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Estimation of Road User's Value of Travel Time Savings Using Large-Scale Household Survey Data from Japan

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Abstract. This paper uses a large Japanese database to empirically estimate road users' value of travel time saving (VTTS). The results of parameter estimation show that the estimated VTTS of business travel is nearly equal to the average wage rate in Japan whereas the estimated VTTSs of home-to-workplace and personal travels are lower than the estimated VTTS of business travel; VTTS increases with the trip length; estimated VTTSs during 8:00 and 10:59 and 18:00 and 19:59 are higher than those during other periods; estimated VTTSs of individuals in their 20s and in their 60s are lower than those of individuals in other age groups; estimated VTTS of males is similar to that of females; estimated VTTS per vehicle when driving alone is higher than the estimated VTTS per vehicle in drive with passenger(s); and estimated VTTS of production/transport workers is lower than the estimated VTTSs of other jobs.

Keywords. Value of travel time saving, route choice, expressway, Japan

INTRODUCTION

Generally, expressways provide road users with high-quality service by reducing traffic congestion to reduce travel time and providing safer driving conditions. These benefits encourage drivers to choose the expressway rather than ordinary roads although they are required to pay toll. With increasing consumer demand for high-speed, high-quality, but high-priced road services, nationwide expressway networks have been developed in many regions. Toll charge has been one of the most important issues in expressway planning. The user's willingness to pay (WTP) for saving travel time by using an expressway service could be one of the most important factors when examining toll charges for expressways. As Hensher and Goodwin (*1*) noted, the value of travel time savings (VTTS) has recently been utilized to estimate the toll charge; here, the important issue is not the hypothetical WTP, but the actual money paid. However, thus far, the VTTS has not worked well for determining the toll charge of an expressway service in Japan. One of its reasons is because the VTTSs have not been well analyzed with the empirical data in Japan.

In Japan, the cost-benefit analysis guideline for road projects in Japan sets the overall framework of project evaluation including the VTTS (Morisugi, *2*). It shows that the VTTS is determined on the basis of the average wage rate for the entire nation. The average-wage-rate approach is applied, not only to business travel, but also to non-business travel. Although the VTTS estimates based on the average wage rate could be used for approximations of the WTP values for saving time in business travel, this may not be the case for non-business travel (Small and Verhoef, *3*). Thus, there is a great need to estimate the VTTSs on the basis of the preference data of travelers. The guideline also assumes that the VTTSs do not vary based on the trip distance or departure time. However, past studies in other countries, such as Mackie et al. (*4*) and Axhausen et al. (*5*), have shown that the VTTS changes as the trip distance increases. The VTTSs could also vary based on the departure time. This is partly because the traffic conditions including the traffic congestion could vary among the time of a day. For example, the guideline of VTTS in UK (Department for Transport, *6*) shows that the VTTSs vary among the time of a day. Although several studies have estimated the national VTTSs empirically in Japan, these have not been estimated in the context of the route choice in the road network, but rather in the context of the modal choice (Kato and Onoda, 7) or urban rail route choice (Kato, *8*).

This paper empirically estimates the VTTSs in a choice context where the expressway service is chosen or not in Japan. Rather than push the state of the art in discrete choice modeling, this paper contributes to the discussions on the VTTSs used for the project evaluation and the toll setting of expressways in Japan. To our knowledge, this is the first report that uses national-level revealed preference data from Japan to estimate the VTTS for road users in the context of choosing the expressway service. The paper is organized as follows: the first section shows the research motivation and goals. Next, the analytical method and data used for the empirical analysis will be presented. Then, the empirical analysis will be presented. The policy implications are discussed on the basis of the analysis results. Finally, the findings of the empirical analysis are summarized, and further research issues are presented.

APPROACH

Three major approaches are used for empirically estimating the VTTSs for road users. The first is the stated choice approach (Louviere et al., *9*). It typically involves asking an individual to compare the given times and costs of a current route with a proposed toll road. The VTTSs are estimated with a discrete-choice type model such as the logit, probit, or mixed choice models (Hensher, *10*; *11*). Unfortunately, no national survey data for the stated choices are available in the context of road route choice in Japan. The second approach is the meta-analysis approach. Wardman (*12*, *13*) analyzed the characteristics of VTTSs using about 1000 data sets collected from UK studies on urban and interurban travel choices. Kato et al. (*14*) also reported the results of a VTTS meta-analysis that used 216 VTTSs estimated during the past decades in Japan. However, the implications of this meta-analysis of the VTTS for road users may be limited since few studies have evaluated the time saving of road use in Japan. The third approach involves estimating the VTTS base on the revealed preference data from road users. This typically includes the route choice from an origin to a destination. This paper applies this third approach to the estimation of the national VTTS for road users in Japan. The dataset from a large-scale car-use trip survey, the Road Traffic Census, is used for the empirical estimation. It includes over 4,436,000 car-use trips covering the entire nation collected using a paper-based in-person interview survey. The Road Traffic Census has been mainly used for traffic assignment to forecast future traffic demands. No study has attempted to estimate the VTTS empirically using this dataset. Because the dataset includes an origin, destination, start point for using an expressway, and end point for using the expressway, the route used by the individual who chose the expressway service can be identified with a high accuracy. Thus, it is expected to provide useful information for estimating the VTTS with a route choice analysis.

