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Spatial externality of railway service improvement; To understand Japanese inter-regional transportation service improvements

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Abstract

Multimodal policy between railway and airlines is of importance in providing seamless transportation service to inter-regional passengers. However, it is difficult to make coordination among the railway and airline service suppliers, especially when they are fiercely competing for the share in passenger market in the target OD. Inter-regional transportation in Japan, fierce competitions are observed between Japan Railway companies and airlines, especially after the 1990's deregulation of the airline entrance; the number of new air service are parallel to the conventionally profitable railway service. Inline with the increase of multimodal trips, which use an airline link as the trunk line, and railway links as the access or egress service, the improvement of railway service of middle to long distance would simultaneously and inevitably improve the short distant railway service, which can be used as the access line to airport. This phenomenon can be called the spatial externality of railway to airline network. This study purposes to clarify the existence and effects of spatial externality of railway service from investigation of longitudinal change in inter-regional transportation service and demand in Japan. The LOS of multimodal routes are calculated by the k-th shortest path algorithm which gives alternative routes to the shortest. Modal choice model is estimated, and passenger utilities of ODs are calculated. The results are aggregated for each distance range of ODs, and compared the LOS improvement measured by estimated utilities. Implications for regional transportation administration are finally made.

Keywords: Network, Externality, Multi-modal, Railway

JEL codes: R40, R49, N75.

1. INTRODUCTION

"Open sky policy" to deregulate entries and exits of airlines started in U.S., had caused drastic change in inter-regional transportation service. A lot of new airlines had been opened, then immediately started competitions with conventional airlines, or with high-speed railway, if they are parallel (Gonzalez-Savignat, 2004). Number of theoretical and empirical studies to clarify the influence of the policy reported that such competitions surely make benefits on passengers by accelerating service improvement (Schipper, Rietveld and Nijkamp, 2002; Noran, Ritchie and Rowcroft, 2001; *et. al*). However, too strong competition in public transportation might cause spatially imbalanced service supply. O'sullivan (2004) pointed out that unexpected inefficiency would occur because a missing of system integrity in inter-regional transportation service causes fragmentation in transport operation, especially for inter-modal service. In order to avoid the fragmented service, multimodal policy and articulated transportation service provision should be promoted to adequately maintain LOS of public transportation system. While the multimodal policy requires an organized cooperation among each service supplier, it is difficult to coordinate their service.

The importance of multimodal policy is often stressed in intra-city public transportation planning, in the context of journey planning problem including several modes, or of connectivity analysis to the other mode. Horn formulated a novel procedure to model journey planning problem (2002, 2003). In his procedure, waiting time at transfer is carefully modeled in order to make an integrated time table. Krygsman, Dijst and Arentze estimated a regression model between shares of access / egress time including waiting time in line-haul with socio-demographic factors (2004), but the fit of the obtained model was relatively low. In inter-regional public transportation planning, development of modal choice model between representative modes of each route (i.e. these routes probably consist of different modal links) is mainly addressed. Cascetta and Papola (2003), Koppelman and Sethi (2005) , or Yao and Morikawa (2005) refined conventional disaggregated logit model to deal with heteroschedasticities of mode (route) alternatives, hierarchical choice structure, and accessibility index by log-sum variable to model induced traffic, respectively. Among these studies, definition of choice set was carefully treated to determine model structure, and the estimated parameters of access / egress time were all significant. Another approach to inter-regional multimodal route was done by Lythgoe and Wardman (2002), that estimated a demand function for all railway links in U.K. used as access or egress lines to / from airports. This study clarified the differences in demand elasticity between general railway passengers and access / egress passengers, and that between inward and outward passengers. Note that such usage of railway is possible in the regions as European countries or Japan, where intensive railway network is already facilitated near airports.

