INTERNATIONAL COMPARISON OF DOMESTIC INTERCITY MOBILITY BY PUBLIC TRANSPORTATION

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ABSTRACT

It is said that improvements in intercity transportation offered by air travel and high-speed rail services, in turn, improve convenience. However, if the convenience of only some intercity transportation services improves, the gaps between intercity mobility services could widen. Thus, focusing on mobility service fairness, it is essential that any disparities between intercity mobility services be narrowed. The present study proposes using Data Envelopment Analysis (DEA) in calculating two indices of service level: individual mobility and population mobility, and compares the regional disparities in the domestic intercity mobility of Japan with those of other countries. The results aid in the discussion and evaluation of current regional disparities in mobility services as well as future improvements in intercity transportation services.

Keywords: Public transportation service, Intercity transportation, International comparison, Mobility, Data Envelopment Analysis (DEA)

1. INTRODUCTION

1.1 Background and purpose

When travelling between cities, most people want to travel at the lowest cost, arrive at their destination in the least amount of time, and appreciate a high frequency of transportation services. In recent years, intercity mobility in Japan has been steadily improving as a result of improved transportation facilities, technical innovations, and other factors, including deregulation of the airline industry. These improvements have led to both reduced fares and shorter travel times. From the perspective of the “equity issue”, however, any widening of disparities in regional mobility services must be prevented as much as possible. Therefore, any existing regional disparities between public transportation services should be minimized in order to ensure service fairness throughout the nation.

Thus, the purpose of the present study is to propose new indices for measuring intercity mobility efficiency in order to show disparities in regional public transportation services. Based on these proposed indices, the regional disparities in domestic intercity mobility in Japan, as well as those in France, Germany and China, are compared, country by country. The differences in mobility levels between the large 10 cities of these countries are also analyzed. By comparing the regional disparities in domestic intercity mobility in Japan to that of other countries, whether or not the size of the disparities in Japan are wider, according to current transportation policies, can be clarified.

1.2 Research review

In the present study, we review related research from three perspectives: 1) transportation service evaluation, 2) regional disparities in intercity mobility and 3) Data Envelopment Analysis (DEA) methodology.

Kaneko et al. (2005) reviewed the current research on intercity transportation, and indicated that a diverse set of tasks still remain to be completed, such as filling in missing data, conducting behavioral analysis and introducing multiple approaches to the evaluation of service. When a transportation service is evaluated, it is important to not only consider frequency and travel time, but also fare. Using the general cost model is a popular method for evaluating the multiple aspects of these services (e.g., Wardman 1994; Nomura et al. 2001). However, both of these previous studies focused on each factor individually. If intercity transportation is to be effectively evaluated, multiple factors must be considered. A study by Hazemoto et al. (2003), using the disaggregate model, considered multiple modes, and indicated an improvement benefit when the transportation networks were improved. Yamaguchi et al. (2009) calculated an accessibility indicator which considers the transport mode share. Amano et al. (1991) and Nakagawa et al. (1998) defined the “piled-up travelling time” as a new indicator of travelling time taking frequency of available service into consideration. Kikuchi et al. (2008) defined the Expected Value of Generation Costs (EVGC) which considered the piled-up travelling time, and subsequently clarified the relationship between intercity transportation potential and the region’s growth. However, when the generation costs are calculated, it is necessary to introduce the value of time. Showing that it is difficult to uniquely determine the value of time, Kato (2006) indicated two values of time when travel time and distance increases; one was a decreasing value of time while the other was an increasing value. Moreover, determining the value of time becomes increasingly complex when considering intercity transportation, since different regions can be targeted. It seems, then, that evaluations of intercity mobility should be done excluding the value of time.

Secondly, there have been a number of studies into regional disparities in mobility. Most of these studies analyzed the issue from the perspective of disparities in transportation price (e.g., Knapp 1983; Anderson 2002). However, it is necessary to analyze regional disparities in mobility taking other factors into consideration. Eitoku et al. (2008) proposed an objective method for evaluating transportation service levels by comparing this factor between each study area. This particular study used a questionnaire survey that is easy to implement in a small study area, but seems difficult to do across an entire country.

Thirdly, research on the DEA methodology is considered. In the present study, DEA is applied to measure mobility efficiency. DEA deals with transportation service indices directly, and, therefore, does not need to provide the value of time for the given condition. DEA is a method of evaluating the effectiveness of each analyzed object, Decision Making Units (DMUs), based on a frontier created by linear programming. The effectiveness is provided by a ratio scale that is evaluated by “output/input.” The highest possible ratio is set as 1, where the input matches the output. Moreover, using the DEA model, it is possible to treat multiple inputs and outputs. Therefore, for each intercity situation, DEA can quantitatively evaluate the regional disparities in mobility efficiency. The DEA model has been used in a number of previous studies. Some examples of the studies using DEA deal with evaluating the productivity for transportation infrastructure systems (Nanthawicht et al. 2005), the productivity for urban railways (Graham 2008), and the productivity for airport capacity (Fernandes and Pacheco, 2002). After reviewing these studies, it was determined that evaluating whether intercity transportation should be improved is possible based on DEA results.

Then, the following three points were considered in the present study. First, intercity mobility indices of transportation services considering multiple modes (e.g., airline, rail, etc) are proposed. Second, intercity mobility by objectively examining data such as fare, travel time and frequency is evaluated. Third, intercity mobility by DEA, excluding the value of time, is evaluated. Thus, the present study seeks to solve multiple mode problems, multiple service index problems and value of time problems, using DEA.