A simple binary logit model (*15*) is used for the route choice analysis to estimate the VTTSs. It is assumed that there are two route options from a given origin to a given destination for any observed trip: an "expressway route" that includes both ordinary road links and expressway links and a "no-expressway route" that includes only ordinary road links. Two types of models are used: a model that utilizes all of the samples in the dataset and one that utilizes subgroups of samples from the dataset.

First, it is assumed that an individual maximizes his/her utility function subject to the constraints of monetary budget and time budget. Suppose the individual faces a discrete choice of routes from a given choice set with a fixed pair of an origin and a destination. Then, the individual maximizes his/her utility function under the condition that a specific route is chosen. It is assumed that the conditional indirect utility function for the model that uses all of the samples in the dataset is identified as follows:

$$v_{i,n} = \theta_c C_{i,n} + \left(\theta_t + \sum_j \theta_{tj} X_{i,j,n} \right) T_{i,n} + \varepsilon_{i,n} \tag{1}$$

where $v_{i,n}$ is the indirect utility function of an individual, n, under the condition that route option i is chosen, $C_{i,n}$ is the travel cost of route option i of individual n, $T_{i,n}$ is the travel time of route option i of individual n, $\varepsilon_{i,n}$ is the error component of route option i of individual n, $X_{i,j,n}$ is the j th variable of route option i of individual n, θ_c is the travel cost parameter, θ_t is the travel time parameter, and θ_{tj} is the parameter of the j th variable relating to the travel time.

The weighted likelihood maximization procedure is used for the parameter estimation because the sampling rate varies among zones in the survey. Let n_m be a respondent whose vehicle is registered at zone m. The weight of the individual, n_m, is defined as follows:

$$\omega_{n_m} = \frac{H_m}{N_m} \tag{2}$$

where N_m is the number of respondents at zone m and H_m is the number of registered vehicles at zone m. Then, the log-likelihood function is defined as

$$\ln L = \sum_{n_m} \sum_i \omega_{n_m} \cdot \delta_{i,n_m} \cdot \ln P_{i,n_m} \tag{3}$$

where δ_{i,n_m} is equal to 1 if individual n_m chooses route option i and is 0 otherwise; and P_{i,n_m} is the probability that individual n_m chooses route option i. As the binary logit model is assumed, the probability is shown as $P_{i,n_m} = 1 / \left(1 + \exp\left(v_{j,n_m} - v_{i,n_m}\right)\right)$.

Next, in the same way as the above model, the conditional indirect utility function in the model estimated using subgroups of samples from the dataset is assumed to be as follows:

$$v_{i,n_k} = \theta_{c,k} C_{i,n_k} + \theta_{t,k} T_{i,n_k} + \varepsilon_{i,n_k} \tag{4}$$

where v_{i,n_k} is the indirect utility function of an individual belonging to subgroup k under the condition that route option i is chosen, C_{i,n_k} is the travel cost of route option i for an individual belonging to subgroup k, T_{i,n_k} is the travel time of route option i for an individual belonging to subgroup k, ε_{i,n_k} is the error component of route option i for an individual belonging to subgroup k, $\theta_{c,k}$ is the travel cost parameter of subgroup k, and $\theta_{t,k}$ is the travel time parameter of subgroup k. Again, the weighted likelihood maximization procedure is used for estimating the parameters of each subgroup of the sample dataset.

Then, the VTTS is estimated using $VTTS = \left(\theta_t + \sum_j \theta_{tj} X_{i,j,n} \right) \Big/ \theta_c$ from the model estimated using all of the samples in the dataset, while the VTTS of a subgroup is estimated using $VTTS_k = \theta_{t,k} / \theta_{c,k}$ from the model estimated using a subgroup of the dataset. In the empirical analysis shown later, the travel cost is assumed to be equal to the toll charge if the route includes the expressway service, while it is equal to 0 if the route does not include any expressway service. This means that the estimated VTTSs are regarded as the estimated values for the WTP for saving travel time by choosing the expressway service. It should be noted that no other costs such as for fuel and maintenance are included in the travel cost. This is because of the difficulties in estimating these costs for an individual trip. Because the differences in the fuel cost and maintenance cost resulting from using one route instead of the other are expected to be very small in the context of fuel/maintenance market in Japan, the impact of these costs on the route choice should be insignificant.

DATA

Original travel data

The empirical analysis will use the 2005 Road Traffic Census Data. This survey was conducted in 2005 by the governments of prefectures and major cities under the supervision of the Ministry of Land, Infrastructure, Transport and Tourism of Japan. This data includes two types of origin-destination (O-D) surveys: an O-D survey based on intercept interviews with drivers crossing given survey points and an O-D survey based on household interviews with vehicle owners. Our empirical analysis uses the vehicle-owner-based O-D survey data. This survey covered the entire nation. It includes information about three types of vehicles, i.e., including private vehicles, privately owned business vehicles, and private trucks; it covers both weekdays and weekends. Surveyors visited households that were randomly selected from an official list of vehicle owners and interviewed individuals about their vehicle use. The survey data includes the vehicle-use travel episodes of any vehicle in an interviewed household on a given survey day and contains information about the origin, destination, departure time, arrival time, number of persons in the vehicle, travel purpose, and origin/destination interchanges in the case of expressway use. It also lists the types of vehicles owned, locations of registered vehicles, household attributes such as the number of people in the household and the vehicle ownership, and the attributes of individual drivers such as their age, gender, and job type. The travel purposes are categorized into the following six types: home-to-workplace travel, home-to-school travel, workplace/school/others-to-home travel, pick-up travel, personal travel, and business travel. Personal travel includes travel for shopping, travel for carrying out maintenance activities, travel for dining, travel for daily leisure, travel for leisure with overnight stay, travel for visiting relatives/friends, travel for driving, and travel for private lessons. Business travel excludes the travel for transporting the business goods or cargos.

