A STUDY ON PASSENGER DEMAND TREND OF INTER-CITY MAGLEV TRAIN BY DIFFERENT LOCATION OF THE TERMINAL

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Abstract: The "Linear Motor Car MAGLEV" that will link the two major cities of Tokyo and Osaka in Japan within about an hour is expected to be operational in the early 21st century. This paper discusses the importance of terminal location for high-speed inter-city train from the Tohoku-Shinkansen experience and how the different location of the terminal influences passenger demand. Results of MAGLEV choice trend using SP analysis is also presented.

1. INTRODUCTION

The "Linear Motor Car MAGLEV" vehicle achieved the maximum speed of 550 kph on December 24th, 1997, at the Yamanashi-test-line. In 1998, with passing tests using a couple of MAGLEV vehicles implemented *(e.g. H.Nakashima et al.[1], 1998 or K.Sawada[2], 1998)*, the application of the super-conductive technology to the transportation system became a reality. Since then the development of the MAGLEV system and its practical use has progressed.

The MAGLEV is a mass transit mode, which can transport 10,000 passengers per hour per direction at peak hours. The MAGLEV uses electric energy which makes it more superior than motor cars and airplanes that depend on internal combustion engines. From the environmental point of view, pollution problems such as the discharge the nitrogen compounds, is minimized.

The MAGLEV, which will connect large cities at speeds of 500km/h, is expected to impact the primary transportation network. Reorganization of the network may become unavoidable because aerial lines as well as the existing Shinkansen will compete with the MAGLEV especially in the Tokaido corridor. This corridor includes the large cities of Tokyo, Nagoya, and Osaka which account for 36% of the country's population and where the main organizations of the economy or the industry concentrate. At the beginning of the 21st century, it is expected that inter-city MAGLEV train will serve Tokyo and Osaka in about an hour. In addition to such a nationwide transportation revolution, the promptness of the service is expected to reform the Japanese life style.

To promote this project, it will be necessary to analyze not only the costs involved but also the passenger demand. This paper focuses on the demand analysis specifically comparing the passenger demand trend by different terminal location which will depend on land acquisition constraints.

2. HISTRICAL REVIEW OF TERMINAL LOCATION

2.1 The Tohoku-Shinkansen Experience

The Tohoku-Shinkansen line connects the Tokyo Metropolitan Area and the Tohoku Area in the Northeast Part of Japan covering a distance of approximately 500 kilometers as shown in Figure 1. The Shinkansen started to operate in June 1982 from the Omiya Terminal as a first Terminal in the Metropolitan Area, which was about 30 kilometers away from the Tokyo Central Terminal (TCT). In those days, the construction of a direct connection to the TCT was delayed because the purchase of the railway site could not be completed due to some lawsuit. Because of suspension of the terminal construction, passengers were inconveniently obliged to transfer to the conventional railway at the Omiya Terminal to go to the TCT.

In February 1985, the Shinkansen line was extended from the Omiya to the Ueno Terminal as a second temporary terminal where passengers were able to directly access the Tokyo CBD (Central Business District) Area. Figure 2 shows a transition of the passenger demand relating to the opening history of the Shinkansen. The influence of terminal location to the passenger demand can be easily observed.

When the connection to the TCT which was a final stage of the permanent terminal location completed in June 1991, the Omiya terminal changed its function to that of a station and the Ueno Terminal converted to the sub-Terminal. After the opening of the TCT, passenger demand still continued to increase as shown in Figure 2. The accessibility from the major attractive places in the Tokyo CBD Area to the terminals changed as shown in Table 1. These observations show that the location of the terminal should be considered as one of the important factors for the passenger demand.