2. ACTUAL CONDITIONS IN SELECTED COUNTRIES

2.1 Public transportation

The target public transportation systems in the present study include rail transit and airlines (Bus services are not considered in the present study) in four countries: France, Germany, China and Japan. Concerning rail transit, France and Germany have a high-speed rail network like Japan. China also has a similar network but, in recent years, it has experienced rapid improvement. The high-speed rail network in each of these countries is shown in Figure 1. The rail networks in Japan and France spread from the capital city. In Germany and China, however, the networks do not have a central hub.

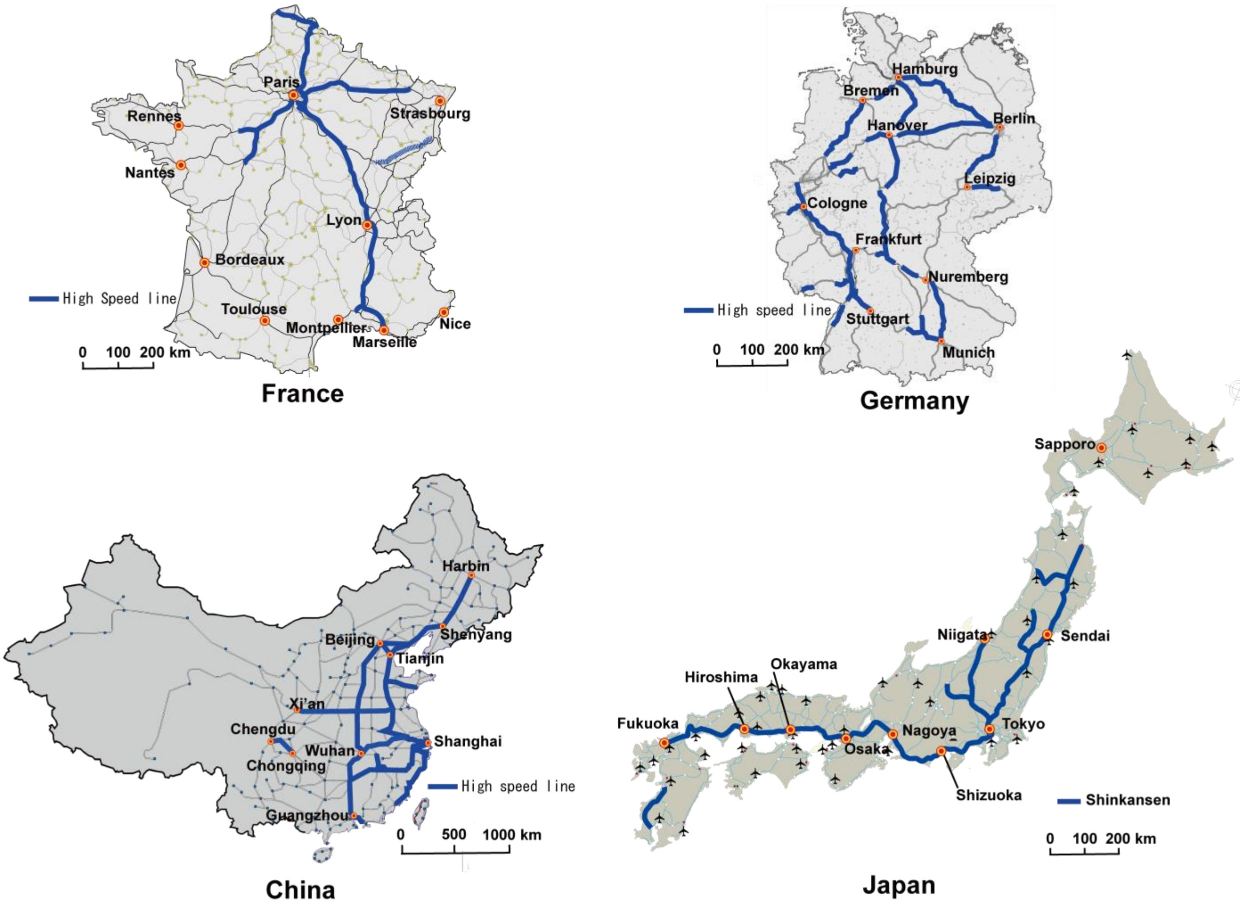


Figure 1 – High-speed rail networks in France, Germany, China and Japan

Concerning the airlines, the deregulation of the air industry in Europe that began in 1987 had some influence on France and Germany. More specifically, if the headquarters of an airline company is in Europe, it can locate a hub not only in its home country, but also in other European countries. This policy has contributed to a well-developed air transportation network throughout Europe. In China, there were 129 airports in 2002, and by 2008, this number had increased to 186. In addition, new airline companies have recently been established and private capital airlines, such as Spring Airlines and Okay Airways, have begun to operate in China. Clearly, the air network in China has improved in terms of available service. In Japan, there were 92 airports as of 2008. With the exception of some of Tokyo's neighboring prefectures, every prefecture has a regional airport, but most of the air routes are between Tokyo and other local cities. If people travel from a local city to another by air, it is often the case that they must transfer at a metropolitan airport.

2.2 Populations

The populations and component ratios of France, Germany, China and Japan are listed in Table 1. The cities within 100 km from a larger city are excluded because the present analysis targets intercity transportation. The data from France and Japan indicate a higher concentration of people in the capital city. The population component ratios of both are over 40%. In Germany, the data for Berlin shows 35.5% as a population component ratio, twice as much as Hamburg, the second largest city. The difference in population between cities in Germany is a little, compared to France and Japan. In China, Shanghai has a larger population than the capital, Beijing. In the case of China, other cities on the list also have large populations, a trend seen throughout the country.