Level-of-service data

The level-of-service data including the travel distance, travel time, and travel cost are prepared for the empirical analysis. First, a zoning system and a nationwide road network were prepared. The entire nation is assumed to be covered by 6 795 zones. The road network including prefectural roads, national roads, and expressways is used on the basis of the Digital Road Map Database in Japan (Japan Digital Road Map Association). The DRM database was created on the basis of the 1:25,000 topographical maps issued by the Geographic Survey Institute, Japan.

Next, link-based level-of-service data for all links in the network was prepared. First, in the case of the link-based link length, the length of links shown in the Digital Road Map Database was applied to the road network. Next, the link-based travel time was estimated using the following BPR function:

$$t(x_l) = \frac{L_l \cdot 60}{V_l^o}\left\{1+\alpha\left(\frac{x_l}{C_l}\right)^{\beta}\right\} \tag{5}$$

where $t(x_l)$ is the travel time of link l under the link flow x_l (min), L_l is the length of link l (km), V_l^o is the free-flow travel speed (km/h), C_l is the capacity of link l, and α and β are the parameters. Japan Society of Civil Engineering (*16*) was followed; it proposes $\alpha = 0.48$ and $\beta = 2.82$ on the basis of the observed travel data in Japan. To estimate the free-flow travel speed of each link, the observed link flows and the observed travel speed that were collected in the 2005 Road Traffic Census were used. The following equation is satisfied during peak hours:

$$\frac{L_l \cdot 60}{V_l^C} = \frac{L_l \cdot 60}{V_l^o}\left\{1+\alpha\left(\frac{x_l^C}{C_l}\right)^{\beta}\right\} \tag{6}$$

where V_l^C is the travel speed during peak hours, and x_l^C is the link flow during peak hours. Thus, the free-flow travel speed is derived as follows:

$$V_l^o = V_l^C\left\{1+\alpha\left(\frac{x_l^C}{C_l}\right)^{\beta}\right\} \tag{7}$$

The estimated free-flow travel speed of a link $\hat{V}_l^o$ and the maximum speed of the link required by the traffic regulation, $\overline{V}_l^o$, are adjusted as follows if $\hat{V}_l^o$ is higher than $\overline{V}_l^o$:

$$V_l^o = \hat{V}_l^o \qquad \text{if} \quad \hat{V}_l^o \le \overline{V}_l^o + 50 \tag{8a}$$

$$V_l^o = \hat{V}_l^o + 50 \qquad \text{if} \quad \hat{V}_l^o > \overline{V}_l^o + 50 \tag{8b}$$

The traffic regulation in Japan imposes penalties on the drivers who drive at the maximum speed or higher in that, particularly, the drivers lose their driving licenses if they drive at speeds higher than the maximum speed plus 50 km/hr. Finally, the link travel time is estimated in the following two cases: the first case is the travel during peak hours, and the second case is the travel during off-peak hours. The link travel time of peak hours is applied to the trip whose departure time belongs to the peak hours, whereas the link travel time of off-peak hours is applied to the trip whose departure time belongs to the off-peak hours. It is noted that the original dataset contains data on whether a trip was made during the peak hours or not. It should be noted that a long-distance journey may cover both the peak hours and off-peak hours even if its departure time belongs to the peak or off-peak hours. The results show that the correlation of the total travel time estimated with the estimated link travel time versus that estimated with the observed departure time and arrival time is over 0.999. This may mean that the accuracy of estimating the link travel time is high enough to be used for the model estimation. Finally, with regard to the link-based travel cost, it is assumed that the only travel cost incurred by the drivers is the toll charge for using the expressway service. Although they also incur the fuel cost for driving, this cost is not taken into account. This is mainly because it is difficult to precisely evaluate the energy efficiency of a vehicle. The fare tables provided by expressway operators are used for cost calculation. In Japan, the cost of most of the inter-urban expressway services includes an initial charge plus 24.6 yen per kilometer.

Next, route-based level-of-service is prepared on the basis of link-based level-of-service. First, if an observed trip made by an individual used a route including only an ordinary road link, the expressway route of the individual is identified by searching the minimum-travel-time route in the road network whereas the no-expressway route of the individual is identified by searching the minimum-travel-time route in the road network without an expressway link. Next, if an observed trip made by an individual used a route including both the ordinary road links and the expressway links, the expressway route of the individual is identified by searching the minimum-travel-time route under the condition that the observed expressway links are included in the route whereas the no-expressway route of the individual is identified by searching the minimum-travel-time route in the road network without the expressway link. It should be noted that the travel data includes the origin/destination interchange of expressway, if the trip uses the expressway service.