2.2 Terminal Location of MAGLEV

In order to realize easy access, it will be desirable that the terminal of the MAGLEV be located inside the Tokyo CBD Area. However, it is very difficult today to acquire the space for the track at ground level. It is also difficult for the construction of the new space to pass through the underground because the Tokyo CBD Area is highly dense with the

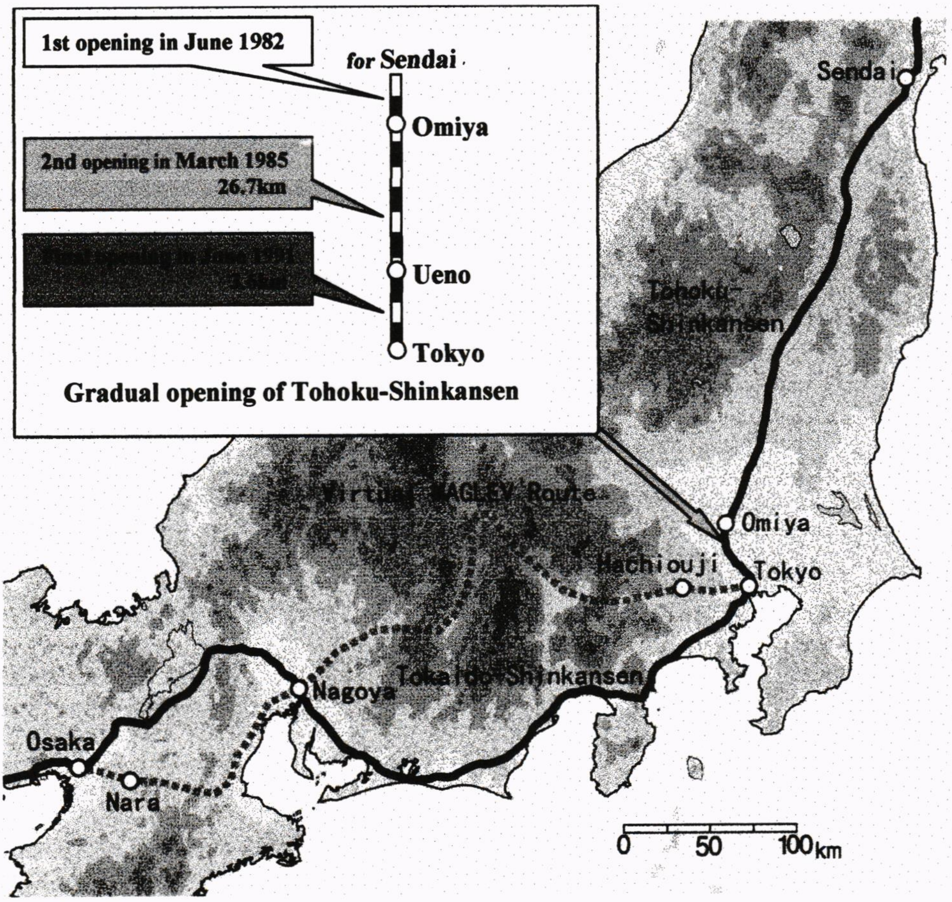

Figure 1. Routes of MAGLEV and Shinkansens

Table 1. Improvements of Accessibility to the Terminals
( ) : the number of transfer times

Terminal / St. in CBD area	Omiya	Ueno	Tokyo (T.C.T)
Kasumigaseki (Office area)	86min. (3)	44min. (2)	21min. (1)
Ginza (Shopping area)	76min. (2)	34min. (1)	19min. (1)
Shinjyuku (Amusement area)	63min. (3)	41min. (1)	29min. (1)

underground metro-network.

Hence, it is proposed to use underground at deep levels. The concept of "the underground at deep levels" is as follows:

(1) The depth is deeper than about 50 meters.
(2) The space where landowners on the ground do not use usually.

The above concept has the advantage of being able to freely draw the route independent of surface rights. At present, the Government is examining the regulations for using the underground at deep levels. In addition to the pending examination of relevant regulations, problems regarding underground excavation at deep levels still remain to be solved. These include among others technical difficulty and huge construction expenses.