Table 1 – Populations and population component ratios of selected countries

	France			Germany		
Rank	City	Population number	Population component ratio	City	Population number	Population component ratio
1	Paris	2,125,017	43.7%	Berlin	3,386,667	35.5%
2	Marseille	796,525	16.4%	Hamburg	1,704,735	17.9%
3	Lyon	444,852	9.2%	Munich	1,194,560	12.5%
4	Toulouse	390,174	8.0%	Cologne	962,507	10.1%
5	Nice	343,166	7.1%	Frankfurt	643,821	6.8%
6	Nantes	270,474	5.6%	Stuttgart	582,443	6.1%
7	Strasbourg	263,682	5.4%	Bremen	540,330	5.7%
8	Montpellier	225,748	4.6%	Hanover	514,718	5.4%
9	Bordeaux	215,277	4.4%	Leipzig	489,532	5.1%
10	Rennes	206,221	4.2%	Nuremberg	486,628	5.1%

	China			Japan		
Rank	City	Population number	Population component ratio	City	Population number	Population component ratio
1	Shanghai	14,348,535	20.6%	Tokyo	8,489,653	43.4%
2	Beijing	11,509,595	16.5%	Osaka	2,628,811	13.4%
3	Chongqing	9,691,901	13.9%	Nagoya	2,215,062	11.3%
4	Guangzhou	8,524,826	12.2%	Sapporo	1,880,863	9.6%
5	Wuhan	8,312,700	11.9%	Fukuoka	1,401,279	7.2%
6	Tianjin	7,499,181	10.8%	Hiroshima	1,154,391	5.9%
7	Shenyang	5,303,053	7.6%	Sendai	1,025,098	5.2%
8	Xi'an	4,481,508	6.4%	Niigata	785,134	4.0%
9	Chengdu	4,333,541	6.2%	Shizuoka	700,886	3.6%
10	Harbin	3,481,504	5.0%	Okayama	674,746	3.4%

3. METHODOLOGY

3.1 Indices of intercity mobility efficiency

When travelers move from city to city, in one case it might take an hour to reach a destination while in another case it might take three hours to cover the same distance (Figure

2). Intercity mobility efficiency is higher if the transportation service per unit distance is good mobility. We call this index, focusing on individuals, “individual mobility.” However, this does not take the size of the demand for the service, such as populations, into account; the priority of the improvement of transportation services (both travel time and frequency) is usually decided considering the populations of the two cities. This particular index is called “pop mobility.”

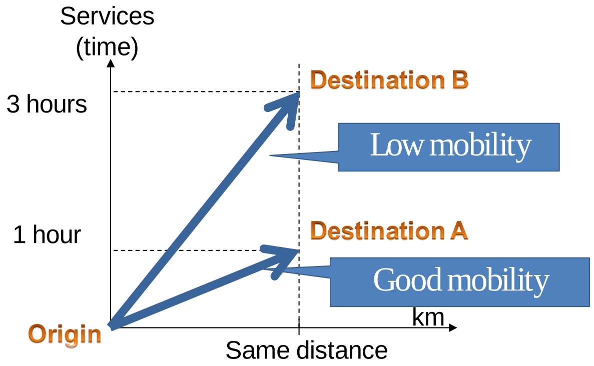
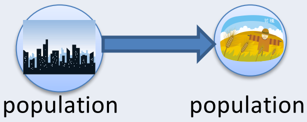


Figure 2 – Comparative indices for intercity mobility

The definition of these two indices is shown in Table 2. Index 1 is the individual mobility, which indicates whether individuals can move between cities at a lower cost and in a shorter amount of time. Index 2, pop mobility, indicates whether the transportation service matches the population size, which helps estimate the potential demands.

Table 2 – Definition of two intercity mobility indices

Indices	Content of estimation	Image
Index 1 Individual mobility	Whether individuals can move between cities at a lower cost and in a shorter time	
Index 2 Pop mobility	Whether the transportation service matches the population	

With these two indices, we attempt to evaluate the regional disparities in intercity mobility, using Data Envelopment Analysis (DEA). Regional disparities in domestic intercity mobility in the four countries can be compared from the results to clarify the convenience level of each intercity transportation service.

3.2 Data envelopment analysis (DEA)

A variation of the basic DEA model is called the Charnes-Cooper-Rhodes (CCR) model (Charnes et al. 1978). CCR is a constant return to scale model. Since the present study regards transportation services as constant returns to scale, the CCR model is adapted. However, the inconsistency of transportation service frequency is well known. The frequency of transportation service is an S-curve against demands; thus, defining transportation services as constant returns to scale is not complete. Therefore, we also use the Banker-Charnes-Cooper (BCC) model (Banker et al. 1984). BCC is an inconstant return to scale model. If the D-value of the BCC and CCR models is the same or nearly the same, it could be said that there are not scale economies. For more details see Charnels (1995).

