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International Comparison of High-Speed Railway Impacts on Transportation, Tourism, and Land Price – Japan, Korea and Taiwan

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Abstract: This study compares the statistics relevant to High-Speed Rail of Japan, Korea and Taiwan. Our focus is on several basic statistics about intercity transportation and economics, which are the most important and direct effect came from the HSR development. Specifically, statistics including number of passengers, modal share, travel time, tourism, and land price are compared with before and after the HSR development. This study shows that HSR development have a diverse but within-a-certain-range of impact on regions and cities. It is applicable to national policymaking and urban planning, for new HSR development as well as extensions to existing HSR in each of these three countries.

Keywords: High-Speed Rail, Passengers Volume, Modal Share, Travel Time, Tourism, Land Price

1. INTRODUCTION

High-speed railway (HSR) in Japan, Korea and Taiwan is highly expected to play an important role not limited to simply intercity transportation, but also in developing regional economics as well as a low-carbon society (The Korea Transport Institute (KOTI) and Eastern Asia Society of Transportation Studies (EASTS) (2015)). This implementation of HSR will likely have effects in economics, communication, employment and innovation that will be felt across several aspects of daily life; however, it also depends on countries' national history, policies and development schemes. Other countries, such as France, Italy, Germany, Spain, China, and the United States have also initiated and continued to invest in this environmentally sustainable mode of intercity travel (Sands, 1993; Vickerman, 1997; Givoni, 2006)

There are several HSR lines and sections which was completed or extended after 2000 in these countries. There are two lines in Japan. Tohoku Shinkansen was extended to Hachinohe in 2002 and Shin-Aomori in 2010. Kyushu Shinkansen was connecting between the southern part of the line; Shin-Yatsushiro and Kagoshima-Chuo in 2004, and then Kagoshima-Chuo and Hakata was build and fully connected with Sanyo Shinkansen at Hakata

in 2011. The Korean HSR, KTX, completed Gyeongbu and Honam line in 2004; Jeolla line in 2010; Gyeongjeon in 2011. The Taiwan HSR was completed in 2007, connecting Taipei and Zuoying.

This study aims to compare the statistics relevant to HSR of Japan, Korea and Taiwan. Our focus is on several basic statistics about intercity transportation and economics, which are the most important and direct effect came from the HSR development. Specifically, our interests are on number of passengers, modal share, travel time, tourism, and land price. The result of this study is expected to provide some benchmarks for those outcomes.

The results should be applicable to national policymaking and urban planning, for new HSR development as well as extensions to existing HSR in each of these three countries. Readers may have some insights on the HSR development in other countries also.

2. METHODOLOGY OF STUDY

2.1. Focus of Study

If we want to know the effect of the HSR completely, we should collect all the data related to the all socioeconomic aspects from 1950's, which was the construction period of the first HSR, Tokaido Shinkansen, until now. Collecting those long data is not feasible. An economic and social background is changed significantly in these sixty years.

We focused on recent development after 2000's. It is the period that Japan, Korea, and Taiwan already matured and became a member of developed countries. Although there are some economic fluctuations in some counties in this fifteen years and economic and political background is not common, it is much easier to compare and consider several aspects which happens around our communities. Data availability is also increased when we look for appropriate statistics.

We tried to collect better available data rather than the best completed data. When it comes to international comparisons, someone may think the data should be described in completely same format, collected under same assumption, recorded in same manners. However, it is not feasible. Thus, the number of years before and after, definitions are depends on existing statistics. Authors in each country used same format of Microsoft Excel sheet and put data from their available sources of statistics.

Table 1. High-Speed railways in this study

Country/Line	Section (Year)	Number of trains per day	Number of vehicles per train	Passenger capacity per train	Average headway (minutes)
Japan					
Tohoku Shinkansen	Morioka & Hachinohe (2002) Hachinohe & Shin-Aomori (2010)	83 (depart from Tokyo) *1)	6, 10, 10+6, 10 + 7 (E5 & E6 connection) etc	1,067 (731 + 336) (E5) (E6) *2)	12.2 (6:04-22:44) *3)
Kyushu Shinkansen	Shin-Yatsushiro & Kagoshima-Chuo (2004) Hakata & Shin-Yatsuhiro (2011)	59 (depart from Hakata) *1)	6 or 8	542 (N700) *2)	17.9 (6:10-23:31) *3)
Korea					

Gyeongbu HSR line	Seoul & Daegu (2004) Daegu & Busan (2010)	61 (K), 6 (S) *4)	18 (K), 8 (S) *4)	935 (K), 363 (S) *4)	16.9 (05:10-23:30)
Honam HSR line	Seodaejeon & Mokpo (2004)	6 (K), 18 (S) *4)	18 (K), 8 (S) *4)	935 (K), 363 (S) *4)	44.6 (05:20-22:15)
Jeolla line	Iksan & Yeosu EXPO (2010)	3 (K), 7 (S) *4)	18 (K), 8 (S) *4)	935 (K), 363 (S) *4)	108.9 (05:20-21:40)
Gyeongjeon line	2011	3 (K), 9 (S) *4)	18 (K), 8 (S) *4)	935 (K), 363 (S) *4)	92.3 (05:15-22:10)
Taiwan					
Taiwan HSR	Taipei & Zuoying (2007)	63 (departs from Taipei, Wednesday)	12	989	16.0 minutes

Source: The Korea Transport Institute (KOTI) and Eastern Asia Society of Transportation Studies (EASTS) (2015)

*1) For weekdays. The numbers are not including specific day's schedule. So each number means at minimum and usually more trains are operated.