In case of implementing multi-modal policy in inter-regional transportation, the difference in spatial externality of railway and that of airline network should be considered. For example, once an improvement of railway path including several links is done, the LOS improvements should inevitably occur for all OD pairs using the path as a sub-path of whole route. Even if the railway company intends to attract passengers from the airline, the railway company can not exclude the passengers using the improved path as an access, or egress path to airport. On the contrary, spatial externality caused by airline link improvement would not strongly occur as observed in railway case, because the airline network is relatively sparse than that of railway, and it generally has lower frequency. While the difference in spatial externality between railway and airline network has not been discussed in conventional study, it is important not only to understand in rapid growth of airline passengers occurred in European countries or Japan in so far, but to positively utilize it in future. We should avoid the following case; a railway company decrease local railway LOS, then it would discourage unrecognized multimodal use, and harm the local transportation service due to the inadequate change in service allocation by private service suppliers. After 2006 or 2007 when total population in Japan is supposed to reach at its peak, inter-regional multimodal policy will be more important to adequately maintain the LOS levels of public transport service by efficiently utilizing of existing infrastructure.

This study purposes to clarify the existence of spatial externality in LOS improvement from railway to airline, through the retrospective network LOS evaluation in Japan. In order to explicitly consider a choice set of route alternatives for each OD pair, the LOSs of routes (access / egress time to airport, line-haul time, fare , line-haul distance, and frequency) are calculated by using the k-th shortest path algorithm which can generate alternative routes other than the shortest one. By this procedure, not only the best route but also some better routes for each railway mode and airline mode can be considered In order to assess the calculated LOS of the generated routes, an aggregated mode choice model for each OD is estimated. Then the passenger utilities of ODs are calculated. The results are aggregated for each OD distance range, and compared the LOS improvement measured by the estimated utilities. The remaining sections are organized as follows; **Section 2** shows the brief procedures in the k-th shortest path algorithm, and the OD based aggregated mode choice model is formulated. **Section 3** shows the results of the proposed procedure applied to Japanese longitudinal data, and some empirical evidences of spatial externality are discussed. Finally, in **section 4**, we discuses the implications for regional transportation administration.

2. METHODOLOGIES

2.1 K-th shortest path search algorithm

K-th shortest path search algorithm consists of three kinds of subroutines (Dijkstra, FSP, KSP). The following procedure was proposed by Kato, et. al (1978). The shortest path between origin and destination node is obtained by using Dijkstra algorithm, which generates a shortest path set from the origin node to all the other nodes, called "a shortest paths tree (from the origin O)". Since the second shortest path has a path length no less than the shortest path, it branches at one of the nodes on the shortest path. Note that the secondly shortest path shares sub-path from the origin node to the branching node (We permit the exceptional case when the shared sub-path is shrunk as the original node, itself). Second path search algorithm (FSP) searches all the branches of the nodes on the shortest path, finds the shortest sub-path from the next node after branching to the destination, and merges them. In this procedure, the inverse shortest path tree from the destination D is convenient, since the shortest sub-path from the any next nodes after branching to destination is included in it. Then FSP finds the path with the shortest path length among the merged paths. In other words, this subroutine finds the shortest path among the paths that branch on the given sub-path (sub-path equals the shortest path at the second path searching).

K-th shortest path search algorithm (KSP) uses Dijkstra, and FSP in order to find the subsequent paths. **Figure. 1** demonstrates a case of the third shortest path search by KSP. Given the shortest and the second shortest path, there are three types of candidates of the third shortest path, classified by the location of the new branch relative to the branching node of the second from the shortest path. Now we call the branching node α_2. Type 1 route branches from the route R_1 between O to α_2, type 2 route branches from the route R_2 between α_2 to D on the sub-path of the second path, and type 3 route branches from the route R_3 between α_2 to D on the sub-path of the shortest path. KSP calls FSP to find three types of candidate path for each, picks up the shortest path among them as the third shortest path, and the other paths are stored as the candidates of the subsequent paths used in the next search. The k-th shortest path ($k \geq 4$) is obtained by repeatedly applying KSP. In order to prevent from generating the path already obtained, KSP also stores a list of branching node α_k and the next node for all paths from second to k th, and stored candidate paths at the end of each routine. The list is used to omit the branches in the next search.

