AN ANALYSIS OF THE EFFECT OF HIGH-SPEED RAILWAY ON INTER-REGIONAL MIGRATION AND TRAFFIC FLOW IN JAPAN

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Abstract: The development of high-speed inter-city railways called “Shinkansen” is still undergoing in Japan. In addition, the MAGLEV system operated at the maximum speed of over 500km/h is planned between Tokyo and Osaka that will realize the “within an hour economic region” with 70 million populations. This will cause the dramatic change of inter-regional migration and traffic flow. The objectives of this paper are to review the characteristics of the inter-regional migration and traffic flow for past 40 years in Japan and to analyze the relation between the development and the speed-up of inter-city railway transport, to give considerations about the effect of the MAGLEV system on the regional economic activities.

Key Words: High-speed railway, Inter-regional migration, Inter-regional traffic flow

1. INTRODUCTION

The high-speed inter-city railway called “Shinkansen” was first introduced between Tokyo and Osaka connecting 550km distance by 3 hours and 10 minutes in 1964 in Japan. As shown in Figure 1, the Shinkansen network has gradually extended to Fukuoka of Kyushu region in 1975, to Morioka and Niigata of Eastern North region in 1987, and to Nagano of Central region in 1998. In addition to the development of the network, the renovation of Shinkansen such as speed-up has been gradually achieved and the travel time between Tokyo and Osaka is now reduced to 2 hours and 30 minutes. Such efforts have increased regional attractiveness, decreased regional disparity and promoted regional settlement, industrial accumulation and inter-regional interchange. In addition, we have the plans of 5 Shinkansen routes as shown in Figure 1.

At the same time, the air transport has become gradually competitive because of the improvement of service conditions such as frequency and fare achieved by the deregulation in air transport. In addition, the time value has been gradually increased. This results in recent decrease of railway share in spite of the renovation in railway transport. It is considered that any speed-up attempt of the Shinkansen cannot be desired more because of the technological limitation.

We still have the plan of MAGLEV system that will be operated at the maximum speed of over 500km/h between Tokyo and Osaka as shown in Figure 1 to increase the competitiveness of railway transport. These attempts will cause the dramatic change of regionalstructure in Japan. Especially the MAGLEV realizes the “within an hour economic region” with 70 million populations that has never existed in history, and is expected to increase regional attractiveness and to rectify the heavily concentration problem in Tokyo capital region.

This paper reviews the characteristics of the inter-regional migration and traffic flow as the indices of regional attractiveness for past 40 years in Japan, analyzes the relation between the development and the speed-up in inter-city railway transport, and give considerations about the effect of the MAGLEV system on the regional economic activities. In Chapter 2, the time-series transition of inter-regional migration for past 40 years is analyzed by the viewpoint of the time distance from Tokyo and Osaka. In Chapter 3, the time-series transition of inter-regional traffic flow for past 40 years is analyzed by the viewpoint of the competition
between air transport and the speed-up of Shinkansen. In Chapter 4, the discussion about the effect of the MAGLEV system on the change of regional structure is given by summarizing the result of Chapter 2 and 3. Chapter 5 is conclusion.

2. INTER-REGIONAL MIGRATION AND DEVELOPMENT OF HIGH-SPEED RAILWAY IN JAPAN

2.1 General Trend

A huge migration to the 3 major economic regions (Tokyo, Osaka and Nagoya) from rest rural regions, backed by absorbing power of employment occurred before 1970 as shown in Figure 2. The trend of GINI coefficient of GRP (prefectural product per capita) is also overlayed in Figure 2. It is reasonable to consider that such phenomena were promoted by regional economic disparity between them. This type of migration settled until 1975 and after that, only Tokyo region absorbed the population.

2.2 Relation between Inter-regional Migration and Development of High-speed Railway

As we introduced before, the Shinkansen network was gradually extended for over 30 years. This suggests that there might be some time gaps for the increase of regional attractiveness. Besides, it may be an important factor for the increase of regional attractiveness whether a region is near from Tokyo capital region or not, considering the recent characteristics of migration. We focus on the time-series migration of several prefectures (Shizuoka, Okayama, Tochigi, Nagano) using “The Report on the Internal Migration in Japan” issued from 1954 to now.

Shizuoka and Tochigi are both within an hour regions from Tokyo capital region. Shizuoka already benefited from the Shinkansen in 1964, while Tochigi benefited in 1987. Okayama is within an hour region from Osaka and the Shinkansen started its operation in 1972. Nagano is located at about 2 hours from Tokyo, the Shinkansen finally started its operation in 1997.