*2) Calculated based on each JR company's web information. Showing a maximum capacity if several cases of capacity.

*3) Average between the first train and the last train in a day using the number of trains per day.

*4) K is KTX, S is KTX-Sancheon (new-type vehicles)

2.2. Literature Review

Substantial prior research has focused on the effects of HSR development. Since we focused on recent development after 2000's, this study basically refers to the most recent research published in the 21st century.

The effects of large transportation investments are highly correlated to the state of regional economics. When the economy grows, infrastructure investment effects may be significant. In contrast, if economic growth is stable or declining, the effects of HSR development may be minimal. There are several studies on economic development of regional points of views. Focusing on large cities along HSR lines, Nakamura and Ueda (1989) reviewed a statistical analysis of socioeconomic changes in municipalities and "daily life regions". In addition, the effects of the Shinkansen at the more disaggregate level of location behavior of firms and households were discussed using the principle of location surplus. Ureña *et al.* (2009) developed a multilevel analysis at the national, regional, and local levels to determine a HSR system's selective capacity to transform time distance and accessibility. They analyzed three different cities as case studies: Córdoba and Zaragoza in Spain and Lille in France.

There are some discussions about economic efficiency or cost issues, since the HSR development needs huge investment. Givoni (2006) reviewed the operational elements of different high-speed trains (HSTs) to determine the associated impacts and output constraints. The review concluded that HSTs are the best suited way to substitute conventional railway services. However, the high costs associated with HSTs infrastructure often cannot be justified because of uncertain economic development benefits. Campos and de Rus (2009) examined the most recent and relevant empirical issues related to HSR implementation by collecting data of 166 HSR projects across the world. This research provided a range of actual costs for building and maintaining HSR infrastructure. Cheng (2010) described Taiwan's HSR system development and conducted a cost-benefit analysis following implementation. This study also

considered the integration of HSR with other existing transportation modes and recommended that local authorities develop a comprehensive post-HSR planning strategy leading to a more integrated transportation system.

We should keep our eyes on the "HSR New World"; China and United States. Although the construction of China's high-speed rail (HSR) network only started in 2003, the network is already the largest in the world. Jiao *et al.* (2014) analyzed the impact of the evolving HSR network on the accessibility by HSR and conventional ground transport of 333 prefecture-level cities and 4 municipalities. Shaw *et al.* (2014) took a timetable-based accessibility evaluation approach to analyze the changes in travel time, travel cost, and distance accessibility for each of the four main stages of HSR development in China. In addition to study network accessibility improvement, Zheng and Kahn (2013) argued that secondary cities stand to gain much from participation in a two-fold improved matching process. They claim that HSR can "encourage firm fragmentation and firm sorting depending on their idiosyncratic demand for megacity access". Some studies discussed the HSR in United States are including Ross (2011), Loukaitou-sideris (2013), and Kimura *et al.* (2012). In comparison with European HSR experiences, Garmendia *et al.* (2012a) reviewed different HSR territorial strategies and station location rationales in China and the United States. This dual review provides useful information for future HSR developments.

There are studies focused in cities and corridors instead of national or regional perspective. Vickerman (2015) considered the impacts of HSR on intermediate areas between major metropolitan cities and the creation of potential cross-border, interregional services. This study emphasized the need for an appropriate regulatory framework for service provision and accompanying measures at the local level. Garmendia *et al.* (2012b) argued what conditions HSR could facilitate the development of small HSR suburban cities as special sub-centers of the metropolitan area. They focus on a comparative study of Madrid (Toledo, Segovia, and Guadalajara stations), Spain, and the London (Ashford, Ebbsfleet, and Stratford stations) cases. Infrastructure layout, station typologies, and rail services are compared together with each city's territorial contexts, activities, and connections with other transport modes. This study show us the effects on small stations rather than the central stations of metropolitan area, however, the effects are descriptive and not rely on any statistics, or quantitative analysis. Murakami and Cervero (2012) examined business agglomerations around Tokaido Shinkansen and proposed corridors in United States. They show eight agglomeration types from cluster analysis and suggest that HSR is likely to induce greater economic benefits in knowledge-intensive businesses, though they are mostly limited to large, globally connected cities at the expense of small intermediate ones.

In addition to those studies, there are case studies which discuss one particular HSR system. Our research project, the Korea Transport Institute (KOTI) and Eastern Asia Society of Transportation Studies (EASTS) (2015) analyzed HSR impacts and successful factors for HSR station area developments based on the cases of Japan, Korea, and Taiwan. Chapters 2, 3 and 4 of the report obtained findings on HSR's impacts and successful factors for HSR station area developments from each county's experiences. Nakagawa and Hatoko (2007) discussed why a contrast between the success and stagnation of Shinkansen construction has come about through case study on the Hokuriku Shinkansen. Terabe *et al.* (2016) and Fuyama *et al.* (2017) investigated the social and economic changes around new stations of Kyushu and Nagano Shinkansen and compare with existing conventional railway stations. They showed changes in intercity travel time and mode share of intercity have influenced some aspects of the society.

There is little published research focused on the impacts of recently opened HSR with the comparative approach. From this approach, this study also aims to compare the three

countries' cases and to generalize the features of HSR. This research has collected all of the available data, and has strived to use a standardized format in order to offer a consistent cross-country comparison.