DEA makes it possible to calculate the efficiency of each DMU as a ratio scale. x_{ij} and y_{rj} are inputs and outputs of the *j*th DMU and $v_i\,(i=1,\cdots,m)$ and $(r=1,\cdots,s)$ are the variable weights to be determined for each DMU. The value of the CCR model can be calculated to solve the following fractional programming equation:

$$\left.\begin{aligned}
&\max \quad h_0=\frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}\\
&subject \quad to:\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}\le 1 \quad ; \quad j=1,\cdots,n,\\
&u_r, v_r \ge 0; \quad r=1,\cdots,s; \quad i=1,\cdots,m;
\end{aligned}\right\} \quad (1)$$

The BCC model differs from the CCR model form only by the addition of the variable $\tilde{u}_0$ in the input orientation and variable $\tilde{v}_0$ in the output orientation. The formulations are given below.

$$\left.\begin{aligned}
&\max \quad \frac{uY_0 + \tilde{u}_0}{vX_0} \\
&subject \quad to: \frac{uY_0 + \tilde{u}_0}{vX_0} \leq 1 \quad ; \quad j = 1, \cdots, n, \\
&u/(vX_0) \geq \varepsilon \cdot \vec{1} \\
&v/(vX_0) \geq \varepsilon \cdot \vec{1}
\end{aligned}\right\} \qquad (2)$$

DEA has some advantages and disadvantages. The first advantage is that DEA is a non-parametric model, so it is not necessary to assume functions, such as that done for regression analysis. Thus, DEA can deal with limited sample data. The second advantage is that DEA can deal with multiple inputs and outputs. On the other hand, one disadvantage is that DEA cannot conduct statistical testing. Another disadvantage is that DEA does not consider a random disturbance term. Therefore, if some data include an error in observation, there is a possibility that the resultant efficiencies are influenced by the error.

The reason for applying DEA on the present analysis is that this study deals with multiple outputs and a large amount of input data on transportation services. Thus, DEA, which is not dependent on sample data, is applied.

The D-value, a result of applying DEA, ranges from 0 to 1. A D-value of “1” indicates the highest efficiency, and anything below 1 indicates lower efficiency.

3.3 Analytical condition

In this analysis, intercity travelers are set as the DMU. That is, if travelers can move a longer distance at a lower fare and in less time, using the transportation service with higher frequency, the mobility efficiency increases (Figure 3).

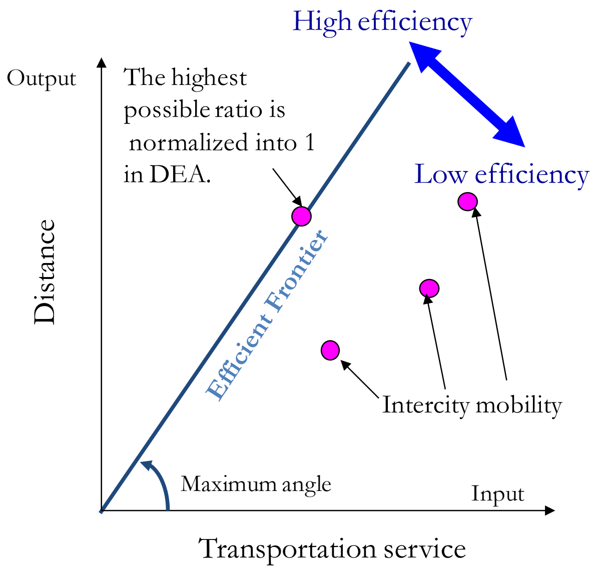


Figure 3 – Comparative indices for intercity mobility

The eight factors chosen as the inputs or the outputs for the analysis are shown in Table 3. These particular inputs (fare, travel time and frequency of train and air services) are introduced, because most travelers want the lowest fare, shortest travel time and shortest waiting time, and these inputs are information that travelers can retrieve prior to their trip. For the outputs, the distance is introduced in the individual mobility index, because the outcome of mobility is measurable in terms of how long individuals can travel given the specific inputs. Population is considered in the pop mobility index. However, the population related intercity transportation includes two cities, the origin city and the destination city. Thus, we introduce two cities in this model by multiplying, based on the concept of the gravity model.

Table 3 – Input/output factors of the indices

Factor of intercity mobility	Individual mobility	Pop mobility	Reference
Train fare	Input	Input	Website of each national rail ways
Minimum travel time by train	Input	Input	Website of each national rail ways
Daily frequency of trains	Input	Input	Website of each national rail ways
Airfare	Input	Input	Website of each national airline
Minimum travel time by flight	Input	Input	OAG Flight Guide
Daily flight frequency	Input	Input	OAG Flight Guide
Populations	-	Output	Website of United Nations
Distance	Output	Output	Calculated from latitude and longitude

4. INTERNATIONAL COMPARISON OF REGIONAL DISPARITIES IN DOMESTIC INTERCITY MOBILITY

4.1 Individual mobility

In the present study, 45 instances of intercity transportation between ten large cities (cities 100 km from a larger city are excluded) in each country are considered.

The results of DEA using the individual mobility index in each country are shown in Table 4. The regional disparity is indicated with its minimum D-value and standard deviation. A minimum D-value indicates the lowest intercity mobility in the respective country; that is, the smaller the minimum D-value is, the wider the regional disparity is. From the standard deviation, the domestic range of disparity can be seen; the smaller the standard deviation is, the narrower the range is.

Examining the results of the CCR model, Germany shows 0.074 as the standard deviation, the smallest disparity of all four countries. In contrast, Japan shows 0.147, the highest standard deviation. This indicates that Japanese intercity mobility has large regional disparity compared to the other three countries. Next, the lowest minimum D-value is 0.271 (Japan): the intercity mobility of this country has the biggest regional disparity of all. The reason that Sendai-Niigata has the smallest D-value is that there is only an indirect path. More specifically, although both Sendai and Niigata have Shinkansen stations, the rail lines go up to Tokyo so that travelers need to transfer to another Shinkansen line at Omiya station, near Tokyo.