Sample travel data

Sample-based travel datasets are constructed by the following steps. First, this paper covers home-to-workplace travel, business travel, and personal travel. It excludes the home-to-school travel and pick-up travel because the size of sample data regarding the choice of the expressway route in these cases is much smaller than that of sample data regarding the choice of the expressway route for other travel types. The sizes of sample data regarding the choice of the expressway route in the home-to-school travel and pick-up travel are 31 and 336, respectively, whereas those of sample data regarding the choice of the expressway route in the home-to-workplace, business, and personal travels are 2 774, 1 130, and 2 083, respectively. This paper also excludes the workplace/school/others-to-home travel because the original dataset does not distinguish workplace-to-home travel from personal- or business-to-home travel.

Next, the intra-zone trips; the trips whose origin, destination, vehicle type, or travel purpose is not available; and the trips including ferry-use are eliminated from the original dataset. The reason for eliminating the intra-zone trips is first that the accuracy of travel data is not sufficiently high for a short-travel-time trip and second that the expressway-way use of the intra-zone trips is expected to be too rare. The reason for eliminating the ferry-use trips is that our empirical analysis highlights the individual's choice of using expressway or not rather than the modal choice. The trips to and from the Shikoku Island are also eliminated from the dataset. The reason for this is that the travelers cannot choose a no-expressway route to and from the Shikoku Island because the Shikoku Island is connected with the Honshu Main Island only by expressways.

Finally, the trips that were made by the individuals whose route choice set have only the no-expressway route were eliminated. For example, an individual who resides very far from the expressway or an individual who travels to a destination that is very far from the nearest expressway interchange may not take the expressway route into consideration.

The results show that the choice rate of the expressway route increases as the travel time of the expressway route becomes less than that of the no-expressway route when the time difference is between –20 min and 70 min, whereas the choice rate does not vary over the time difference when the time difference is less than –20 min or from 70 min to 120 min. The choice rates vary in the subgroups whose time difference is greater than 120 min, mainly because the data sizes in those subgroups are extremely small. The above results suggest that the expressway route is one of the route options for individuals when the time difference is between –20 min and 70 min. Therefore, the trips whose time difference was less than –20 min or over 70 min were eliminated.

As a result of data screening, 146 409 samples were obtained, including 82 262 samples for home-to-work travel, 12 363 samples for business travel, and 51 784 samples for personal travel. TABLE 1 summarizes the descriptive statistics of the sample dataset. First, 77.2% of the home-to-workplace trips are made by males, while 85.6% of the business trips and 61.6% of the personal trips are made by males. These indicate that the majority of car drivers are males in car-use travels. Second, the share of home-to-workplace, business, and personal trips made

TABLE 1: Descriptive statistics of sample dataset

		Home-to-workplace						Business						Private					
		Exp.	%	No-Exp.	%	Total	%	Exp.	%	No-Exp.	%	Total	%	Exp.	%	No-Exp.	%	Total	%
Gender	Male	2,352	3.7	61,164	96.3	63,516	77.2	1,022	9.7	9,561	90.3	10,583	85.6	1,588	5.0	30,333	95.0	31,921	61.6
	Female	422	2.3	18,324	97.7	18,746	22.8	108	6.1	1,672	93.9	1,780	14.4	495	2.5	19,368	97.5	19,863	38.4
Job	Agriculture	34	2.4	1,379	97.6	1,413	1.8	30	9.8	276	90.2	306	2.6	95	4.4	2,086	95.6	2,181	7.7
	Production/Transport	298	2.0	14,843	98.0	15,141	19.0	64	9.1	640	90.9	704	5.9	114	3.7	2,961	96.3	3,075	10.9
	Retailing/Service	607	3.4	17,302	96.6	17,909	22.5	384	8.6	4,081	91.4	4,465	37.3	393	5.1	7,284	94.9	7,677	27.1
	Office work/Technology	1,169	3.9	28,846	96.1	30,015	37.6	384	10.7	3,189	89.3	3,573	29.9	357	4.6	7,452	95.4	7,809	27.6
	Others	593	3.9	14,658	96.1	15,251	19.1	250	8.6	2,666	91.4	2,916	24.4	332	4.4	7,221	95.6	7,553	26.7
Age	20 - 29	193	1.7	11,441	98.3	11,634	14.5	43	8.3	478	91.7	521	4.4	123	3.4	3,545	96.6	3,668	8.2
	30 - 39	615	3.6	16,509	96.4	17,124	21.3	159	10.2	1,393	89.8	1,552	13.1	251	3.6	6,683	96.4	6,934	15.4
	40 - 49	781	3.9	19,488	96.1	20,269	25.2	303	10.7	2,524	89.3	2,827	23.9	338	3.9	8,282	96.1	8,620	19.2
	50 - 59	866	3.6	23,154	96.4	24,020	29.9	399	8.7	4,206	91.3	4,605	39.0	533	4.4	11,466	95.6	11,999	26.7
	60 -	272	3.7	7,134	96.3	7,406	9.2	191	8.3	2,116	91.7	2,307	19.5	628	4.6	13,113	95.4	13,741	30.6
Departure time	0:00 - 6:59	839	5.2	15,423	94.8	16,262	18.7	172	25.9	491	74.1	663	2.2	204	17.4	968	82.6	1,172	2.2
	7:00 - 7:59	1,407	3.5	38,924	96.5	40,331	46.4	264	20.9	998	79.1	1,262	4.2	192	10.9	1,577	89.1	1,769	3.3
	8:00 - 8:59	463	2.8	15,982	97.2	16,445	18.9	381	16.8	1,890	83.2	2,271	7.6	275	8.0	3,167	92.0	3,442	6.3
	9:00 - 9:59	142	3.7	3,706	96.3	3,848	4.4	454	12.2	3,253	87.8	3,707	12.5	319	5.2	5,773	94.8	6,092	11.2
	10:00 - 10:59	71	5.6	1,192	94.4	1,263	1.5	398	10.1	3,545	89.9	3,943	13.3	316	4.1	7,365	95.9	7,681	14.1
	11:00 - 11:59	36	4.1	846	95.9	882	1.0	397	12.6	2,751	87.4	3,148	10.6	163	3.0	5,321	97.0	5,484	10.1
	12:00 - 17:59	138	2.8	4,707	97.2	4,845	5.6	1,536	11.3	12,071	88.7	13,607	45.8	706	3.1	22,385	96.9	23,091	42.5
	18:00 - 19:59	54	3.2	1,643	96.8	1,697	2.0	91	12.1	664	87.9	755	2.5	112	2.7	4,107	97.3	4,219	7.8
	20:00 - 23:59	52	4.0	1,246	96.0	1,298	1.5	55	16.1	286	83.9	341	1.1	53	3.8	1,345	96.2	1,398	2.6
Trip distance	0km - 10 km	87	0.3	27,033	99.7	27,120	31.1	121	1.2	10,188	98.8	10,309	34.9	57	0.2	23,906	99.8	23,963	44.2
	11km - 20km	525	1.5	33,462	98.5	33,987	38.9	457	5.2	8,358	94.8	8,815	29.9	236	1.4	16,391	98.6	16,627	30.7
	21km - 30km	710	4.7	14,360	95.3	15,070	17.3	554	13.8	3,455	86.2	4,009	13.6	301	5.1	5,649	94.9	5,950	11.0
	31km - 40km	654	10.7	5,484	89.3	6,138	7.0	578	25.2	1,716	74.8	2,294	7.8	328	11.1	2,636	88.9	2,964	5.5
	41km - 50km	465	17.8	2,142	82.2	2,607	3.0	483	34.1	934	65.9	1,417	4.8	316	18.4	1,400	81.6	1,716	3.2
	51km - 70km	495	28.4	1,248	71.6	1,743	2.0	711	44.1	900	55.9	1,611	5.5	470	25.6	1,366	74.4	1,836	3.4
	71km - 100km	233	38.4	374	61.6	607	0.7	603	56.9	456	43.1	1,059	3.6	394	34.3	754	65.7	1,148	2.1