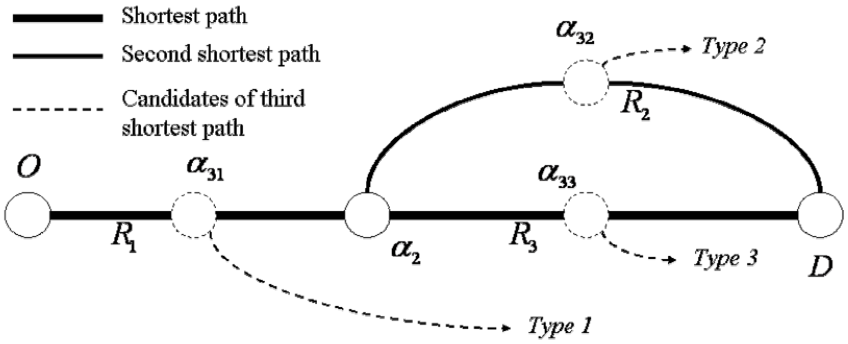

Figure 1. The third shortest path search by KSP subroutine

For example, at the fourth shortest path search, KSP convert the origin and branching node information (O, α_2) on Figure 1 into (O, α_{31}) if the third path is type 1, (α_2, α_{32}) for type 2, (α_2, α_{33}) or for type 3, then sends it to FSP with the latest omitting branch list. The validity of the above procedure is also proved by Kato.

K-th shortest path search algorithm generates the routes from the shortest line-haul time to much longer in order, but all the generated routes can not be directly adopted as the alternative route for the route choice model. Firstly, far inferior routes to the shortest will not be actually used, so that we set two termination conditions as follows; if $k = 20$, or the line-haul time of the latest route excesses 1.5 times of that of the shortest. Secondly, a set of routes includes many similar routes sharing most of their sub-path. Such the similar routes should not be used as the independent alternative route, however. Therefore we classified the generated routes into much fewer groups, based on the similarity index S_{lm} ($0 \le S_{lm} \le 1$) between route l and m, defined in eq.(1).

$$S_{lm} = S_{ml} = \frac{L_{lm}}{\sqrt{L_l \times L_m}} \tag{1}$$

where, L_{lm}, L_l, L_m are a physical length of shared sub-path of route l and m, a length of route l, and a length of route m, respectively. Each route is classified into the group of $S_{lm} \ge \theta$ (θ: classification threshold), and the LOS of the group is represented by that of the shortest route in the group. In case of $S_{lm} \ge \theta, S_{ln} \ge \theta$ for both m and n, route l belongs to superior group concerning to its representative LOS. We set $\theta = 0.7$ in this study following after Hazemoto, Tsukai, and Okumura (2003).

The outputs of route LOS information is line-haul time (T_{ij}^k), line-haul distance (D_{ij}^k), and minimal link frequency on the route (F_{ij}^k) that gives the strongest constraint on passenger's schedule. Since line-haul fare (C_{ij}^k) of railway routes is not equal to simple summation of each link fare, we approximately calculated it based on the line-haul velocity ($v_{ij}^k = T_{ij}^k / D_{ij}^k$). Using the OD fare data of the shortest path, following fare models (2a) - (2e) are estimated to calculate line-haul fare of railway route C_{ij}^{rk}.

