housing market so, each household chooses a location, which can maximize its utility [22]. Besides, Friedman (1981) developed model by including utility function i.e. local public services, neighbourhood, distance for work and housing services [23].

## **2.2. Effect of High-speed rail on population dynamics**

The impact of HSR on the population dynamics has been shown regarding employment and population. Urban economy directly determines population dynamics and, the employment should move in the same direction with the increase of wages [24]. In USA, the trend of income and population concurrently grew across the countries. Many researches showed region economy and urbanization develops in population dynamics [25, 26, 27] but, some research argued that the accessibility play the most essential role on population dynamics [29, 30].

On the other hand, the effect from HSR differently effect on individual areas. The study on the population dynamics in Finland during 1990 to 2008 found that the accessibility had highly impact on the changing on population [30]. However, the transportation did not have significant role due to the area has small size, and normally dominated by private cars.

Regarding the regional employment, the HSR provides positive effect on increasing accessibility for labour participation to their workplaces. The effect of HSR service in route Seoul and Pusan and, the result showed that the service enhanced employment opportunities and expanded economics space [31]. Also, the analysed though the changing of economic after coming of HSR and, the result pointed out that the transport infrastructure generates positive impact on employment rate [32]. It also provides more advantage for women in rural area to get a job in metropolitan area, which could be led to increasing wages.

## **3. Methodology**

### **3.1 Combination of Empirical Study and Theoretical Research**

Based on high level of research for urban economics, traffic location theory, urbanisation study and other related fields have been constructed between theoretical derivation and analysis framework. Then, the structural framework of the theoretical part will be established, and the corresponding verification will be conducted by the case study of Shanghai HSR with a comparison between other countries. There are different aspects of the framework, which are represented with sub-models. In this section, the qualitative analysis and quantitative analysis will be discussed.

### **3.2 Qualitative Analysis and Quantitative Analysis**

Both a qualitative and quantitative analysis are conducted based on the findings from the literature reviews. A combination of them will also be employed to analyse several case studies for further research. Dummy variable regression analysis will be conducted by statistical software named Eviews to measure whether there is a highly significant relationship between HSR service and urban dynamics or land pricing in the Shanghai case study. Then, the discussion of the impact of HSR service will use the reviews from Japan, France, and Hong Kong to compare the result of urban planning, labour force dynamics, and land pricing.

Dummy variables are independent variables, which show the value of either 0 or 1. The dummy variable in this research is represented for the existence of HSR. Otherwise, it is in the treatment group. The analysis of variance (ANOVA) is used to test the significance of the impacts of HSR on population changes and property pricing. The equation is shown below

$$Y_i = C + dX_1 \quad (1)$$

Where;  $X_1$  is the dummy variable, and  $Y_i$  is a dependent variable (population or property price).

The data will be represented in a time series and thus, the problem of autocorrelation should be considered. An explanatory variable AR (1) is added to correct for autocorrelation. In this case, the series lagged one period and then the variables are re-estimated. Equation (2) is set as the remedial measures.

$$Y_i = C + dX_1 + AR(1) \quad (2)$$

Where;  $X_1$  is the dummy variable,  $Y_i$  is dependent variable (population or property price) and AR is autocorrelation.

#### 4. The case study of HSR in China

Various case studies of HSR will examine the significance of results using dummy variable regression. Moreover, this section aims to explore the role of HSR on urban dynamics, which includes land use, labour force and population changes and its interrelation with sustainable policy within a metropolitan area.

##### 4.1 Introduction of HSR in China

Railway construction in China has attracted worldwide attention especially the expansion of the most extensive HSR network. More than 20,000 km of HSR service have operated in China, and there is further planning for a 30,000 km HSR network for 2020. China is forming a one-hour economic circle along its eastern coastal line [33].

According to the Mid-to-Long term railway network plan of China. Ministry of Railway (MOR) in 2008, China's HSR network mainly consists of a HSR grid and intercity HSR. A national HSR grid project connected the region centres, parts of new/upgrade original line to accommodate high-speed trains, and intercity HSR lines for metropolis commuting. The national HSR grid was known as the 4+4 project, consisting of four vertical lines operating from north to south and four horizontal lines moving from east to west [34]. A report from the World Bank has pointed out that agglomeration economies are present in China, and from both panel data and on-the-ground surveys it seems that the effect is more significant than in other countries. It also shows that HSR projects in China have the potential to deliver agglomeration benefits. It shows competitive in travel time for 2-3 hours than other modes of transportation; moreover, the stations, which conveniently locate for a city residents and businesses, have highly impacted for the society.