Using the BCC model, France shows 0.045 as the standard deviation, the smallest disparity of all. Japan, on the other hand, shows 0.105 as, again, the highest standard deviation. For the minimum D-value, the smallest is of the same section in Japan (0.590).

Focusing on constant returns to scale, Japan and France show differences in the D-values of the CCR and BCC models, indicating the presence of scale economies.

Table 4 – Efficiency data for individual mobility

		France				Germany			
		CCR model		BCC model		CCR model		BCC model	
	Rank	DMU	D-value	DMU	D-value	DMU	D-value	DMU	D-value
Highest intercity mobility	1	Paris—Marseille	1	Paris—Lyon	1	Berlin—Frankfurt	1	Berlin—Hamburg	1
	1	Paris—Toulouse	1	Paris—Strasbourg	1	Berlin—Hanover	1	Berlin—Munich	1
	1	Paris—Nice	1	Paris—Montpellier	1	Hamburg—Munich	1	Berlin—Cologne	1
	1	Marseille—Rennes	1	Paris—Bordeaux	1	Hamburg—Frankfurt	1	Berlin—Stuttgart	1
	1	Toulouse—Nantes	1	Marseille—Lyon	1	Munich—Hanover	1	Berlin—Leipzig	1
	1	Nice—Bordeaux	1	Marseille—Toulouse	1	Munich—Nuremberg	1	Berlin—Nuremberg	1
	1	Nantes—Strasbourg	1	Marseille—Nice	1			Hamburg—Cologne	1
	1	Strasbourg—Montpellier	1	Marseille—Montpellier	1			Hamburg—Bremen	1
	1	Strasbourg—Bordeaux	1	Lyon—Strasbourg	1			Hamburg—Hanover	1
	1			Lyon—Montpellier	1			Hamburg—Nuremberg	1
				More 16 intercity mobility				More 17 intercity mobility	
Low intercity mobility	41	Bordeaux—Rennes	0.643	Marseille—Strasbourg	0.927	Leipzig—Nuremberg	0.779	Hanover—Nuremberg	0.870
	42	Nantes—Rennes	0.627	Lyon—Nantes	0.918	Frankfurt—Stuttgart	0.766	Stuttgart—Bremen	0.863
	43	Marseille—Nice	0.600	Nice—Montpellier	0.843	Bremen—Hanover	0.762	Leipzig—Nuremberg	0.856
	44	Lyon—Nice	0.583	Nice—Strasbourg	0.837	Munich—Stuttgart	0.762	Frankfurt—Stuttgart	0.833
	45	Marseille—Montpellier	0.554	Bordeaux—Rennes	0.825	Hamburg—Leipzig	0.758	Hamburg—Leipzig	0.770
Standard deviation			0.134		0.045		0.074		0.055

		China				Japan			
		CCR model		BCC model		CCR model		BCC model	
	Rank	DMU	D-value	DMU	D-value	DMU	D-value	DMU	D-value
Highest intercity mobility	1	Shanghai—Beijing	1	Beijing—Xi'an	1	Tokyo—Sapporo	1	Tokyo—Osaka	1
	1	Shanghai—Xi'an	1	Chongqing—Wuhan	1	Tokyo—Fukuoka	1	Tokyo—Nagoya	1
	1	Shanghai—Chengdu	1	Chongqing—Chengdu	1	Tokyo—Hiroshima	1	Osaka—Nagoya	1
	1	Beijing—Guangzhou	1	Guangzhou—Wuhan	1	Osaka—Sapporo	1	Osaka—Fukuoka	1
	1	Beijing—Wuhan	1	Wuhan—Xi'an	1	Nagoya—Sapporo	1	Osaka—Sendai	1
	1	Beijing—Tianjin	1	Shenyang—Harbin	1	Nagoya—Fukuoka	1	Osaka—Niigata	1
	1	Beijing—Shenyang	1	Xi'an—Chengdu	1	Sapporo—Fukuoka	1	Osaka—Okayama	1
	1	Beijing—Chengdu	1	Shanghai—Beijing	1	Sapporo—Hiroshima	1	Nagoya—Niigata	1
	1	Beijing—Harbin	1	Shanghai—Xi'an	1	Fukuoka—Sendai	1	Sapporo—Sendai	1
	1	Chongqing—Shenyang	1	Shanghai—Chengdu	1	Fukuoka—Okayama	1	Sapporo—Niigata	1
		More 8 intercity mobility		More 15 intercity mobility		More 2 intercity mobility		More 15 intercity mobility	
Low intercity mobility	41	Chongqing—Guangzhou	0.748	Shanghai—Shenyang	0.876	Osaka—Shizuoka	0.701	Sendai—Shizuoka	0.797
	42	Wuhan—Xi'an	0.748	Wuhan—Tianjin	0.863	Osaka—Nagoya	0.686	Hiroshima—Niigata	0.727
	43	Chongqing—Xi'an	0.744	Tianjin—Xi'an	0.854	Niigata—Okayama	0.625	Niigata—Shizuoka	0.663
	44	Chongqing—Wuhan	0.743	Chongqing—Tianjin	0.845	Niigata—Shizuoka	0.579	Niigata—Okayama	0.662
	45	Shanghai—Wuhan	0.708	Tianjin—Chengdu	0.845	Sendai—Niigata	0.271	Sendai—Niigata	0.590
Standard deviation			0.095		0.053		0.147		0.105

4.2 Pop mobility

The results of DEA using the pop mobility index of each country are shown in Table 5. In the results for the CCR models, Germany shows 0.047 as the standard deviation and 0.818 as the minimum D-value. Both scores are the smallest of the four countries; identical to the results of individual mobility. In contrast, France shows 0.110 as the standard deviation and 0.607 as the minimum D-value. Both scores are the highest of all. In France, the scores of the sections between cities with small populations turn out to be 1 from the individual mobility index, while those between the cities with mid-sized populations show low mobility. It could be said that although the former sections have smaller populations than the latter, both sections have an identical level of train and air services.