In this context, the terminal of the MAGLEV may be difficult to locate inside the Tokyo CBD Area, which means it should be temporarily constructed away the CBD in order to realize an earlier operation of the service. This study analyzes how the location of the MAGLEV terminal impacts passenger demand using the Stated Preference approach. The SP approach was adopted because the MAGLEV is not a mode in the real world but a future oriented mode.

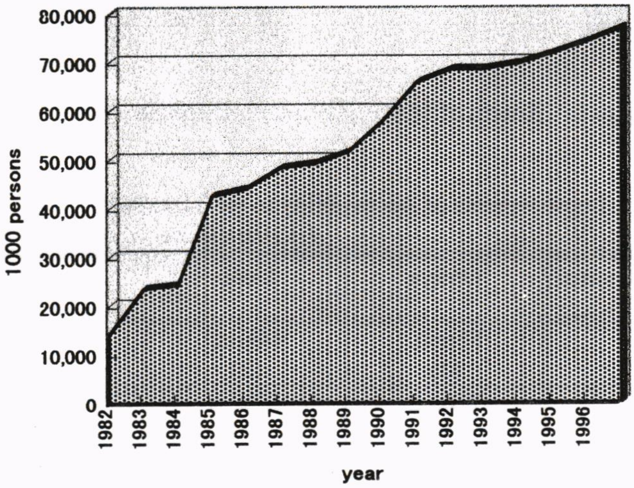

Figure 2. Number of Passengers of Tohoku-Shinkansen (Source:Ministry of Transport)

3. METHOD OF ANALYSYS

3.1 Stated Preference Approach

The MAGLEV is a new transportation mode very much different from the conventional ones. Because of the novelty of MAGLEV, the application mode shift models calibrated using existing modes is not appropriate. Analysis of passenger demand on new modes can best be done using the Stated Preference (SP) approach (*e.g. Ben-Akiva et al.*[3]*, 1989*). The SP approach has been applied in several feasibility studies for an urban transportation system (*e.g. H.Uchiyama et al.*[4]*, 1995*) and high-speed inter-city railway system (*e.g. D.Hensher*[5]*, 1997*).