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by individuals whose job is agriculture amount to 1.8%, 2.6%, and 7.7%, respectively. This reflects the small share of agricultural population in Japan. The share of home-to-workplace trips made by individuals whose job is retailing/service is 22.5% while that of business by them is 37.3%. This means that the retailers and/or service workers travel more for business purposes than those who work in other jobs. Third, 39.0% of the business trips are made by individuals in their 50s. This means that senior workers travel for business more than young workers. 30.6% of the personal trips are made by individuals in their 60s. This may reflect that the retired people have more free time for personal travels than the younger generation. Fourth, 46.4% of the home-to-workplace trips commence during 0700–0759. This means that, on an average, the period of 0700–0800 is the peak hour in Japan. Fifth, the trip distances of 70.0% in the home-to-workplace trips, 64.8% in the business trips, and 74.9% in the personal trips are 20 km or less. Sixth, the shares of expressway users account for less than 10 % in the short-distance trips. Although the dataset was screened carefully, it is afraid that the database may include many captive individuals who may use only expressway route or only no-expressway route. The improvement of data screening method is one of the further research issues. Finally, the correlation between travel time and cost in the sample trips using expressway is 0.765. This is probably because the toll charge of expressway is determined on the basis of route distance whereas the travel time is also highly dependent on the trip distance. This may be one of the unavoidable characteristics in the revealed-preference-based dataset.

EMPIRICAL ANALYSIS

TABLE 2 lists the estimation results of models and VTTSs with a subgroup of the sample dataset. Note that this analysis excludes mini-vehicles from the empirical dataset. Note also that the original standard in Japan defines a mini-vehicle as one having a length, width, and height of up to 400 mm, 1,480 mm, and 2,000 mm, respectively, and an engine displacement of up to 660 cc. Such vehicles are used for both personal and freight transportation. Mini-vehicles are excluded in the subgroup analysis of VTTS because the sample size of choosing the expressway route by a mini-vehicle is too small to be analyzed by the subgroup.

TABLE 2 shows that all models are well estimated from a statistical viewpoint. The test results for most of the coefficients indicate that they are highly significant. The likelihood ratios are also sufficiently high. In addition, the signs of all coefficients are reasonable. Although the models including the alternative-specific constant were also estimated, they are not statistically acceptable. Because the route is chosen by a vehicle, the VTTSs estimated from the route-choice model should be the VTTSs per vehicle. Then, the VTTSs per person are calculated by dividing the VTTSs per vehicle by the average number of persons per vehicle. Note that the VTTS per person is calculated under the assumption that all persons including a driver and passenger(s) in a car have the same VTTS.