In the analyses using the BCC model, France shows 0.030 as the standard deviation, showing the smallest disparity of the four countries. In China, the highest minimum D-value of all the sections is 0.845. Japan shows 0.055 as the standard deviation and 0.740 as the minimum D-value, indicating the highest disparity of the four countries.

Focusing on constant returns to scale, all countries show a small difference in the D-value of the CCR and BCC models. Germany, especially, indicates a smaller difference. In this case, scale economies are not present.

Table 5 – Efficiency data for pop mobility

		France				Germany			
		CCR model		BCC model		CCR model		BCC model	
	Rank	DMU	D-value	DMU	D-value	DMU	D-value	DMU	D-value
Highest intercity mobility	1	Paris—Marseille	1	Paris—Lyon	1	Berlin—Leipzig	1	Berlin—Hamburg	1
	1	Paris—Toulouse	1	Paris—Strasbourg	1	Hamburg—Nuremberg	1	Berlin—Munich	1
	1	Paris—Nice	1	Marseille—Lyon	1	Munich—Cologne	1	Berlin—Cologne	1
	1	Paris—Montpellier	1	Marseille—Toulouse	1	Munich—Bremen	1	Berlin—Stuttgart	1
	1	Paris—Bordeaux	1	Marseille—Nice	1	Cologne—Bremen	1	Berlin—Nuremberg	1
	1	Marseille—Rennes	1	Marseille—Montpellier	1	Cologne—Hanover	1	Hamburg—Cologne	1
	1	Lyon—Montpellier	1	Lyon—Toulouse	1	Frankfurt—Bremen	1	Hamburg—Bremen	1
	1	Lyon—Bordeaux	1	Lyon—Nantes	1	Frankfurt—Hanover	1	Hamburg—Hanover	1
	1	Toulouse—Nantes	1	Lyon—Strasbourg	1	Frankfurt—Leipzig	1	Munich—Frankfurt	1
	1	Toulouse—Strasbourg	1	Toulouse—Montpellier	1	Frankfurt—Nuremberg	1	Cologne—Stuttgart	1
		More 13 intercity mobility		More 24 intercity mobility		More 14 intercity mobility		More 27 intercity mobility	
Low intercity mobility	41	Nice—Montpellier	0.766	Lyon—Nice	0.952	Frankfurt—Stuttgart	0.897	Munich—Stuttgart	0.950
	42	Paris—Rennes	0.738	Marseille—Nantes	0.952	Berlin—Nuremberg	0.894	Cologne—Nuremberg	0.928
	43	Lyon—Nice	0.642	Marseille—Strasbourg	0.927	Hamburg—Bremen	0.892	Berlin—Bremen	0.916
	44	Marseille—Montpellier	0.627	Nice—Strasbourg	0.917	Munich—Stuttgart	0.858	Cologne—Frankfurt	0.901
	45	Marseille—Nice	0.607	Nice—Montpellier	0.843	Hamburg—Leipzig	0.818	Hamburg—Leipzig	0.820
Standard deviation			0.110		0.030		0.047		0.034

		China				Japan			
		CCR model		BCC model		CCR model		BCC model	
	Rank	DMU	D-value	DMU	D-value	DMU	D-value	DMU	D-value
Highest intercity mobility	1	Shanghai—Beijing	1	Chongqing—Wuhan	1	Tokyo—Sapporo	1	Tokyo—Osaka	1
	1	Shanghai—Xi'an	1	Chongqing—Chengdu	1	Tokyo—Fukuoka	1	Tokyo—Nagoya	1
	1	Shanghai—Chengdu	1	Guangzhou—Wuhan	1	Tokyo—Hiroshima	1	Tokyo—Sapporo	1
	1	Beijing—Guangzhou	1	Wuhan—Xi'an	1	Osaka—Sapporo	1	Tokyo—Fukuoka	1
	1	Beijing—Wuhan	1	Shenyang—Xi'an	1	Osaka—Sendai	1	Tokyo—Hiroshima	1
	1	Beijing—Tianjin	1	Xi'an—Harbin	1	Nagoya—Sapporo	1	Tokyo—Sendai	1
	1	Beijing—Shenyang	1	Shanghai—Beijing	1	Nagoya—Fukuoka	1	Osaka—Nagoya	1
	1	Beijing—Xi'an	1	Shanghai—Xi'an	1	Sapporo—Fukuoka	1	Osaka—Sapporo	1
	1	Beijing—Chengdu	1	Shanghai—Chengdu	1	Sapporo—Hiroshima	1	Osaka—Fukuoka	1
	1	Beijing—Harbin	1	Beijing—Guangzhou	1	Sapporo—Sendai	1	Osaka—Sendai	1
		More 13 intercity mobility		More 19 intercity mobility		More 10 intercity mobility		More 24 intercity mobility	
Low intercity mobility	41	Chongqing—Chengdu	0.784	Shanghai—Shenyang	0.876	Osaka—Okayama	0.785	Nagoya—Okayama	0.910
	42	Chongqing—Xi'an	0.776	Tianjin—Chengdu	0.867	Tokyo—Shizuoka	0.772	Sendai—Shizuoka	0.858
	43	Chongqing—Guangzhou	0.767	Wuhan—Tianjin	0.863	Hiroshima—Niigata	0.738	Tokyo—Niigata	0.853
	44	Chongqing—Wuhan	0.752	Tianjin—Xi'an	0.854	Osaka—Shizuoka	0.716	Osaka—Shizuoka	0.824
	45	Shanghai—Wuhan	0.708	Chongqing—Tianjin	0.845	Osaka—Nagoya	0.686	Hiroshima—Niigata	0.740
Standard deviation			0.089		0.052		0.088		0.055