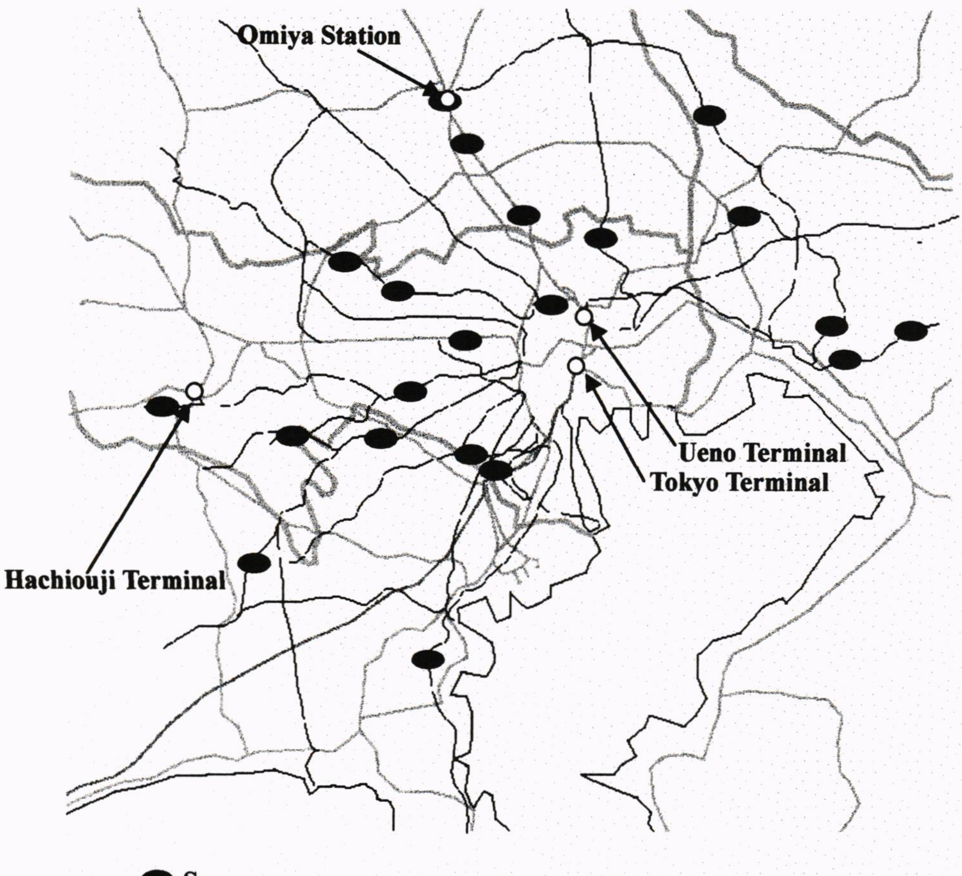

Figure 3. Survey Zones in Tokyo Metropolitan Area

3.2 Questionnaire Survey

Choice based sampling is one method often used in implementing a questionnaire survey. Using this method, questionnaires are distributed to the passengers in railway cabins and the airplanes to efficiently gather samples. Choice based sampling has some inherent weakness specifically on the perception of alternative modes. This means that decisions might be based not on real choice but captive choice. Another weakness is even though it can estimate the volume of modal shift (transferred demand) from the existing modes, it cannot estimate induced demand for a new mode.

Because of the above inefficiencies, the study used home-based sampling to gather samples from residents in the Tokyo Metropolitan Area. The questionnaires were distributed mainly to the residents who dwell in 21 representative zones shown in Figure 3. The survey was conducted in December 1998 distributing a total number of 437 questionnaires and getting back 401 replies.

3.3 Contents of Questionnaire

The questionnaire was designed to consider the following:

(1) Decrease the bias caused by SP approach against a non-existing mode,
(2) Illustrate the difference in the terminal locations,
(3) Understand the change in choice for different travel purposes, different departure times, etc.

The SP approach necessitates to design the questionnaire to restrain the bias which might be contained in the answer. The model, which is calibrated using such data with the bias, may have a tendency of over-estimating passenger demand. Because the MAGLEV is generally called "Linear" which is the simplified term of "Linear Motor Car MAGLEV", the term of "Linear" with a sense of the future dream might bring an over-expectation to the respondents. Therefore, the questionnaire uses only an expression of "the fictitious very high-speed new inter-city train" instead of the term "Linear".

The questions about a mode choice consist of two parts as shown in Figure 4. In Part 1, the respondent has to choose one existing mode among a Shinkansen "Hikari" (the ordinary type), a Shinkansen "Nozomi" (the express type), an airplane, an overnight bus and an overnight train. He/she can refer to the level of services (LOS), such as the fare and the traveling time listed on tables of the questionnaire sheet.

In Part 2, under a given condition of the LOS of the MAGLEV, the respondent has to judge whether the MAGLEV is more attractive or not compared to the mode which was chosen in Part 1. Various conditions of the MAGLEV are given by travel purpose, by departure time and so on as shown in Table 2. In addition, 6 conditions by fare and by location of the terminal for the MAGLEV are also given. Two levels of fares of the MAGLEV, (a little more expensive and more expensive than that of the airplane), are offered. A departure place of travelers from their home or office is assumed using cases listed in Table 2. The respondent has to consider his/her access route to the terminal from the nearest station of the departure place.