First, the estimated VTTSs of home-to-workplace, business, and personal travels are found to be 25.1, 35.2, and 21.6 yen per min. per person. The estimated VTTS of business travel is nearly equal to the average wage rate in Japan. Note that the average wage rate in Japan is 37.2 yen per min. The estimated VTTSs of home-to-workplace and personal travels are 71.3% and 61.4% of the estimated VTTS of business travel. These results are slightly higher than those that have been found in the results of meta-analyses carried out in other countries (for example, in Great Brain, *12*). One of the possible reasons is that the traffic congestion is more serious in Japan than that in other countries. Other is that the time constraint is tighter in the home-to-workplace travels because the most of Japanese companies apply the fixed-work-hour system in which the official-work start time is fixed such 9:00 am. Second, the estimated VTTS of males is 25.3 yen/min and that of females, 24.6 yen/min. This implies that the gender does not affect the VTTS. Third, the estimated VTTS per vehicle and per person when driving alone are 25.9 yen/min./veh. and 25.9 yen/min./per., respectively, whereas those when driving with passenger(s) are 36.2 yen/min./veh. and 15.5 yen/min./veh., respectively. This means that the estimated VTTS per vehicle when driving alone is 39.8% greater than the estimated VTTS when driving with passenger(s). This may imply that the driver's VTTS is more than twice that of a passenger's. Fourth, the estimated VTTSs of agriculture, production/transport, retailing/service, office work/technology, and others are 24.3, 20.2, 24.7, 25.4, and 25.5 yen/min./per., respectively. The VTTS of production/transport workers is apparently lower than the estimated VTTSs of other jobs. This is probably because the wage rate in production/transport is lower than that in other jobs. Fifth, the estimated VTTS of individuals in their 20s, 30s, 40s, 50s, and 60s or more are 19.2, 25.2, 26.5, 24.2, and 22.7 yen/min./per., respectively. The estimated VTTS of individuals in their 20s is the lowest among all age groups and is followed by that of individuals in their 60s. Their VTTSs are lower than those of other age groups simply because they have lower WTP for saving time by using the expressway service because of their lower wage rate. Sixth, the estimated VTTS of trips starting between 1000 and 1059 is the highest in a day, followed by that between 1800 and 1959, between 0800 and 0859, and between 0900 and 0959. The VTTS is the highest between 100 and 1059 probably because more business trips are made during this period than during other period. The VTTSs between 0800 and 0959 and between 1800 and 1959 are high because the traffic congestion is serious during morning and evening peak hours. Finally, the longer the trip distance, the

TABLE 2: Models and VTTSs estimated with subgroup of sample datasets

		Travel time		Travel cost		Initial log-likelihood	Final log-likelihood	Rho-squared	Num of observation	Ave. passengers per car	Estimated VTTS per veh. yen/min./veh.	Eestimated VTTS per per. yen/min./per.
		Coeff.	T-stat.	Coeff.	T-stat.							
Travel purpose	Home-to-workplace	-0.1497	-60.7	-0.0057	-78.0	-5200.5	-15429.7	0.66	87444	1.05	26.2	25.1
	Business	-0.1224	-47.0	-0.0028	-48.5	-3559.3	-6224.9	0.43	30076	1.23	43.3	35.2
	Private	-0.1634	-55.8	-0.0049	-63.1	-3709.7	-10607.2	0.65	54876	1.54	33.3	21.6
Gender	Male	-0.1458	-51.0	-0.0058	-66.7	-3797.9	-11144.6	0.66	63516	1.04	25.3	24.3
	Female	-0.1823	-23.7	-0.0074	-31.5	-694.0	-3106.4	0.78	18746	1.04	24.6	23.7
Passengers	Drive alone	-0.1512	-58.8	-0.0058	-76.1	-4864.7	-14813.8	0.67	84395	1.00	25.9	25.9
	Drive with passenger(s)	-0.1282	-13.2	-0.0035	-14.6	-266.8	-542.3	0.51	2704	2.34	36.2	15.5
Job	Agriculture	-0.1901	-6.8	-0.0074	-8.4	-51.9	-214.5	0.76	1413	1.06	25.7	24.3
	Production/Transport	-0.1556	-21.5	-0.0076	-30.3	-640.4	-2639.0	0.76	15141	1.02	20.6	20.2
	Retailing/Service	-0.1528	-26.7	-0.0060	-34.8	-1001.8	-3132.4	0.68	17909	1.04	25.6	24.7
	Office work/Technology	-0.1524	-35.1	-0.0058	-45.1	-1716.8	-5134.3	0.67	30015	1.03	26.3	25.4
	Others	-0.1466	-25.6	-0.0054	-32.4	-934.9	-2661.7	0.65	15251	1.06	27.0	25.5
Age	20-29	-0.1650	-16.6	-0.0084	-24.5	-379.4	-1870.0	0.80	11634	1.02	19.7	19.2
	30-39	-0.1549	-26.1	-0.0059	-33.8	-951.3	-2964.7	0.68	17124	1.04	26.2	25.2
	40-49	-0.1566	-29.0	-0.0057	-36.9	-1153.0	-3474.8	0.67	20269	1.03	27.4	26.5
	50-59	-0.1469	-31.4	-0.0058	-40.7	-1412.5	-4192.1	0.66	24020	1.04	25.3	24.2
	60-69	-0.1384	-18.5	-0.0057	-23.7	-493.9	-1435.5	0.66	7406	1.06	24.1	22.7
Departure time	0:00 - 6:59	-0.1133	-26.5	-0.0047	-36.2	-1359.1	-3036.5	0.55	16262	1.06	24.0	22.7
	7:00 - 7:59	-0.1638	-38.4	-0.0062	-50.2	-2023.4	-6673.1	0.70	40331	1.04	26.5	25.6
	8:00 - 8:59	-0.1751	-26.0	-0.0062	-32.2	-836.1	-2987.9	0.72	16445	1.05	28.4	27.1
	9:00 - 9:59	-0.1666	-13.7	-0.0060	-16.2	-225.1	-736.7	0.69	3848	1.06	27.9	26.3
	10:00 - 10:59	-0.1626	-8.5	-0.0046	-9.6	-93.3	-243.2	0.62	1263	1.08	35.1	32.5
	11:00 - 11:59	-0.1422	-6.6	-0.0055	-8.2	-60.0	-165.8	0.64	882	1.07	26.0	24.3
	12:00 - 17:59	-0.1412	-14.8	-0.0056	-18.9	-301.8	-913.1	0.67	4845	1.07	25.4	23.7
	18:00 - 19:59	-0.1555	-8.9	-0.0053	-11.0	-109.3	-312.6	0.65	1697	1.05	29.2	27.8
	20:00 - 23:59	-0.1459	-8.3	-0.0057	-9.8	-88.6	-243.8	0.64	1298	1.06	25.7	24.3
Trip distance	0km - 10 km	-0.2199	-13.2	-0.0150	-21.5	-312.2	-5171.7	0.94	27120	1.05	14.7	13.9
	11km - 20km	-0.1224	-20.8	-0.0087	-44.7	-1256.7	-5882.6	0.79	33987	1.04	14.1	13.6
	21km - 30km	-0.0939	-17.3	-0.0054	-33.1	-1039.1	-2519.7	0.59	15070	1.04	17.4	16.7
	31km - 40km	-0.0688	-12.2	-0.0031	-19.3	-655.1	-1010.5	0.35	6138	1.05	22.3	21.2
	41km - 50km	-0.0503	-7.7	-0.0020	-10.8	-344.5	-438.0	0.21	2607	1.09	25.1	23.1
	51km - 70km	-0.0420	-6.1	-0.0012	-6.7	-259.4	-287.3	0.10	1743	1.08	35.5	33.0
	71km - 100km	-0.0358	-3.2	-0.0008	-3.0	-88.1	-94.0	0.06	607	1.18	43.7	37.0