3. IMPACT OF HIGH SPEED RAIL - QUANTITATIVE APPROACH

3.1. Number of Passengers

Let us compare several sections in terms of distance and passengers increase. Number of passengers who ride HSR is expected to gradually increase if there is no financial crisis or huge disaster. Figure 1 shows that passengers increase based on distance between major cities. Most of the data are of specific one year which the data available.

The most significant increase is 226% between Shin-Yatsushiro and Kagoshima-Chuo from 2004 to 2005. It was the year that the partial opening of the Kyushu Shinkansen in 2004. This increase was from passengers' volume of conventional rail to HSR. It shows that the HSR development can achieve more passengers than before. Two sections from same lines are Hakata - Kumamoto and Kumamoto - Kagoshima-Chuo in this comparison. Both sections experienced 137% and 165% respectively from 2010 to 2011, which is the year of the Kyushu Shinkansen fully opened.

The passengers increase in Taiwan, between Taipei and Zuoying, was 113% from 2006 to 2007. It came from the total passenger volume of the main line of the conventional rail; Keelung – Kaohsiung and the HSR; Taipei – Zuoying. It can be said that the HSR development can induce some inter-city travel from this case.

The statistics from Korea are Dongdaegu – Busan and Seodaejeon-Mokpo in 2005-2006, Miryang-Jinju in 2011-2012, and Iksan-Yeosu Expo in 2012-2013. Except for Miryang-Jinju, which achieved 142%, all the KTX lines have increased around 110-120%. Miryang-Jinju is located the rural area of Korea and the HSR development may stimulate regional economy and then attract more travelers around this region. The other three lines increase as almost same percentage of passengers as Takasaki – Nagano, Tokyo - Shin-Aomori, Miyagi & Fukushima – Aomori, and Taipei – Zuoying. It means that most HSR, which is newly operated and replaced or coexist with conventional rail, attract around 110-120% more passengers than before. This amount is not changed along with the distance of the sections. A certain amount of passengers have increased after the HSR development.

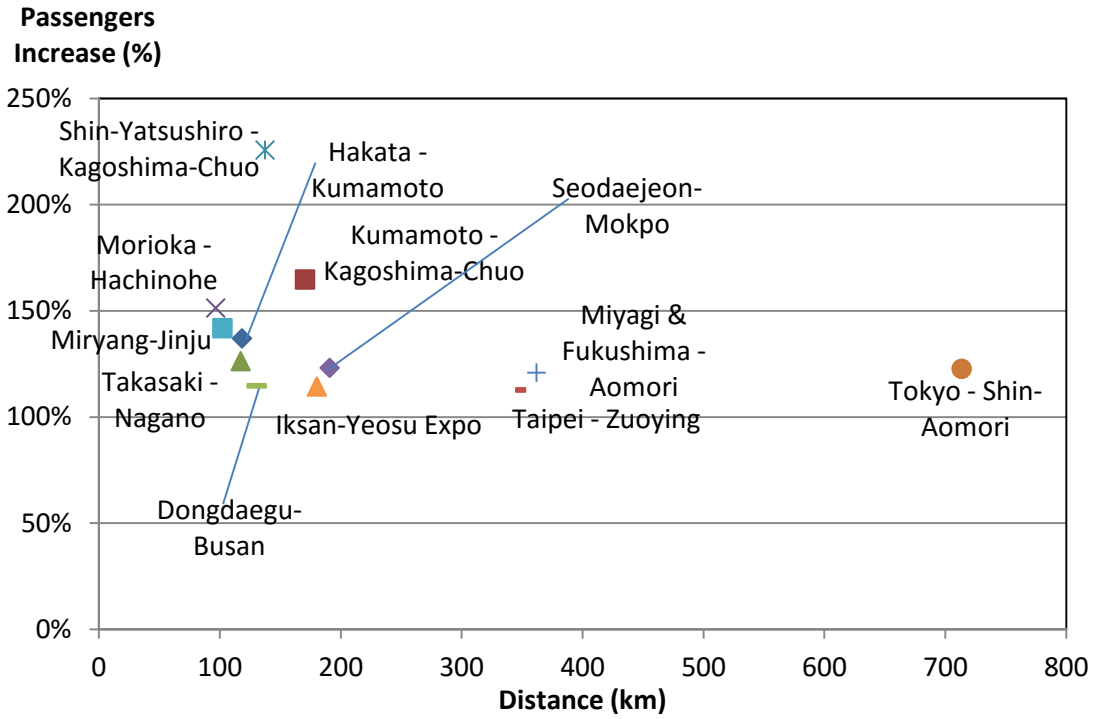

Figure 1 Passenger increases based on distance between major cities

3.2. Modal Share

Development of HSR affects modal share of intercity travel. Generally speaking, air travel is preferred by most of the travelers who move more than 700 km. Conventional rail, or regional rail is used by travel less than 100 km. An intercity travel among 100-700 km distance is under the market which airlines and HSR compete with each other. A long distance bus travel may have a certain share of any intercity travel. A car travel is considered to belong under a different market because it is not a public transit but a private transportation, even though many travelers do not want to drive by themselves for a long distance.

Figure 2 shows the comparison of modal share between several cities before and after the HSR commencement. Years that statistics taken are different based on the beginnings of each line service.