$$C_{ij}^{rk} = f_{ij}^{k} + \delta^{1} f_{ij}^{k1} + \delta^{2} f_{ij}^{k2} + \delta^{1} f_{ij}^{k3} \quad (2)$$

$$f_{ij}^{k} = -0.043\left(D_{ij}^{k}\right)^{2} + 16.49 D_{ij}^{k} + 58.47 \quad (2a)$$

$$f_{ij}^{k1} = 3.46 D_{ij}^{k} + 973.37 \quad (\delta^{1} = 1 \mid v \leq 120) \quad R^{2} = 0.735 \quad (2b)$$

$$f_{ij}^{k2} = 5.70 D_{ij}^{k} + 1971.0 \quad (\delta^{2} = 1 \mid 120 \leq v < 170) \quad R^{2} = 0.886 \quad (2c)$$

$$f_{ij}^{k1} = 6.49 D_{ij}^{k} + 2528.5 \quad (\delta^{3} = 1 \mid v < 170) \quad R^{2} = 0.993 \quad (2d)$$

where, $\delta^{1}, \delta^{2}, \delta^{3}$ are dummy variables to indicate line-haul velocity categories. For airline route, C_{ij}^{ak} is calculated by summation of each link if they consists of access / egress link and airline link. If the route includes railway sub-path, eq.(2) to (2d) is applied for the railway sub-path distance, then railway sub-path fare and airline sub-path fare are summed up.

2.2 OD based aggregated modal choice model

We use simple logit model to describe aggregated route choice behavior by OD base. Since available data in net passenger survey is aggregated for each representative mode, route utilities should be aggregated for the representative modes, therefore we defined modal utility of railway and airline, that consists of route group utilities. In this study, a number of route groups for each mode is less than three. When there is no second and third group for specific OD, dummy variables $\delta_{ij}^{2r}, \delta_{ij}^{3r}, \delta_{ij}^{2a}, \delta_{ij}^{3a}$ are 0, otherwise 1. The choice probability of railway in *ij* is eq.(3).

$$P_{ij}^{r} = \frac{\exp\left(V_{ij}^{r1}\right) + \delta_{ij}^{r2}\exp\left(V_{ij}^{r2}\right) + \delta_{ij}^{r3}\exp\left(V_{ij}^{r3}\right)}{\exp\left(V_{ij}^{r1}\right) + \delta_{ij}^{r2}\exp\left(V_{ij}^{r2}\right) + \delta_{ij}^{r3}\exp\left(V_{ij}^{r3}\right) + \exp\left(V_{ij}^{a1}\right) + \delta_{ij}^{a2}\exp\left(V_{ij}^{a2}\right) + \delta_{ij}^{a3}\exp\left(V_{ij}^{a3}\right)} \quad (3)$$

$$V_{ij}^{rK} = \beta^{rt} RT_{ij}^{rK} + \beta^{c} C_{ij}^{rK} + \beta^{f} F_{ij}^{rK} + \beta^{v} v_{ij}^{rK} + \beta^{r} \quad (K = 1,2,3) \quad (3a)$$

$$V_{ij}^{aK} = \beta^{rt} RT_{ij}^{aK} + \beta^{at} AT_{ij}^{aK} + \beta^{c} C_{ij}^{aK} + \beta^{f} F_{ij}^{aK} + \beta^{v} v_{ij}^{aK} \quad (K = 1,2,3) \quad (3b)$$

where, RT_{ij}^{rK} is line-haul time of railway route, RT_{ij}^{aK} is railway sub-path time of airline route, AT_{ij}^{aK} is airline sub-path time of airline route, $\beta^{rt}, \beta^{c}, \beta^{f}, \beta^{v}, \beta^{r}$, and β^{at} are parameters. Given a number of railway and an airline passengers in *ij* (RP_{ij}, AP_{ij}), and aggregated modal split in *ij*: $S_{ij}^{r} = RP_{ij} \big/ \left(RP_{ij} + AP_{ij}\right)$, parameters are estimated by maximum likelihood method. Likelihood function L is shown in eq.(4).

$$\mathrm{L} = \sum_{i,j} S_{ij}^{r} \log P_{ij}^{r} + \left(1 - S_{ij}^{r}\right)\log\left(1 - P_{ij}^{r}\right) \quad (4)$$

Based on the estimated parameters, consumer surplus of passengers for each OD can be calculated by using log-sum utility of route alternatives, and number of passengers, shown in eq.(5).