4.3 Conclusions on analyses of individual and pop mobility

Results of these analyses (individual mobility and pop mobility) clarify that Japan, scoring the worst in all of the categories except pop mobility using CCR, has the biggest regional disparity of the four countries examined in the present study. This indicates that individuals in Japan cannot move between cities at lower costs and in shorter amounts of time and that its transportation services do not match the population size.

5. COMPARING MAIN INTERCITY TRANSPORTATION CONVENIENCE OF EACH COUNTRY

Although the data in Section 4 show the actual state of the intercity mobility of each country, the differences of economical conditions or monetary values are not taken into account; that is, the data are efficient in investigating the domestic situations. Here, for the international comparison, we introduce PPP (Purchasing Power Parity) to convert the train- and airfare, for analysis using one criterion.

The frequency distribution of the D-value by individual and pop mobility, using and modifying the CCR scores of each section in Tables 4 and 5 is shown in Figure 4. As for the individual mobility, all sections in Germany are close (0.4–0.9) while there are no scores of 1. The data from France has a similar shape but exhibit a higher level than those of Germany. In Japan, the largest value is between 0.8 and 0.9, and there is a larger distribution in the higher levels, the lowest of all the sections in the four countries is in Japan (0.255). This means that the intercity mobility between big cities in Japan is generally high compared to the other countries, but intercity mobility between local cities has the lowest level. The scores for China are the highest in all four categories; this may be because the air and train fare is lower in PPP than the other countries.

For pop mobility, Germany, China and Japan show the same tendency as that of individual mobility. For France, though, the shape is different from that of the individual mobility. Specifically, the numbers gradually increase toward 1 and the transportation services exhibit levels similar to those of China and Japan when considering the population.

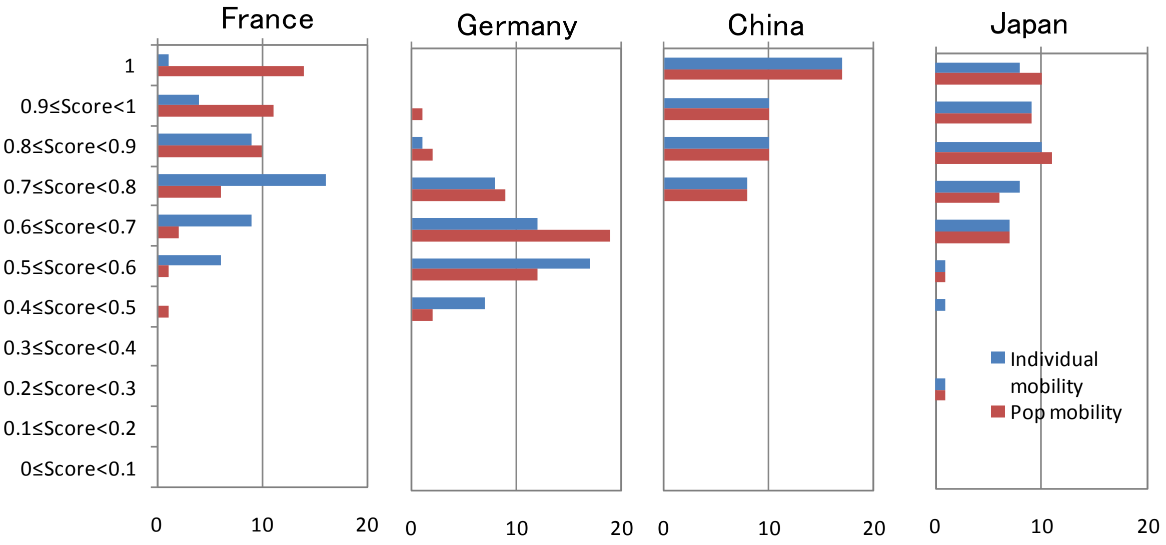

France
Germany
China
Japan

Figure 4 – Frequency distribution of intercity mobility score

6. CONCLUSIONS

In the present study, mobility efficiency indices of public intercity transportation services were proposed, and the regional mobility disparities through the comparison of four countries were analyzed. From the results, the disparities and the characteristics of the intercity mobility can be clarified as follows:

- For individual mobility, Japan shows the biggest disparity in intercity mobility. This is because some intercity services between local cities do not have direct high-speed railways or air routes.
- For pop mobility, Japan and France show big disparities in intercity mobility. In these two countries, the populations, as well as public transportation, are concentrated in the capital cities. Thus, intercity mobility between cities with mid-sized populations decreases.
- It appears that if the disparities are to be narrowed, public transportation networks should deviate from the hub-and-spoke system as seen in Japan and France, and use a more interconnected system as seen in Germany and China.
- In Japan, the intercity mobility between main cities, such as Tokyo and Osaka or Tokyo and Fukuoka, is higher, while that between local cities, such as Sendai and Niigata or Niigata and Shizuoka, is lower. Concerning the other countries examined in this study, Germany does not exhibit high levels of mobility, but most intercity transportation shows nearly identical mobility levels. In future developments, if the maglev trains are built connecting Tokyo and Osaka, the disparities in intercity mobility in Japan will widen.