The share of the HSR between Tokyo and Aomori, which are located 714 km apart, is almost replaced of conventional rail. The HSR also gain some share from the airlines and other mode of travel. The share of airlines loses almost half of its previous share between Osaka and Kumamoto, which are located 741 km apart. The share of its longer distance between Osaka and Kagoshima, 911 km apart, loses less than Osaka and Kumamoto. With regard to competition between airlines and HSR, the airlines increase its share when the trip length increases. The share of the conventional rail was disappeared after the HSR development because the conventional rail was replaced with the HSR in most corridors in Japan.

The car travel in Taiwan is still majority of inter-city trips. Only the data for national average is available. It is the data of all inter-city travel in the country and extracted as the 300 km length. The HSR seems to have a small share compared to the car, however it is expected to have more share when we limit to the inter-city travel between Taipei and Kaohsiung (Zuoying).

The most share of conventional rail was replaced with the HSR in Korea. The HSR gains more than the previous rail share, which are from the other modes. The bus and car, keep their share even after the HSR development. It may owe to its length of travel; the bus and car is still effective transportation of around 300 km length. The air travel between Seoul and Dongdaegu and the one between Yongsan and Gwangju Songjeong was gone after the HSR development. Even Seoul and Busan lost its half of air travel. Interestingly, the bus and car travel have same share before and after the HSR development between Seoul and Busan. It shows that there seems to be a certain market for road travel between these cities and it is not affected by the HSR.

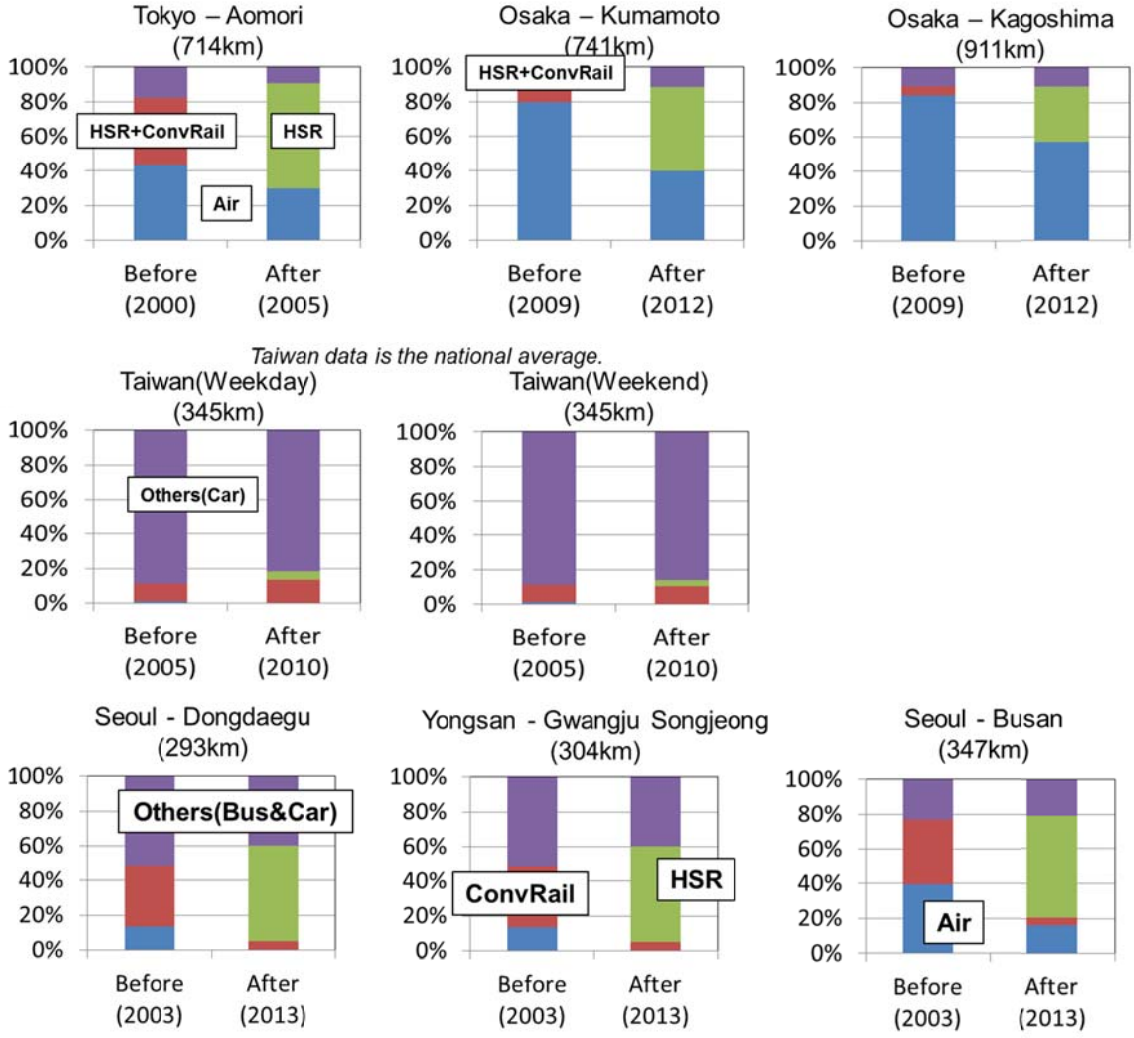

Figure 2 Change in modal share between major cities
(Taiwan: National average of all inter-city travel in the country and extracted as the 300 km length)

3.3. Travel Time

Travel time between cities definitely decreases after the HSR development. The HSR runs at 250-350 km/h whereas the conventional rail runs at 100 km/h. The number of HSR stations is less than the conventional rail. Alignment of the HSR consists of long strait and large curve so as to keep its speed higher.