$$CS_{ij} = \frac{RP_{ij} + AP_{ij}}{\beta^{c}} \times \log\left(\exp\left(V_{ij}^{r1}\right) + \delta_{ij}^{r2}\exp\left(V_{ij}^{r1}\right) + \delta_{ij}^{r3}\exp\left(V_{ij}^{r3}\right) + \exp\left(V_{ij}^{a1}\right) + \delta_{ij}^{a2}\exp\left(V_{ij}^{a2}\right) + \delta_{ij}^{a3}\exp\left(V_{ij}^{a3}\right)\right) \quad (5)$$

3. EMPIRICAL ANALYSIS OF SPATIAL EXTERNALITY

3.1 Data

As input datasets to k-th shortest path search, we prepared Japanese inter-regional network data in 1980 and in 2000. Attributes of each link are travel time, length, frequency per day, and modal information (railway, airline, and public transportation other than railway to / from an airport, called "access"). While railway network consists of railway links only, an airline network includes whole railway network plus airports nodes and available flight links between the airports, and access links between airport and the nearest railway station nodes (often supplied by bus). The railway / airline network in 1980 have 194 nodes and 281 links, 240 nodes and 420 links, and those in 2000 have 194 nodes and 286 links, 242 nodes and 492 links, respectively. The modal choice model is estimated by using inter-regional net passenger traffic data among 46 prefectures surveyed by Japanese Ministry of Land, Transportation, and Infrastructure in 2000. Therefore, the estimated parameters reflect the intermodal preference in 2000, and the consumer surplus reflects the actual passenger flow in 2000.

3.2 Evidence of spatial externality in supplied LOS

The k-th path search algorithm is applied for both railway, and airline network for each OD pair in totally $1035 = (46 \times 45)/2$, then the generated routes are grouped by using similarity indices in eq.(1). From the primal group with the shortest line-haul time, we considered up to third groups as the route alternatives.

Since the algorithm is terminated until $k = 20$, or by line-haul time condition of 1.5 times of the shortest, considered number of route groups is no more than three. **Table 1** summarizes numbers of available route groups (called routes, hereafter), aggregated for distance band. If the routes on airline network are including railway sub-path, we categorized them into multi-modal route called as "MM", otherwise, shown as "non-MM" on **table 1**. The numbers of MM and non-MM routes in 1980 were 2171and 534, respectively, and in 2000 they were 2076 and 579, respectively. Less numbers of routes of airline (MM plus non-MM) than that of railway are obtained in all distance band, because the line-haul time of the second or third route in airline tends to excess 1.5 times of the shortest, so then they are excluded. In terms of railway routes, more routes become available in longer distance band. Up to 499 km bands, number of available routes increased by year 2000 due to the improvement of railway network. About airline routes, numbers of MM routes generally excess non-MM routes, except over 1000 km in 2000. The largest number of MM routes is available in 500-599 km in 1980, and 600-799 km in 2000. The numbers of airlines routes in 2000 are generally less than those in 1980. Considering the increase of links on airline network in 2000, the decrease of generated routes seems to be caused by relatively larger improvement in the shortest route

Table 1. Number of available route groups for distance band

	Distance band (km)								
	-199	200-299	300-399	400-499	500-599	600-799	800-999	1000-	total
No. of data	203	148	125	118	106	149	107	79	1035
Rail in 80	2.20	2.70	2.88	2.98	2.99	3.00	2.99	3.00	2.78
MM in 80	1.46	2.20	2.45	2.57	2.57	2.56	2.21	1.66	2.18
non-MM in 80	0.41	0.42	0.43	0.38	0.42	0.41	0.77	1.33	0.52
Rail in 00	2.30	2.83	2.90	2.95	3.00	2.99	3.00	3.00	2.82
MM in 00	1.35	1.82	2.10	2.34	2.50	2.58	2.38	1.46	2.03
non-MM in 00	0.44	0.52	0.54	0.44	0.42	0.42	0.61	1.52	0.56