TABLE 3: Estimation results of VTTS model estimated with all sample datasets

Variable	Coefficient	t-statistic
Travel time (θ_t)	–0.0993	–15.0**
Travel time x ln(Distance) (θ_{t_dist})	–0.0288	–14.1**
Travel time x Dummy of senior generation (θ_{t_senior})	0.0071	1.6
Travel time x Dummy of drive-alone (θ_{t_alone})	0.0349	7.6**
Travel time x Dummy of mini vehicle (θ_{t_mini})	0.0251	7.3**
Travel time x Dummy of early-morning departure time ($\theta_{t\_morning}$)	0.0126	3.8**
Travel time x Dummy of peak hours (θ_{t_peak})	–0.0087	–2.0*
Travel time x Dummy of business purpose ($\theta_{t\_business}$)	–0.0393	–8.9**
Travel cost (θ_c)	–0.0062	–102.0**
Initial log-likelihood		–34269
Final log-likelihood		–10892
Likelihood ratio		0.68
Number of observation		196,672

Note: * means the significance at 95% confidence level and ** means the significance at 99% confidence level.

higher is the estimated VTTS. This is the same result as earlier studies in other countries including UK (*4*) and Switzerland (*5*).

TABLE 3 lists the results of the model estimated with all sample datasets on the basis of eq (1). The travel time is defined as the travel duration (min.) from an origin to a destination. The distance is defined as the length (km) of a non-expressway route from the origin to the destination. The dummy for the senior generation is 1 if an individual making the trip is in his/her sixties or older and 0 otherwise. The dummy for drive-alone is 1 if an individual making the trip drives alone and 0 otherwise. The dummy for mini-vehicle is 1 if the car used in the trip is a mini-vehicle and 0 otherwise. The dummy for early-morning departure time is 1 if the departure time of the trip is between 000 and 659 and 0 otherwise. The dummy for peak hours is 1 if the departure time of the trip is between 700 and 859 and 0 otherwise. The dummy for business purpose is 1 if the purpose of the trip is business and 0 otherwise. The travel cost is defined as the expressway toll charge (yen) paid for using the expressway service and this is 0 if the route does not include any expressway. The model is well estimated from a statistical viewpoint. The results of the tests for coefficients except Travel time × Dummy for senior generation indicate that they are highly significant. The likelihood ratios are also sufficiently high. In addition, the signs of all coefficients are reasonable. TABLE 3 shows that the VTTS increases with the travel distance. It also shows that the VTTS of the senior generation is lower than that of other generations, VTTS when driving alone is lower than that when driving with multiple passengers, VTTS of trips made using a mini-vehicle is lower than that of trips made using standard vehicle, VTTSs of trips made in the early morning are lower than those of trips made in other hours of the day, VTTS of trips made during peak hours is higher than that of trips made during other hours of the day, and VTTS of business travel is higher than that of non-business travel.