A standard issue in China is that the decision is influenced by route alignment, cost, and constructability considerations, but city leaders also play the most essential role and decide the final decision whether to use an existing or upgraded station for new HSR services. HSR centres play an essential role in the urban spatial restructuring due to investment in infrastructure by the government [35]. Also, another critical factor was that large cities such as Beijing and Shanghai are more likely to negotiate a better location for their HSR stations, without considering the increased cost. As a result, vast cities could play a more active role in the HSR-driven decentralization than small and medium-sized cities.

Thus, HSR provides a unique opportunity for a large city to facilitate its urban spatial restructuring, namely, the redistribution and optimization of the locations and functions of its multiple urban centres, or a successful transition from monocentric to the polycentric urban structure. In contrast, new HSR towns in small and some medium-sized cities were misplaced to areas that were far away from the existing metropolitan area; this placement often leads to leapfrog development with inefficient use of land and other resources.

## **4.2 Case Study of HSR in Shanghai**

### *4.2.1 Overview of HSR in Shanghai*

Shanghai, the largest city in China with a population of over 24 million in 2014, has taken the lead in the country's recent rail transit boom [36]. The existing HSR in Shanghai is the main arterial transport in China known as the 4+4 project, which includes various HSR lines like Beijing–Shanghai line, Shanghai-Wuhan-Chengdu line and Shanghai-Kunming line and some intercity lines.

### *4.2.2. Parameters of HSR line in Shanghai*

Taking Beijing–Shanghai line as an example, it launched in July 2011, with a total distance of 1,318 km and operating speed of 350 km/h. This route links 23 big cities including Tianjin, Jinan, and Nanjing. Focusing on the Nanjing to Shanghai line, HSR provides the shortest travel time from 4 hours 2 minutes to 1 hour 31 minutes with 200 km/h HSR and 1 hour with 300 km/h HSR. Moreover, the frequency of the HSR service is changing home-workplace relationships and commuting type between Nanjing to Shanghai, thereby influencing the regional and urban land planning [37]. Some researchers have found evidence of HSR impacts on workforce flow using a survey [38]. In the two core cities (Shanghai and Nanjing), they presented a visible phenomenon of a type of work-living commuting. People work in Shanghai/Nanjing on the weekday and go home on the weekend using the HSR with three hours commuting time, including the time from the workplace/home to train station.

Shanghai Hongqiao HSR station is located in central Shanghai and opened in July 2010, connecting the rail and metro [37], including Beijing-Shanghai HSR, Beijing-Shanghai railway, Shanghai-Nanjing intercity railway (HSR), Shanghai-Kunming HSR, Shanghai-Hangzhou-Ningbo passenger railway (HSR), Shanghai-Hangzhou intercity maglev line (similar HSR). Besides, the Hongqiao Transportation Hub is also a "green interchange" for sustainable transport, connecting outside public transport like the metro and the fast bus [37]. The Hongqiao transport hub aims to encourage an industry agglomeration effect to bring benefits from new urbanization.

## **5. Result and Analysis**

### **5.1 Analysis Methods and indicators**

#### *5.1.1 Dummy Variable Regression*

Dummy variables are independent variables that represent the value of either 0 or 1. In this case, a dummy variable is used to describe the existence of HSR. The value 1 represents the existence of HSR and 0 represents the inexistence of HSR. In this research, analysis of variance (ANOVA) is applied to test the significance of the impacts of HSR on population changes and property pricing. Therefore, the research follows the equations (1) and (2) as mentioned.

#### *5.1.2 Content and Indicators*

Three things should be considered, population change, land pricing, and land use, to obtain the quantitative result of the potential impact of HSR on urban dynamics and land pricing. Firstly, population change reaction and behaviour towards a HSR service, especially in regards to the labour force market. Secondly, land and property pricing is a direct effect of HSR service as it provides convenience to people who live around the HSR station. However, the land pricing data that is influenced by the HSR service should be used differently in China due to the land belonging to the government.

Lastly, land use is the instinctive observation of HSR service by agglomeration and urbanization. In this case, urbanization is more significant because its successful industrial clusters drive rapid development and lead to phenomenal economic growth; thereby governments could facilitate and invest further in urban planning [39].