Using our proposed methodology, it may be possible to evaluate policies for improving high-speed railways, air services and other public transportation. This will be investigated more closely in future studies. Moreover, to allow for a broader comparison it will be necessary to include more cities and countries.

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REFERENCES

Amano, K., Nakagawa, D., Kato, Y. and Hatoko, M. (1991). A study on Definition of Travelling Time for Inter City Traffic. Infrastructure Planning Review, Vol. 9, 69–76. (In Japanese)

Anderson, W. P., Gong, G. and Lakshmanan, T. R. (2002). Geographical Variation in Cost of Air Travel. Analysis of the Domestic Airline Fares Consumer Report. Transportation Research Record, No. 1788, 13–18.

Aratani, T. and Todoroki, T. (2009a). Analysis of Regional Disparities in Intercity Mobility in Japan. Proceedings of the Eastern Asia Society for Transportation Studies Vol. 7. CD-ROM.

Aratani, T., Todoroki, T. and Kaneko Y. (2009b). An Analysis of Regional Disparity on Intercity Mobility by Public Transportation Service. Infrastructure Planning Review, Vol. 26, 807–816. (In Japanese)

Banker, R. D., Charnes, A. and Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science 30, 1078–1092.

Charnes, A., Cooper, W. W. and Rhodes, E. (1978). Measuring the efficiency of decision-making units. European Journal of Operational Research, Vol. 2, 429–444.

Charnels, A. (1995). Data Envelopment Analysis, Theory, Methodology and Application. Kluwer Academic Pub.

Eitoku, Y. and Mizokami, S. (2008). A Method on Evaluation of Differences in QoM among Regions. Infrastructure Planning Review, Vol. 25, 109–119. (In Japanese)

Fernandes, E. and Pacheco, R. R. (2002). Efficient Use of Airport Capacity. Transportation Research Part A, Vol. 36, 225–238.

Graham, D. J. (2008). Productivity and efficiency in urban railways. Parametric and non-parametric estimates, Transportation Research Pert E Vol. 44, No. 1, 84–99.

Hazemoto, J., Tsukai, M. and Okumura, M. (2003). Evaluation of Rail/Air Network Considering Alternate Paths. Infrastructure Planning Review, Vol. 20, 255–260. (In Japanese)

Kamioka N. (2008). Framework for quantification of the Association for the Research of Transportation Problems and Human Rights. Conference of Association for the Research of Transportation Problems and Human Rights 2008, 21–27. (In Japanese)

Kaneko, Y. and Kato, H. (2005). Review of Studies for Inter-Urban Transportation in Japan. Proceedings Infrastructure Planning, Vol. 31, Japan Society of Civil Engineers. (In Japanese)

Kato, H. (2006). Nonlinearity of the Utility Function and the Value of Travel Time Savings: Empirical analysis of interregional travel mode choice of Japan. Proceedings of European Transport Conference 2006.

Kikuchi, T., Nakagawa, D. and Oba, T. (2008). Study on effects of the Interurban Transportation in Consideration of Frequency on Region's Growth and National land Structure. Journal of the City Planning Institute of Japan, No 43-3, 247–252. (In Japanese)

Knapp, S. F. and Laga, A. M. (1983). Results of a parametric cost analysis of differences between urban and rural transportation services for transportation-disadvantaged persons. Transportation Research Record, No. 934, 1–8.Mori, T., Arakawa, E., Horie, M. and Kumamoto, Y. (2000). Development of evaluation methods for level of transportation services. Proceedings of Infrastructure Planning, No. 23 (2), 239–242. (In Japanese)

Nakagawa, D., Hatoko, M., Itoh, T. and Nishizawa, Y. (1998). A study on the Piled-up Traveling-Time as an Accessibility Index of International Transportation. Journal of Infrastructure Planning and Management, No. 590 iv-39, 43–50. (In Japanese)

Nanthawicht, C., Satoh, K. and Kishi K. (2005). Comprehensive Evaluation of Transportation Infrastructure Systems Efficiency Using Data Envelopment Analysis. Journal of the Eastern Asia Society for Transportation Studies Vol. 6, 573–585.

Nomura, T., Aoyama, Y., Nakagawa, D., Matsunaka, R. and Shirayanagi, H. (2001). The Evaluation of the Benefit of the Intercity High-speed Train Project Using the EVGC. Infrastructure Planning Review, Vol. 18, 627–636. (In Japanese)

Tozaki H. (2008). Schemes of historic development of deregulation and public administration. Conference of Association for the Research of Transportation Problems and Human Rights 2008, 1–8. (In Japanese)

Yamaguchi K. and Maku R. (2003). Inter-prefecture Accessibility and Macro Economic Productivity in Japan. Annual Report on transportation Economics 2003, 9–20. (In Japanese)

Wardman, M. (1994). Forecasting the Impact of Service Quality Changes on the Demand for Inter-urban Rail Travel. Journal of Transport Economics and Policy, Vol. 28, 287–306.