Travel time decrease after the HSR introduction at each section are shown in figure 3. The significant decrease was achieved between Taipei and Zuoying in Taiwan. The travel time between two cities by the HSR is 1:30 in 2007, whereas it took 4:50 in 2006 by conventional train. The Taiwan HSR is dedicated new railroad only for high-speed trains. The train operation for the HSR is completely separated from the ordinary train. That is the reason why Taiwan HSR is beneficial to shorter travel time.

On the other hand, the most sections of the HSR in Korea, or KTX, share its track with slower conventional trains. That is why the KTX cannot utilize its highest speed.

A weak correlation can be observed between travel time decrease and distance between those cities. It is natural, because longer distances of travel tend to take longer time. And the HSR can shorten it after its commencement.

It should be explained why two sections in Japan could not obtain the travel time decrease as the other sections. Both of Tokyo – Shin-Aomori and Tokyo – Hachinohe is the data came from the HSR extension in around 100 km approximately. The short length of extension resulted in short travel time decrease.

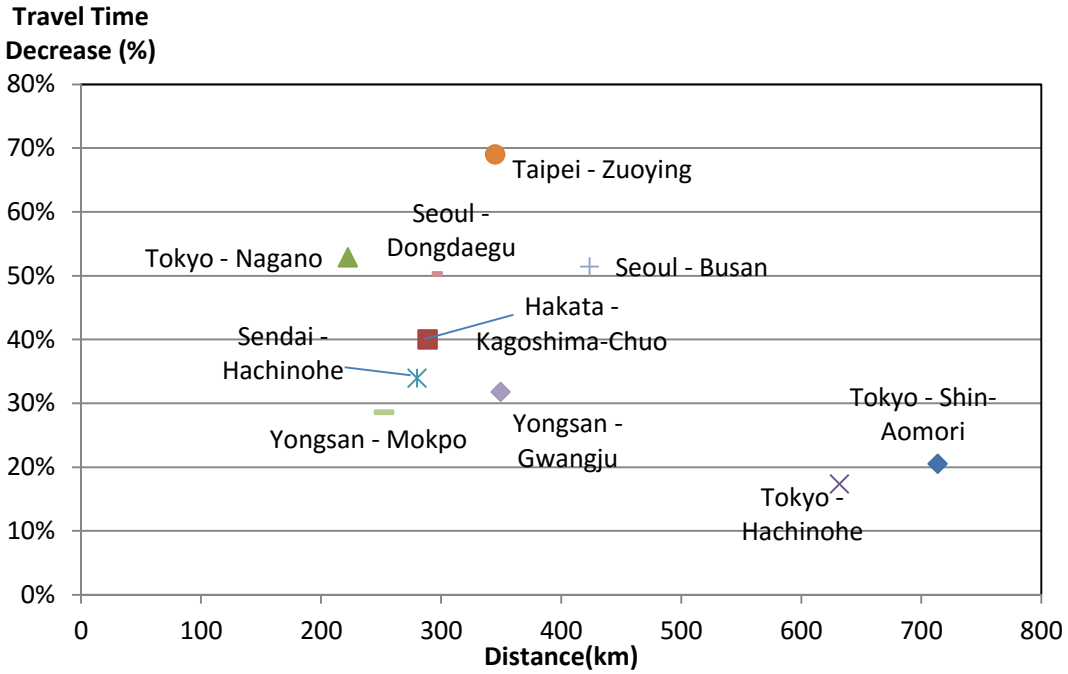

Figure 3 Travel time decrease between major cities

(Some city pairs contains existing HSR and conventional railways, e.g. Tokyo – Shin-Aomori and Tokyo – Hachinohe: Travel time saving is achieved by the approx. 100 km HSR extension.)

3.4. Tourism

Tourism is one of the important aspects for regional economics. When visitors increase at tourism attractions, economics around the locations are expected to improve because more visitors pay for the entrance fee of tourism facilities, accommodations, transportation, restaurant, and goods. A lot of people living in the cities which have the HSR stations hope to see more visitors after the HSR development. Thus, it is interesting for us to see how much visitors increased after the HSR commencement.

The percentages of visitors increase are collected from some tourism attractions located near HSR stations. Four HSR sections are applied and each symbol in figure 4 indicates it

individually.

There are five statistics from tourism attractions along with the Tohoku Shinkansen between Morioka and Hachinohe, which was opened in 2003. They are festivals, museums and historical parks and visitors of each attraction increased at 135% -212% comparing to the previous year, which is a year before the HSR extension.

There are another five statistics from same lines, which extended further to Shin-Aomori in 2010. The increase are ranging from 155% to 304%, that the highest number is Jomon Jiyukan (Sannai Maruyama Site, historic site about 5,500 – 4,000 years before). 4,698 visitors to this site in 2009 grew to 14,284 visitors in 2010.

There are 19 facilities which attract visitors at 82% - 248% increase or decrease after the Taiwan HSR opening in 2007. They are museums, national parks, historical parks, theme parks, and national forest recreation areas located near the HSR stations. The biggest increase was National Museum of History in Taipei of 248%, from 242,844 in 2006 to 601,292 visitors in 2007. Some of the facilities lose their visitors are located in Taoyuan and Hsinchu, which are intermediate stations. It seems that big cities like Taipei, Taichung, Tainan, and Zuoying attract more tourism visitors from middle and small cities with HSR stations.