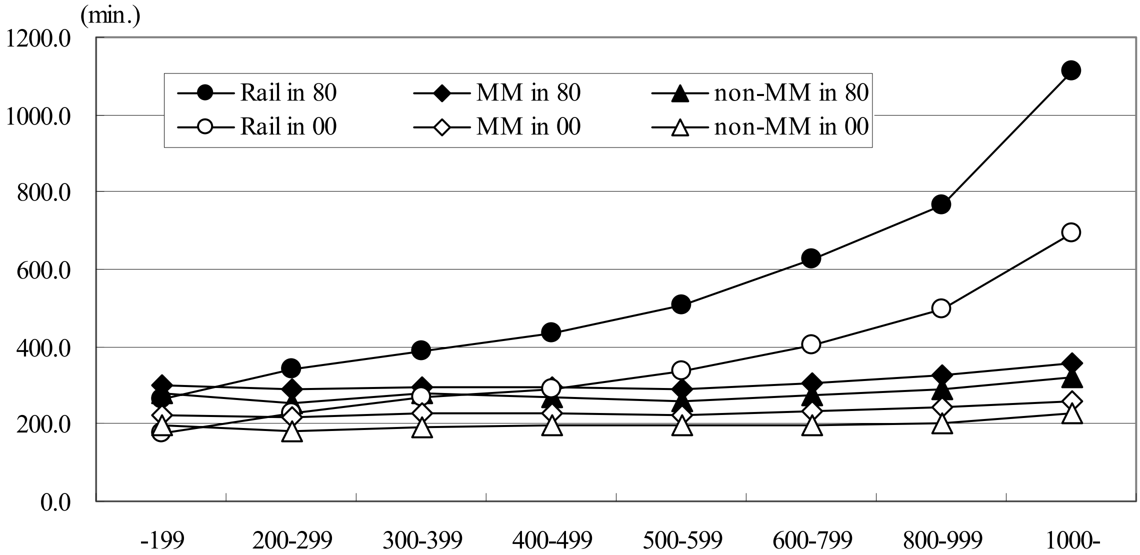

Figure 2. Line-haul time

that makes 1.5 times rule severe to be passed.

Figure 2 shows the average line-haul times of railway, MM and non-MM routes in 1980 and 2000. The line-haul time of railway increases in proportion to distance band, but they are considerably decreased in 2000, that are 62.1 to 67.4 % of line-haul time in 1980. Relative improvement for the original line-haul time, shorter range enjoys stronger than the longer distance. It shows that there is intra-model spatial externality from the longer routes to the shorter. If we improve the service level for the longer routes, the shorter OD pairs can enjoy the fruits, automatically. However, the line-haul time of airline is almost constant over distance band, or slightly less around 400 to 599 km. Comparing MM with non-MM, MM routes have longer line-haul time than that of non-MM, because MM routes include railway links. This feature is seen for both in 1980 and 2000. In order to closely understand the characteristics of line-haul time of airline routes, inter-temporal ratio in travel time decomposed by the modes of links are shown in **table 2** and **table 3**. On MM routes, decrease in line-haul travel time is mainly caused by airline link (59.3 to 64.8 %), secondly caused by

Table 2. Inter-temporal ratio in travel time of multi-modal routes

	-199	200-299	300-399	400-499	500-599	600-799	800-999	1000-
line-haul	74.1%	75.0%	76.3%	76.9%	75.8%	75.4%	74.9%	72.0%
railway	71.3%	70.8%	76.4%	83.4%	77.8%	78.7%	75.2%	75.5%
airline	64.8%	64.6%	64.1%	60.7%	61.4%	60.6%	61.5%	59.3%
access	101.4%	105.9%	101.7%	101.3%	102.1%	101.4%	108.2%	104.5%

Table 3. Inter-temporal ratio in travel time of non-multi-modal routes

	-199	200-299	300-399	400-499	500-599	600-799	800-999	1000-
line-haul	70.1%	72.5%	68.3%	73.5%	76.9%	73.2%	69.8%	71.5%
airline	64.7%	65.3%	61.1%	66.6%	67.5%	67.2%	63.8%	61.7%
access	86.0%	93.5%	90.0%	96.5%	101.8%	93.5%	92.2%	102.4%

railway links (72.0 to 76.9 %). On the other hand, (non-rail) access links in all distance bands were not improved. The results of non-MM routes are similar to MM routes, but the extents of decrease in those ratios are generally larger in non-MM routes, except 500 to 599 km band of line-haul time.