Figure 3 shows the migration of 4 focused prefectures in 4 time periods. In 1955, all 4 prefectures gave huge out-migration to 3 major economic regions, while Shizuoka and Okayama took on out-migration from rural regions. Industrialization already started in the
Pacific Belt Region that is range from Tokyo to Fukuoka, including Shizuoka and Okayama, at that time. In 1965, Shizuoka took on huge out-migration from many prefectures widely distributed in whole Japan, while gave out-migration to Tokyo and Nagoya regions. It is considered to be one reason that such phenomena were promoted by the increase of attractiveness resulted from the development of the Shinkansen. In 1975, Okayama took on out-migration from Osaka region and gave out-migration to Tokyo region keeping in step.

Figure 2. Migration to 3 Major Economic Regions in Japan

Figure 3. Regional Migration (In-Out) of Focused Prefectures
with the general trend of migration, while Shizuoka still gave out-migration to Tokyo and Nagoya regions. This suggests that the attractiveness of Shizuoka was possibly not conspicuous because of the location between larger economic regions. In 1990, it is remarkable that Tochigi took on out-migration from not only adjacent prefectures but also Tokyo capital region. This phenomenon can be explained by the joint effect of the increase of attractiveness resulted from the development of the Shinkansen and the huge increase of housing price in Tokyo capital region by “bubble economy”. Opposite to these 3 prefectures, Nagano has almost no experiences to take on large out-migration from any region until now. The delay of the development of the Shinkansen is considered to be one reason.

Thus, it is considered that one of factors of regional attractiveness is the time distance from Tokyo capital region. Especially, 1 hour may be a turning point to be recognized as attractive region.

3. INTER-REGIONAL TRAFFIC FLOW AND SPEED-UP OF HIGH-SPEED RAILWAY IN JAPAN

3.1 General Trend

Figure 4 shows the trend of annual number of passengers of rail and air transport between Tokyo and 3 regions with different distance. It is remarkable that air transport withdrew by start of the Shinkansen service between Tokyo and Sendai (350km) in 1.5 hours. The frequency of air transport increased because of a new airport opened in Osaka region in 1994, while the speed-up of the Shinkansen between Tokyo and Osaka (550km: decreased from 3 hours to 2.5 hours) was achieved in 1992. This resulted in the strong competition between rail and air transport, and number of passenger has been gradually decreasing from 1995. A
number of rail passengers from Tokyo to Fukuoka (1,170km) once increased by start of the Shinkansen service in 1975. However, a number of air passengers have gradually been increasing although the speed-up of the Shinkansen (decreased from 6 hours to 4.5 hours) was achieved in 1993. Thus, it is considered that high-speed railway service is competitive if the distance is less than 700-800km in Japan.

Here we focus on initial impact of the development of the Shinkansen for the railway share. Figure 5 shows the increase of railway share between Tokyo and local cities by the development of the Shinkansen. The air transport withdrew between Tokyo and Niigata, Miyagi (Sendai), Aichi (Nagoya), Iwate (Morioka) after the operation of the Shinkansen. The railway share increased about 10% in medium distance such as Osaka, Okayama and Akita. There is almost no effect on the increase of railway share in longer distance such as
Yamaguchi and Fukuoka.

Figure 6 shows the change of average speed between Tokyo and local cities. The maximum operating speed was 210km/h when the Shinkansen was introduced in 1964. It was increased to 260km/h (Nagano), 270km/h (Tokaido, Tohoku, and Jyoetsu), and 300km/h (Sanyo) now. The average speed between Tokyo and Several cities without transfer exceeds 200km/h.

It is very interesting to know whether such speed-up makes the Shinkansen competitive or not compared with air transport. Figure 7 shows the trend of modal share between Tokyo and Osaka, and Tokyo and Okayama (730km). Figure 8 shows the relation between difference of line-haul time and difference of line-haul fare for rail and air transport. The share of rail transport between Tokyo and Osaka was almost stable until 1990 because service conditions between air and rail did not change. However, the share of rail transport has been gradually decreasing in 1990’s although the speed-up was achieved in the Shinkansen. The reasons are that frequency of air transport increased because of new airport opened in Osaka as already mentioned and the difference of fare between air and rail became smaller. The share of rail transport between Tokyo and Okayama had been gradually decreasing after new airport was opened in 1988 in Okayama region. However, its share became stable after the speed-up of the Shinkansen in 1994. Thus the speed-up of railway is a key factor of competition between air and rail transport for middle distance in Japan.