There are eight tourism attractions at 62% - 207% increase or decrease after the Korean HSR, KTX Gyeongbu line. They are museums, science park, temples, and sightseeing spots. The significant increase are observed at Busan Museum, which have 322,257 visitors in 2003 and increased to 666,741 visitors in 2005, resulted in 207% increase. A famous attraction in big city achieve biggest increase, which is similar to Taiwan.

Regarded from these cases, the HSR affect mostly positive on tourism, especially tourists' attractions of big cities gather more people after the HSR opening.

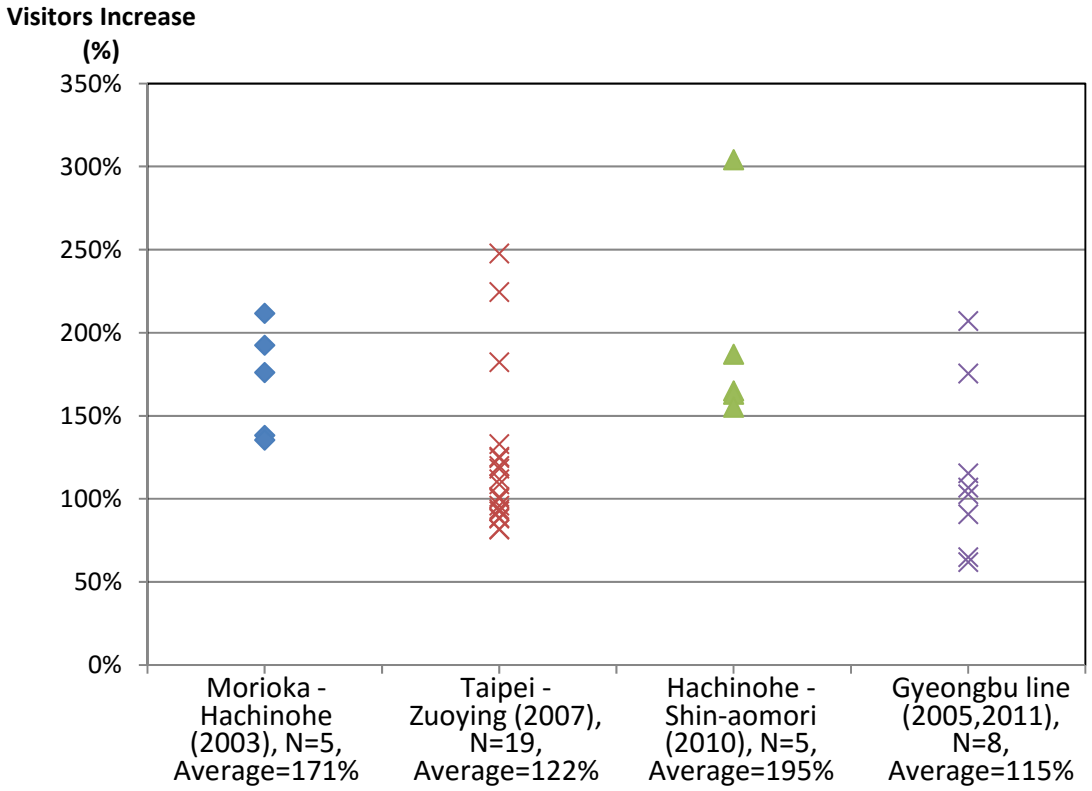

Figure 4 Visitors increase at tourism attractions before and after the HSR development

3.5. Land Price

Land price is one of the most difficult aspects to see as an impact for regional economics. It is affected by not only HSR development but other related development such as urban planning, road network, and buildings. National economics also affects land transactions. Sometimes, international economics affects national land market. Therefore, it is not easy to discuss whether the changes in land price were the result of HSR development.

Figure 5 shows changes in land price index of several Taiwan cities. These indexes are the average of each city along with HSR line. They are compared as six and one year before and one and six years after the line opening on 5 January 2007. The land prices are standardized as 100 in those of 2008, although data in only 2007 are shown in the figure. No land price index of the cities/counties is decreased in this case. Most significant increase is 141.1 % increase of New Taipei City, where Banqiao station located. The second one is 131.8% increase of Hsinchu County, where Hsinchu station located. The third one is 125.6% increase of Taipei City, where Taipei station located. With regard to this case, the HSR development affects more to the northern part of Taiwan HSR line than the southern part. Although there is a fundamental economic difference between north and south of Taiwan, the HSR development takes part in this increase of land prices.