## 5.2 Results

### 5.2.1 Result of Shanghai District

**Table 1.** Population Dynamics in Shanghai (Million)

Year	Residence	Citizenship	Year	Residence	Citizenship
1990	13.34	12.83	2003	17.66	13.42
1991	13.50	12.87	2004	18.35	13.52
1992	13.65	12.89	2005	18.90	13.60
1993	13.81	12.95	2006	19.64	13.68
1994	13.98	12.99	2007	20.64	13.79
1995	14.14	13.01	2008	21.41	13.91
1996	14.51	13.04	2009	22.10	14.01
1997	14.89	13.05	2010	23.03	14.12
1998	15.27	13.07	2011	23.47	14.19
1999	15.67	13.13	2012	23.80	14.27
2000	16.09	13.22	2013	24.15	14.32
2001	16.68	13.27	2014	24.26	14.39
2002	17.13	13.34			

**Table 2.** Dependent Variable: Residence and Citizenship

Dependent Variable	Residence	Citizenship
Durbin-Watson stat	0.264	0.293

Base on Durbin-Watson static, autocorrelation exist on both residence and citizenship data in Table 1. The autocorrelation of a random process is the correlation between values of the process at different times in statistics. In this case, the result in Table 2 shows that residence and citizenship data might not be influenced by other observations (i.e. travellers, visitors). Thus, the problem of autocorrelation might result in the usual t test and F test not being reliable. The further remedial measurement is employed to remove the disturbance of autocorrelation.

**Table 3.** Remedial Measurement of Residence and Citizenship

Dependent Variable	Residence	Citizenship
DUMMY	-0.186 (-1.340)	-0.024 (-1.199)
R-squared	0.998	R-squared 0.998
Adjusted R-squared	0.998	Adjusted R-squared 0.998
S.E. of regression	0.169	S.E. of regression 0.023
F-statistic	3595.1	F-statistic 3477.5
Prob(F-statistic)	0.000	Prob(F-statistic) 0.000
Durbin-Watson stat	1.943	Durbin-Watson stat 1.945

Table 3 shows the coefficient of the dummy variable, representing the existence of high-speed railway and T-statistic in the parenthesis. T-statistic shows that the HSR does not have a significant impact on both residence and citizenship in Shanghai.

### 5.2.2 Result of Minhang District

**Table 4.** Population Dynamics and Property Price in Minhang

Year	Volume of trading (m <sup>2</sup> )	Average Property price (CNY/m <sup>2</sup> )	Citizenship (000)	Residence(000)
2005	2973400	9873	825.24	1707.60
2006	2654400	10477	855.34	1824.80
2007	2860300	11246	885.84	1845.70
2008	1200300	16383	915.00	1804.70
2009	2417700	16533	942.79	1834.30
2010	837900	23118	967.50	2431.20
2011	440900	27496	984.78	2484.00
2012	587300	27411	1001.22	2508.00
2013	833700	29460	1019.68	2532.20
2014	632000	35771	1045.18	2539.50
2015	1116900	39908	1065.78	2561.30

**Table 5.** Analysis of Citizenship

Dependent Variable: Citizenship		Remedial measure	
Regression			
C	898.618*** (48.349)	C	1417.981*** (10.399)
Dummy	124.710*** (4.524)	Dummy	-6.481398* (-1.795)
		AR(1)	0.947568*** (63.914)
R-squared	0.6945	R-squared	0.998195
Adjusted R-squared	0.6606	Adjusted R-squared	0.997679
S.E. of regression	45.5263	S.E. of regression	3.308817
F-statistic	20.4646	F-statistic	1935.701
Prob(F-statistic)	0.0014	Prob (F-statistic)	0.0000
Durbin-Watson stat	0.9273	Durbin-Watson stat	1.6786

Note: T-statistic is in the parenthesis, \*\*\* represents significant of HSR at 1% level, and \* represent substantial of HSR at 10% level.

Based on Durbin-Watson static, autocorrelation exists on citizenship data in the Minhang district in Table 3. In this case, the Durbin-Watson stat in Table 5 shows at 0.9273, which means that other observations might not influence citizenship data. The further remedial measurement is employed to remove the disturbance of autocorrelation. The additional result of citizenship data shows the significance of HSR at a 10% level, which means that HSR influences citizenship at a low level of significance.

**Table 6.** An Analysis of Residence

<b>Dependent Variable: Residence</b>	
<b>Regression</b>	
<b>C</b>	1908.05*** (23.894)
<b>Dummy</b>	616.95*** (5.209)
<b>R-squared</b>	0.7509
<b>Adjusted R-squared</b>	0.7232
<b>S.E. of regression</b>	195.6057
<b>F-statistic</b>	27.1310
<b>Prob(F-statistic)</b>	0.0006
<b>Durbin-Watson stat</b>	2.0124

Note: T statistic is in the parenthesis and \*\*\* represents significant of HSR at 1% level.