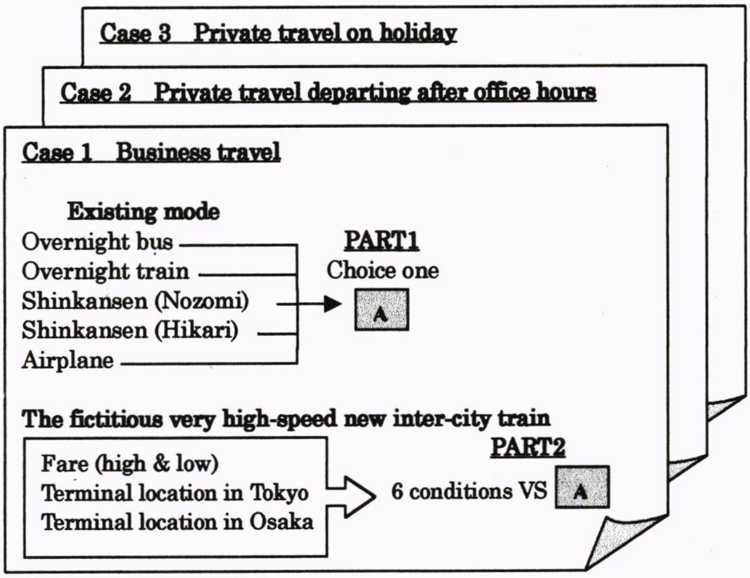

Figure 4. The Questions about the Mode Choice

Table 2. Travel Case Scenarios Considered

Case	Purpose Fare payer	Place of departure	Departure time	Place of Arrival	Arrival time
1	Business	Office	Previous night or Early morning	Osaka City Hall (Central Osaka)	During morning
2	Private	Office	Evening	Northern new town in Osaka suburban Area	Up to midnight
3	Private	Home	Previous night or Early morning	Northern new town in Osaka suburban Area	During morning

Because the actual MAGLEV route between Tokyo and Osaka has not been decided, a virtual route shown in Figure 1, is assumed in this questionnaire. The route is based on a future expansion plan of the Shinkansen network. In this study, one Central Terminal and one Alternative Terminal are considered in both Metropolitan Areas. The Central Terminal is located in the CBD Area while the Alternative Terminals are located outside the CBD Area. The Alternative Terminals are in Hachiouji (outside of Tokyo) and in Nara (outside of Osaka). Both Alternative Terminals are located on the virtual route and can connect to the conventional railway. They are almost 30 kilometers away from the Central Terminal and are expected to be constructed more easily than the Central Terminal.

Because the sampling of questionnaires was not choice based but home based, this study can examine the disparity between the respondents' choice and the actual one. The two-tier approach, which makes questionees choose the existing mode first, can confirm this disparity. Moreover, the choice of the existing mode is useful to estimate the transfer of passengers from each mode to the MAGLEV.

4. INITIAL FINDINGS

Figure 5 shows the choice trend of the respondent for the existing mode. It is found that the "Nozomi" or "Hikari" Shinkansen is the preferred choice. The airplane share ranged from 12 to 24 % (higher than that of "Inter-regional Net Flow Survey Data" in 1995, which is about 10%). The higher airplane share (with respect to the 1995 data) may be explained by the new direct access line to the Tokyo Air Terminal which started to operate just a month prior to conduct of the questionnaire survey. Moreover, the destination of Cases 2 and 3 is a northern new town near the Osaka Air Terminal, which has a good egress conditions. On the other hand, the destination of Case 1 is the Central Osaka which is advantageous to the Shinkansen. The Inter-regional Net Flow Survey Data mostly accounts for the business purpose samples. This sampling tendency is similar to the conditions of Case 1. Because the airplane choice percentage of Case 1 is 12%, the results of the questionnaire survey may be said of have little difference against the actual shares.

With regards to the questions in Part 2, the choice tendency clearly changes by the location of the Terminal as shown in Figure 6. This illustrates that the preference to the MAGLEV depreciates when the Terminal is located outside of the CBD Area. In comparison between access and egress side of the location, the egress side decreases in the percentage of the MAGLEV. With regard to the fare structure of the MAGLEV, the preference is seriously sensitive in all Cases and locations.