DISCUSSION

First, our analysis results show that the VTTS increases with the trip distance. As shown in Mackie et al. (*4*), this is because a longer travel time increases the value of time as a resource. It should be noted that the VTTS is theoretically equal to the sum of the value of time as a resource and the value of time as a resource (De Serpa, *17*). A long travel time reduces the individual's leisure time. The marginal utility with respect to leisure time is expected to increase as the leisure time decreases when it is assumed that the marginal utility with respect to leisure time is decreasing. The increase in marginal utility leads to an increase in the VTTS. The value of time as a resource is defined as the ratio of the marginal utility with respect to leisure time to the marginal utility with respect to income. This is because a longer travel time increases the value of time as a commodity. The value of time as a commodity is defined as the ratio of the marginal utility with respect to travel time to the marginal utility with respect to income under the condition that the utility is maximized. A longer travel time causes fatigue and/or boredom during travel and it is expected that they lead to an increase in the marginal utility with respect to travel time. Higher VTTS of longer journey may imply that the toll charge per kilometer increases with the trip distance. This suggests that the toll charge system should be nonlinear with respect to distance.

Note that the current toll-charge system of Japanese expressways is a linear system in which a distance-based charge is levied in addition to an initial charge.

Second, our results suggest that VTTS of senior drivers is significantly lower than that of younger drivers. This means that the income impacts the WTP for saving time significantly. As Mackie et al. (*5*) pointed out the variation of VTTS by income should be incorporated into the VTTS estimation and even into the project evaluation. One of the practical problems of introducing the variation by income into the project evaluation is the difficulty of forecasting the future distribution of income among the road users. In terms of setting the toll charge, this result may indicate that the toll charge of senior drivers should be discounted because they have lower WTP for saving time by choosing the expressway. Although a discount program for senior users is quite popular in public transport services, for example, the subway service operated by the Tokyo Metropolitan Government, it is rarely applied to the expressway service. To the best of our knowledge, the current Japanese toll-charge system does not include any discount program for senior drivers.

Third, our results suggest that the VTTSs vary among the time of a day. One of the possible reasons is that the share of road users by journey type varies among the time of a day. Many business travelers drive during 1000 and 1059 while many commuters drive from home to workplace during 0800 and 0959. As the VTTSs of business travels and home-to-work travels are higher than that of personal travels, this could lead to higher VTTSs in the travels departing at these periods. Other possible reason is that the traffic congestion increases the value of time as a commodity. If the traffics of both the expressway route and the no-expressway route are highly congested, the drivers must face the traffic congestion whether they choose expressway route or not. The quality of service in the congested traffic should be lower than that in the less congested traffic. Thus, the marginal travel time savings during the congested hours critically reduces the disutility of driving in the traffic jam such as fatigues and boredom. This may result in higher VTTS of driving during the congested hours than that during the less congested hours. This may also suggest that the toll charge for a trip starting in early morning or in late evening should be discounted. For example, the East Nippon Expressway Company Ltd. has recently introduced a discount program in which drivers pay 50% of the standard charge for using the given routes of their expressway network between 2200 and 0600. This aims to promote expressway demand during off-peak hours. This may also suggest that the toll charge for a trip starting during peak hours should be increased. Theoretically, this will lead to peak-load pricing or congestion charging. This may match the concept of congestion pricing theory that aims to internalize the externalities of traffic congestion during the peak hours. Note no congestion pricing scheme has been introduced for any Japanese expressway.

Finally, the VTTS per vehicle when driving alone is lower than that when driving with passengers, whereas the VTTS per person when driving alone is higher than that when driving with passengers. This may be one of the controversial issues in transportation planning. This is because it is unclear whether the vehicle-based WTP or the individual-based WTP influences the decision-making process of route choice. If higher toll charge is levied when driving alone, it may reduce the expressway demand when driving alone and reduce traffic congestion. This follows the concept of a high-occupancy toll (HOT) lane. In contrast, if lower toll charge is levied when driving alone, it may promote expressway demand when driving alone and increase traffic congestion. This goes against the HOT lane policy.

CONCLUSIONS

This paper empirically estimates the WTP for saving travel time by choosing the expressway route that is equal to the VTTS of road users with a large-scale database in Japan. Parameter estimation indicates that (1) the estimated VTTS of business travel is nearly equal to the average wage rate in Japan whereas the estimated VTTSs of home-to-workplace and personal travels are lower than the estimated VTTS of business travel; (2) VTTS increases with the trip length; (3) estimated VTTSs during 0800 and 1059 and 1800 and 1959 are higher than those during other periods; (4) estimated VTTSs of individuals in their 20s and in their 60s are lower than those of individuals in other age groups; (5) estimated VTTS of males is similar to that of females; (6) estimated VTTS per vehicle when driving alone is higher than the estimated VTTS per vehicle in drive with passenger(s); and (7) estimated VTTS of production/transport workers is lower than the estimated VTTSs of other jobs. Then, policy implications for the toll charge of the expressway service are discussed assuming that toll charge should reflect the VTTS of road users.

Finally, it should be noted that the VTTS estimation presented in this paper uses one specific form of the function, including the socio-demographics and travel environment. Another specification of utility function should be explored. It is also noted that the variation of VTTSs by income was not analyzed because the database does not include the individual's income data. Additionally, the influences of other transportation modes on road users should be also examined with another database. Further studies are still required to conclude the national VTTS study in Japan.

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