From these inter-temporal comparison of LOS characteristics in MM routes including airline, decrease in travel time of railway links contributes to that of the whole MM routes, while it is much lower than that on railway routes themselves, shown in **figure 2**. This is an obvious evidence of spatial externality from railway to airline in LOS supply side. Another characteristic of airline MM route is the increase in access time ratio. Because newly facilitated airports generally locate far from the downtown of local capital cities, the share of access time in line-haul time increased, while the travel time of railway and airline links inter-temporally showed remarkable decreases. Therefore, improvements in access time will be a cumbersome bottle-neck in decrease of line-haul time in the future.

3.3 Evidence of spatial externality in the consumer surplus simulation

Table 4 shows the estimated parameter of OD based aggregated modal choice model. Since it was impossible to obtain airline routes in some close OD pairs, 89 pairs in total 1035 pairs are dropped at model estimation. Fitness of the model by $\bar{\rho}^2$ is significantly high. All the parameters satisfy the sign conditions, but parameters in cost and minimal frequency on the route are not statistically significant. Using estimated parameters in 2000 and network datasets in 1980 and 2000, four cases of consumer surplus: CS are calculated as following; case 1 : railway routes in 1980 + airline routes in 1980, case 2 : railway routes in 1980 + airline routes in 2000, case 3 : railway routes in 2000 + airline routes in 1980, case 4 : railway routes in 2000 + airline routes in 2000. Then in order to simulate the hypothetical scenarios when the LOS improvement only occurs in railway, or in airline, else simultaneously occurs for both,

Table 4. parameter estimates of OD based aggregated modal choice model

varables	estimates		t-value
Airline & access time	-0.008	**	-2.92
Cost	-0.029		-0.20
Minimal frequency on the route	0.001		0.06
Line-haul velocity	0.070	**	4.13
Railway time	-0.017	**	-12.87
Constant in railway	3.113	**	5.69
Adjusted $\bar{\rho}^2$	0.439		
No. of observations	946		

** : significant in 1%

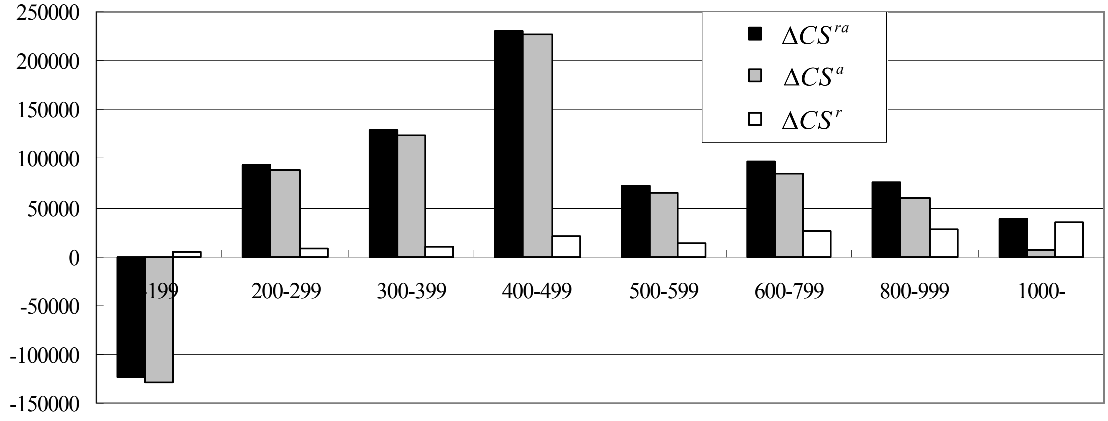

Figure 3. Increments of consumer surplus for network improvement scenarios

increment of CS s are calculated. These are denoted by $\Delta CS^r, \Delta CS^a$ and ΔCS^{ar}, respectively.