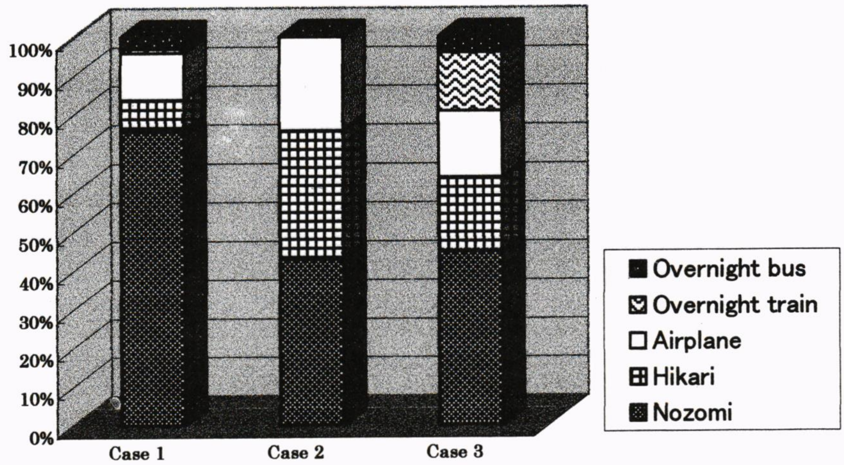

Figure 5. Result of Mode Choice

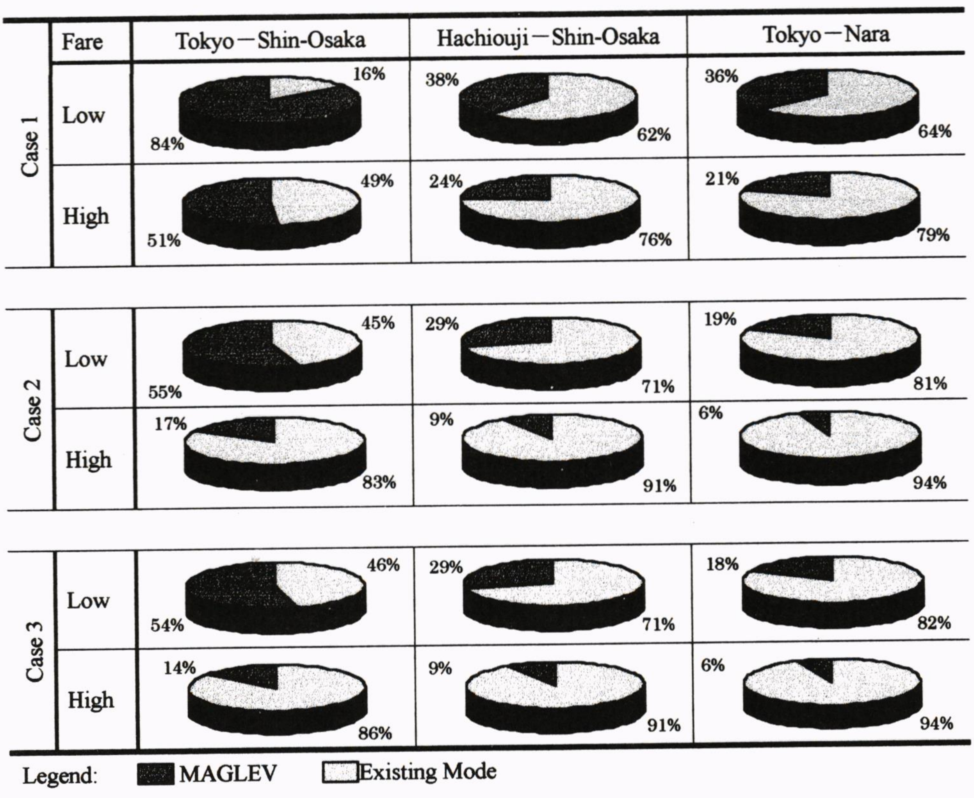

Figure 6. Choice Split Between Existing Mode and MAGLEV

5. FURTHER FINDINGS

The disaggregate logit models are calibrated using the preference data derived from the questionnaire survey. Results of the model calibration are shown in Table 3. From the viewpoint of the value of time, the respondents who have selected the overnight bus or train may have a negative tendency to transfer to the high-speed mode. Their life style is far from a concept of the promptness. Hence, they as well as the samples that have not answered a reasonable choice are excluded from the calibration.