3.2 Analysis of Time Value for Line-haul Transport

The time value is most important factor to develop new transport systems or improve existing transport systems. This is derived by modal split model that contains two parameters of travel time and fare. We made it by aggregated binary logit model using level of service data between Tokyo and 22 prefectures in several focused years. The share of rail transport is expressed by the equation written below,
1. CHANGE OF REGIONAL STRUCTURE AND MODAL SHARE BY MAGLEV

Table 1. Parameter Estimation of Modal Sprit Model

<table>
<thead>
<tr>
<th>Year</th>
<th>LH time(min)</th>
<th>LH fare(yen)</th>
<th>Time value(yen/min)</th>
<th>t-value</th>
<th>Likelihood ratio</th>
<th>$R^2$</th>
<th>OD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>-0.00422</td>
<td>-0.000692</td>
<td>6.11</td>
<td>-33.8</td>
<td>0.338</td>
<td>0.901</td>
<td>20</td>
</tr>
<tr>
<td>1975</td>
<td>-0.00771</td>
<td>-0.000556</td>
<td>13.8</td>
<td>-113</td>
<td>0.368</td>
<td>0.946</td>
<td>22</td>
</tr>
<tr>
<td>1985</td>
<td>-0.00820</td>
<td>-0.000439</td>
<td>18.7</td>
<td>-75.5</td>
<td>0.218</td>
<td>0.941</td>
<td>21</td>
</tr>
<tr>
<td>1999</td>
<td>-0.00862</td>
<td>-0.000345</td>
<td>25.0</td>
<td>-82.0</td>
<td>0.223</td>
<td>0.916</td>
<td>19</td>
</tr>
</tbody>
</table>

Figure 9. Regional Economic Scale and Time Distance

$$S_\nu = \frac{1}{1 + \exp(V_{in} - V_{\nu})}$$  \hspace{1cm} (1)

$$V_{in} = \beta_1 T_{in} + \beta_2 F_{in}, \hspace{0.5cm} (m = a, r)$$ \hspace{1cm} (2)

where suffix $a$ and $r$ are air and rail, suffix $i$ is OD, $S$ is share, $T$ is line-haul time, $F$ is line-haul fare and $\beta$ is parameter.

Table 1 shows the result of parameter estimation. The absolute value of line-haul time parameter in 1999 is larger than that in 1965, 1975 and 1985. This means that passenger in 1999 has higher possibility to change his/her mode when the line-haul time of alternative mode is shorten. On the other hand, the absolute value of line-haul fare is decreasing yearly, and passenger in 1999 has lower possibility to change his/her mode when the line-haul fare of alternative mode becomes cheaper. The time value listed in Table 1 is derived by the ratio of these two parameters. The time value is increasing yearly. These results suggest that the faster but more expensive rail transport like the MAGLEV may be acceptable and competitive.

4. CHANGE OF REGIONAL STRUCTURE AND MODAL SHARE BY MAGLEV

The MAGLEV system connecting between Tokyo and Osaka in an hour will give dramatic change of the regional structure in Japan. Figure 9 shows the comparison of regional economic scales and time distances in Japan, EU and United States. It is easily understood that four greatest regional economies in Japan will be concentrated by introducing the MAGLEV.

One of roles of the MAGLEV is to make Osaka region more attractive. Figure 10 shows the...
migration of Osaka in 5 time periods. As we mentioned in Section 2.1, Osaka took on huge out-migration from wide rural regions until 1970, and gave out-migration to Tokyo capital region. However, Osaka gave out-migration to wide rural regions in contrast from 1975. This tendency basically continues until now. The estimation of regional population by national research center shows that this tendency will continue in the future. If travel time between Tokyo and Osaka become an hour, some industries or companies may move to Osaka region, and this results in the increase of population. The rest of rural regions near Osaka will also become attractive by the MAGLEV.

The MAGLEV will also introduce the variety of regional attraction along its route. Figure 11 shows several economic indices along the MAGLEV route. If these regions become one economic region, these indices become apparently equal. Therefore, each region does not need to develop by own effort. These changes will finally solve the heavily concentration problem in Tokyo capital region. The land price will decrease or keep constant because housing or office demand decrease. This results in the improvement of living and recreational environment in Tokyo. Thus, the development of the MAGLEV has a possibility to change regional structure and to rescue the Tokyo capital region.

Finally, we analyze the effect of the setting of operating time and fare on the share of the MAGLEV. Figure 12 shows the estimation of share of the MAGLEV between Tokyo and Osaka. If line-haul time difference between air and the MAGLEV is zero (in case of non-stop service) and fare is equal (in case cost down is achieved), the share becomes 80%. If line-haul time difference between air and the MAGLEV is an hour (in case of several stops) and fare is 5,000 yen larger than air (in case cost down is not achieved), the share becomes 29%.

5. CONCLUSION

This paper reviews the Post-war trend and the characteristics of the inter-regional migration and traffic flow focusing on the development and the speed-up of railway transport. It is supposed that the development of the Shinkansen increased the regional attractiveness, decreased regional disparity and promoted regional settlement, industrial accumulation and industrial exchanges. However, these developments have also caused the problem of heavily concentration in Tokyo. The railway speed-up of the Shinkansen is expected to solve this problem. The MAGLEV is also expected to play an important role in solving this problem.
limitation of railway technology itself. The MAGLEV system is burdened with the restoration of railway transport. The MAGVEL system will be competitive with higher time value and adequate service conditions. In addition, the MAGLEV system is expected to assure the variety of the regional attractiveness and to rescue the concentration problem in Tokyo capital region.

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