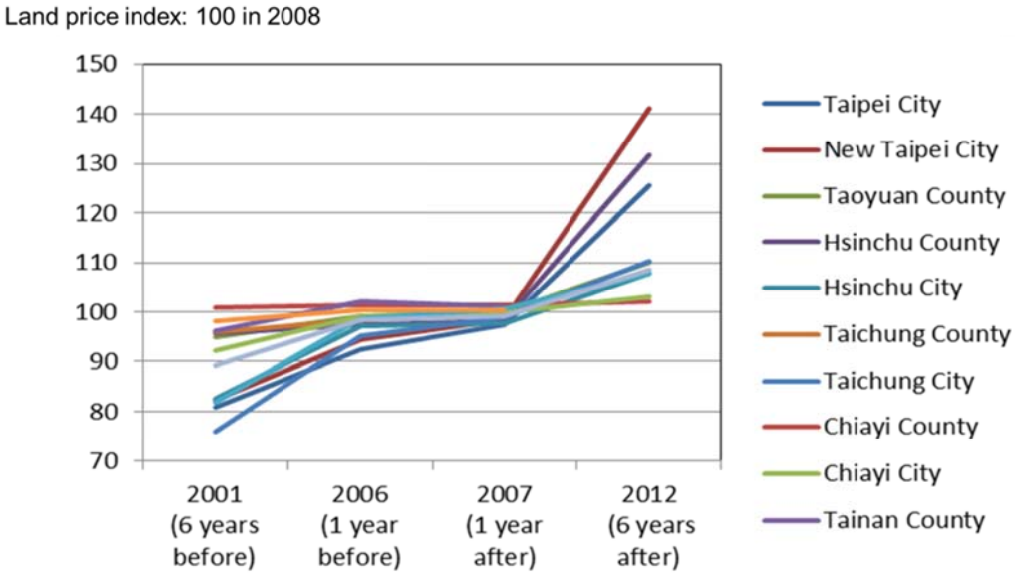

Figure 5 Changes in land price index of Taiwan cities

The land price indexes of three Korean cities, shown in figure 6, are same tendency as Taiwan cities. These indexes are from some points in Daejeon, Daegu, and Busan, which are along with Gyeongbu line of KTX. The section between Seoul and Daejeon was opened in 2004, and the section between Daegu and Busan became operational on November 1, 2010. The land prices are standardized as 100 in those of 2010, that was the year of full service are available until Busan. Most indexes are increased except for a few points. Although most significant increase is 133.0 % of Busan15 and the second one is 124.0% of Busan16, Busan4 decreased 79.5%. Many points in Daejeon and Daegu are increased their land prices, however, a few points are decreased. Thus it is hard to grasp the distinction among these cities. We should understand there is some difference among points in one city. It depends on local urban planning, road network, and buildings. Although there is a difference in points, the HSR development takes part in this increase of land prices.

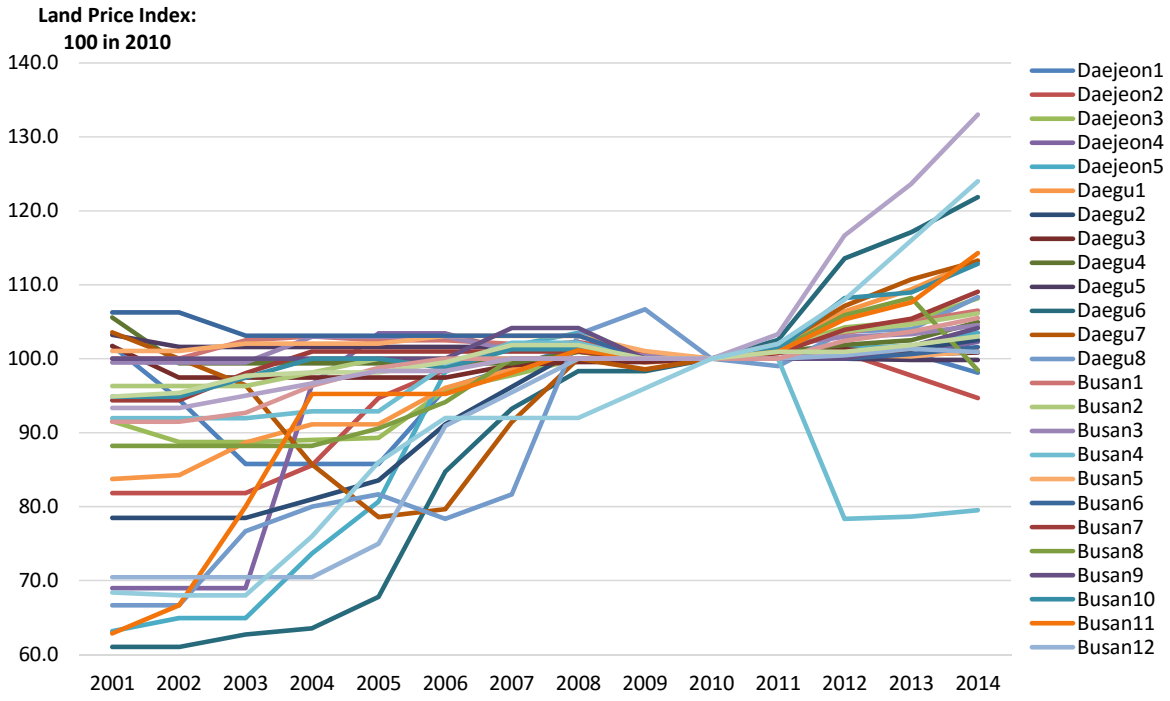

Figure 6 Changes in land price index of Korean cities

Japanese HSR, Shinkansen, extended the Tohoku line until Shin-Aomori on December 4, 2010. Shin-Aomori station is located 3 km west of Aomori central area and 6 minutes apart from Aomori station, which is the old and central station of Aomori city.

The land price indexes of Aomori city, shown in figure 7, are limited to the ten points 2 km around Shin-Aomori station. Contrary to Taiwan and Korea, the land price is decreasing even before the HSR development. There seems to be a few reasons for this. First, station area development was limited due to the urban development policy of Aomori city. The compact city is a famous concept of urban planning here. Second, Aomori station is still center of the business activities. There are little companies relocate near the Shin-Aomori station. Third, national economy from 2000 to 2010 was not good in Japan. The average of GDP (Gross Domestic Product) growth was 0.9 % in these years.