Table 3. Parameters and t-values for Mode Choice Models

Variables	Scene 1		Scene 2		Scene 3	
	Parameter	t-value	Parameter	t-value	Parameter	t-value
Access time (hour)	-0.372	-3.7	-0.409	-1.9	-0.106	-0.8
Line-haul time (hour)	-2.676	-13.9	-1.248	-8.6	-0.787	-5.4
Egress time (hour)	-4.549	-17.5	-3.080	-15.1	-3.282	-14.0
Cost (10,000yen)	-2.937	-12.1	-5.558	-16.0	-5.837	-15.6
Hachiouji dummy	-2.603	-16.5	-2.233	-9.6	-2.424	-11.5
Constant-MAGLEV	-0.965	-4.9	1.720	6.6	2.474	9.6
Number of samples	2,148		1,215		1,344	
ρ	0.183		0.268		0.277	
$\bar{\rho}$	0.181		0.265		0.274	
Hit Ratio	71.2%		79.0%		80.0%	

Table 4. Estimation Results of MAGLEV Shares (%)

Operating Line	Tokyo-Osaka (Whole line)		Hachiouji-Osaka (Temporary line)		Tokyo-Nara (Temporary line)	
Fare of MAGLEV	Low ¥17,980	High ¥22,400	Low ¥16,410	High ¥20,440	Low ¥17,530	High ¥21,660
Scene 1	85	61	43	19	44	19
	91	75	59	31	59	30
Scene 2	85	33	52	11	33	5
	79	25	43	8	25	3
Scene 3	86	32	54	10	33	5
	87	35	57	11	36	3

(Upper: vs. Shinkansen Nozomi, Lower: vs. Airplane)
(Nozomi=¥15,040, Airplane=¥16,540)

The result of the model for Case 1, of which the travel purpose is business, shows a tendency to give weight to the travel time. On the other hand, Cases 2 and 3, which are private ones, show a tendency to give weight to the fare. Even with the same travel purpose, the weights of access and line-haul times of Case 2, in which the traveler leaves in the evening, are greater than those in Case 3. The resistance in the case of locating a Terminal in Hachiouji is introduced as a dummy variable because the adoption of the dummy variables tends to improve the reliability of the models. As these dummy parameters show relatively large values, it implies that the location of a Terminal outside of the CBD Area brings a psychological resistance to users compared with their sense for physical time distance.

Table 4 lists the mean values of MAGLEV share from hundreds of railway stations in the Tokyo Metropolitan Area. In Case 2, MAGLEV shares are 85% vs. Shinkansen Nozomi and 79% vs. airplane. If the Hachiouji Terminal is adopted, the percentages decrease sharply to 52 and 43%. On the other end, if the Nara Terminal is adopted, the percentages decrease to 33 and 25%. These table shows that the different locations of the Terminals influence the passenger demand in a very sensitive manner.

6. CONCLUSIONS

This paper highlighted the importance of the location problem of terminals for a high-speed inter-city train from the experience of the Tohoku-Shinkansen and the results of the MAGLEV choice analysis using the SP approach. Analysis of a home-based questionnaire survey resulted in measuring how the preference to the MAGLEV changed by location of Terminal alternatives. In other words, the location of the Terminal outside of the CBD Area brings an large reduction of passengers. From the viewpoint of the passengers, the MAGLEV will not be a primary surface transport system but an intermediate system between airplanes and railways because it strongly depends on the accessibility to its terminals.

It is concluded that these findings will lead us to reorganize the aerial network as follows: both Air-Terminals in Tokyo and Osaka will be able to afford to assign some flights to the other destinations corresponding to the decrease of direct flights between Tokyo and Osaka. Furthermore, these findings will also give us important information in taking into account of the future nationwide comprehensive transportation planning and policy.

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