The result in Table 6 shows t-statistic of dummy variable in the regression equal to 5.209, reflecting that the relation between HSR service and residence (representing labour force) is significant at a 1% significant level, which is more reliable than the substantial test in citizenship. The result means that HSR does play an essential role in the flow of the labour force rather than citizenship; namely it increases employment.

**Table 7.** An Analysis of Property Price

<b>Dependent Variable: Property Price</b>			
<b>Regression</b>		<b>Remedial measure</b>	
<b>C</b>	14605*** (6.726)	<b>C</b>	474036 (0.056)
<b>Dummy</b>	17404.2*** (5.404)	<b>Dummy</b>	1568.144 (0.505)
		<b>AR(1)</b>	0.994*** (8.546)
<b>R-squared</b>	0.7644	<b>R-squared</b>	0.9345
<b>Adjusted R-squared</b>	0.7382	<b>Adjusted R-squared</b>	0.9157
<b>S.E. of regression</b>	5318.9150	<b>S.E. of regression</b>	2910.5280
<b>F-statistic</b>	29.2005	<b>F-statistic</b>	49.9103
<b>Prob(F-statistic)</b>	0.0004	<b>Prob(F-statistic)</b>	0.0001
<b>Durbin-Watson stat</b>	1.1844	<b>Durbin-Watson stat</b>	2.2720

Note: T-statistic is in the parenthesis and \*\*\* represents significant of HSR at 1% level.

As shown in Table 7, autocorrelation exists on property price data in regression. The further remedial measurement is employed to remove the disturbance of autocorrelation. After correctly measuring however, the dummy value represented at 0.505 means there is no significant relation between HSR service and property price in the Hongqiao station area.

Positive socio-economic impacts of HSR on urban dynamics and property pricing have been shown in the case studies above, namely, increase of employment, property pricing and effect of agglomeration economy (i.e., coordinating well with the support of urban planning) within a specified region. A case study in Shanghai showed significant impacts on population dynamics at a district level, but not at the regional level. One of the main reasons for the lack of a substantial effect on HSR and population dynamics was the ratio of passengers compared to the regional population.

The daily expectation on patronage between 2011 and 2013 on the Hongqiao Hub, which delivered 25.1, 31.7 and 36.7 million passengers each year, of 69,000, 87,000 and 101,000 passengers per day

respectively [40]. Moreover, it was predicted in 2020 to carry 52.7 million passengers and 0.14 million passengers per day, while the temporary population and citizenship were less than 25 million. Thus, the volume of the passengers was not the main reasons for population dynamics.

Another reason is some regions have massive scales. HSR might influence spatial structure in urban centres surrounding space in a range of 1 - 2.5 hours or 250 to 600 km reachable [41]. However, for urban dynamics and land price, it was HSR stations that play an important role. For example, Shanghai owns 210 towns with 6,340.5 km<sup>2</sup> land, which is defined as a station-centred area with 6 km radius [42]. Compared with the small city in Portugal named Aveiro, it entirely different conditions in Shanghai [42]. It approximately 1,200 m radius is the core impact area of a HSR station [43]. Paris showed no significant impact as a result of the HSR service; in contrast, the smaller city named “Lille” achieved favourable benefits from the HSR service. Thus, testing of the suitable scale of HSR station catchment areas should be done at a district level and within 5 km radius.

## 6. Conclusions

This research has shown the positive socio-economic potential impacts of HSR on urban dynamics and property pricing from case studies in China. This study has used the dummy variable to check the significance of HSR with each factor. The results have found that the effect of HSR on increasing employment rate was direct and substantial. Moreover, HSR may lead to stimulating property pricing and agglomeration economics within a specified region. The suitable scale of the area HSR catchment was found within a 5 km radius at a district level.

Based on the existing evidence, the study found that with HSR network expansions, economic activities could be encouraged by agglomeration effect. Nevertheless, the positive impacts do not occur from HSR services automatically but, also from the cooperation of city development and its regional accessibility. HSR inequitably affected each area even within the same HSR line. One of the main reasons is because each area has particular characteristics, i.e. geography, the distance between cities and, other factors including population and current economics. These factors directly generated different outcomes from the HSR service.

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