Figure 3 shows the results. Note that the absolute values of consumer surplus are too small for significant improvement accumulated in 20 years (amount to only 60 million dollars per year in case of ΔCS^{ar}, therefore it might be underestimated. Such result would be caused by inappropriate cost parameter of modal split model that absolutely scales CS in eq.(5), but relative CS distribution for distance bands would be valid owing to significantly high value of $\bar{\rho}^2$. On **figure 3**, ΔCS^r shows only a few increases in all distance bands because the CS calculation reflects the characteristic of passenger flows in 2000 including many longer trips, where airway are mainly used. ΔCS^a and ΔCS^{ar} show significant increases similarly, except over 1000 km band. The largest increment of CS appears at 400 to 499 km band that contains the largest demand OD with a couple of the first and the second largest cities in Japan (Tokyo-Osaka), which corresponds to the distance band supplied least line-haul time. The negative increment of CS appears 0 to 199 km band. Two possible explanations for the reason can be considered, such as increase in access time to airports, or taking the airline out of this range comparing to 1980. In other words for later case, airline companies efficiently shift their transport resource into much competitive distance band.

The finding that most of CS increments appear in airline improvement scenario, directly implies that airline companies have spatially relocated their service corresponding to the passenger flow in 2000. However, airline service will be never supplied without access and egress links. Considering the facts that many number of MM routes appears in 2000, and the contribution of railway access / egress path to line-haul time of airline route, the flexibility of airline network largely depends on the spatial externality of railway network. Again, improvements of railway service without improving the MM route of airline can not be accomplished in the above calculations; the improvement of network LOS of both modes always appears concurrently. In addition to above uni-lateral spatial externality, difference in spatial mobility of service gives a reasonable explanations to current success of airline companies in inter-regional passenger's transportation in Japan. On the other hand, spatial relocation of LOS is difficult for railway companies due to the immobility of trucks and stations, and railway service is basically uncompetitive to airline for speed. These are the reasons of few improvement of consumer surplus by the sole railway improvements.

4. REMARKS AND CONCLUSIONS

This study investigated spatial externality in LOS improvement from railway to airline, through the retrospective network LOS evaluation in Japan. By alternative shortest path search, we found many multi-modal routes of airline, and their line-haul time are strongly decreased owing to the decrease of railway links used as access or egress path. This is an evidence of spatial externality in LOS supply side. The other evidence in demand side is clarified by consumer surplus calculation under the passenger flow in 2000, that most of consumer surplus is brought by airline improvement. Since the airline LOS largely depends on access links including railway path, we can conclude that spatial externality of LOS is one of the reason for these results.

Based on the above discussion, some suggestions for inter-regional transportation policy are possible. From the perspective of system integrity, inevitable spatial externality of LOS should be considered at the spatial rearrangement of LOS. Investment of transferability among different mode, or to access links will strengthen the uni-lateral spatial externality. On the stand point of railway companies, spatial externality of LOS may cause the decrease in passengers of railway in short term, but the LOS improvement can also induce additional passengers in longer term. This is one of the further topics to be researched.

There are several issues to require further investigation. First, we ignored the difference of capacity between airline and railway. Strong constraints exist on airline (or exactly to say, airport slot allocation) would surely work as a limit of airline success, so that the situation is perfectly different from thick and thin passenger market. An approach to the difference in modal capacity and market thickness from the viewpoint of optimal management of inter-regional transportation seems important. As an matricidal issue, the proposed procedure that route grouping, or to estimate the significant parameters are also important to obtain the credible implications.

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