The average of all points in Aomori city is also in this figure. As you can see, the ten points around Shin-Aomori station are better than the average. Thus, the HSR development of Aomori have a limited effect on the land price, even if the local economy in this area is not improved.

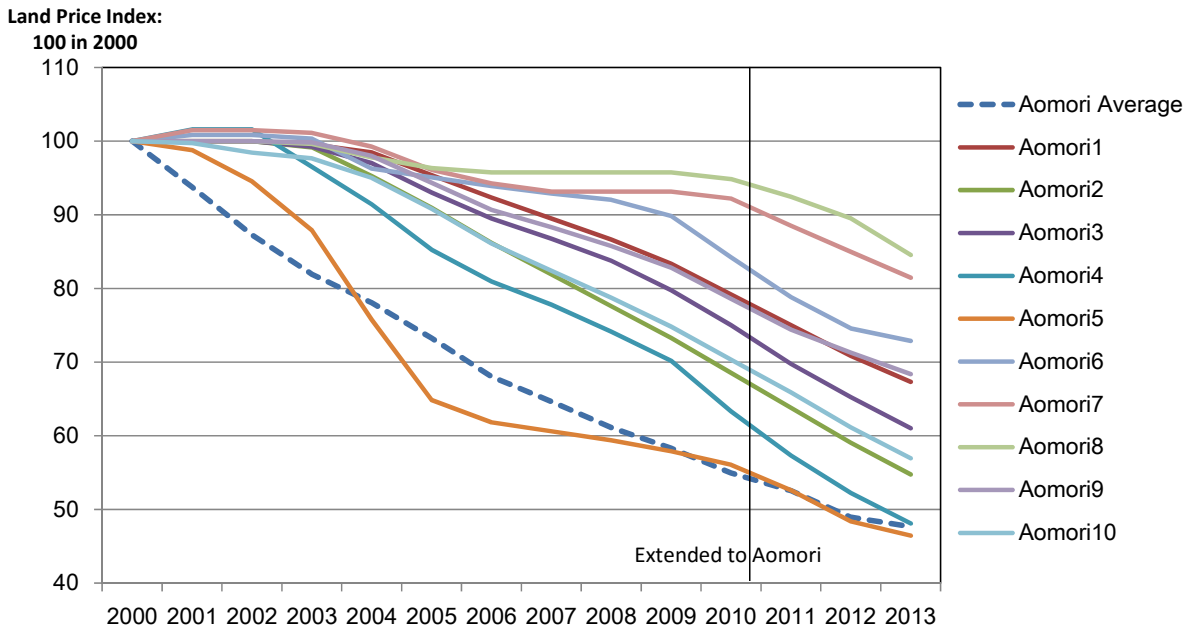

Figure 7 Changes in land price index of Aomori city

4. CONCLUSION

This study aims to compare several data affected by HSR development in Japan, Korea, and Taiwan. We found common and different characteristics from these international comparisons.

The passengers increases are ranging from 110 % to 170 % and no HSR line lose their passengers along with the corridors. There seems to be a weak relationship between passengers increase and distance traveled. When the distance between major cities is long, the passengers increase is small. It is quite reasonable because the HSR service is most significant in 100-500 km distant travel and three countries are relatively small. The travel beyond 500 km has limited effect from the HSR development.

Same discussion is applicable to modal share, although there is a limitation on data from Taiwan. There is a firm relationship between modal share change and travel distance. The 300 km distant travel by conventional rail and airline between one city and another is definitely replaced by HSR. The airlines lose their share in more than 700 km travel.

Travel time savings is much affected by its previous condition of conventional rail. When the HSR line make a short cut of the previous railroad, the travel time is decreased very much. With this regard, Taiwan HSR decreases the travel time between northern and southern area of the country. We can expect 30-50 % travel time decrease for 250-450 km distance in average.

The HSR affect mostly positive on tourism, especially tourists' attractions of big cities gather more people from the HSR corridors. The expected increase of tourists for attractions around HSR stations is 151% based on our case studies. Tohoku area of Japan achieved a good impact on their tourisms by comparing three countries.

Contrary to the tourism, there seemed to be good impacts on land price in both of Korea and Taiwan rather than in Japan. Although there are the other aspects which affect on land price, the land price index of Korea and Taiwan increased after the HSR development. The rapid growth of land price is not suitable for some business entities that need more land or building properties. However, it can be said that the HSR had positive effects on land price which reflects the goodness of overall economy.

The focus of this study is on several basic statistics about intercity transportation and economics, however, it is needed to collect more data on station area development rather than overall impacts of the HSR development in future study. The HSR development pulls the station area development. Whereas the effect on the station area development is relatively narrow and little come up to the statistics, it is better to assess the HSR impact on the station area development qualitatively based on the evidence.

Many Asian countries including India, Indonesia, Malaysia, Singapore, Thailand, and Vietnam have HSR development plan. Since each regional, historical, and economical background is different, it is not easy to tell impacts on transportation, tourism, and land price of those countries. Although the demand estimation based on a certain modelling is possible and necessary, it has still uncertainty. This study shows that HSR development have a diverse but within-a-certain-range of impact on regions and cities. We found a distinct outcomes after the HSR development even among three northeastern Asian countries; Japan, Korea and Taiwan. Experiences in these countries show us what to expect after the HSR development and what to do during HSR planning.

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