1. INTRODUCTION

The willingness to pay (WTP) for travel time saving is termed as the value of travel time saving (VTTS). It is widely used in the economic evaluation of transport investment. Although a constant VTTS is often used in practical transport planning, the constancy of VTTS is derived simply from the assumption of a linear utility function. When using a nonlinear utility function, we can derive a nonconstant VTTS with respect to travel time. Many researches have been conducted on the variation in the value of time over travel time or over trip distance. Wardman (1998, 2001, 2004) reviews past British evidence on the value of time and indicates that the value of travel time is expected to increase as trip distance increases. De Lapparent et al. (2002) formulate the Box-Cox Logit model and estimate the value of travel time using empirical data in Paris. They conclude that the WTP is effectively neutral to travel time variation. Axhausen et al. (2005) examine the variation in the VTTS over trip distance by using stated preference (SP) data in Switzerland. They show that the VTTS increases as travel distance increases. Hultkrantz and Mortazavi (2001) and Hensher (1997) show that the VTTS may decrease as travel time increases. The present paper will add fresh evidence to the previous analyses on the VTTS over travel time.

This paper examines the VTTS over travel time for interregional, leisure-purpose travel. We eliminate urban travel from the scope of this analysis because it may be closely related with the choice of residential location, as pointed out by Small (1999). Consumers’ joint behavior with respect to both travel choice and choice of residential location may bias the estimated VTTS. In addition, we eliminate interregional business travel because the fact that most business travelers can avail of travel allowance from their companies may bias the demand elasticity with respect to travel cost.

The rest of the paper is organized as follows. Section 2 formulates a time allocation model and derives the VTTS from the model. Thereafter, it examines
the variation in the VTTS over travel time from a theoretical viewpoint. Section 3 shows the derivation of the VTTS from a discrete choice model with a nonlinear utility function. Next, Section 4 presents the empirical analysis with interregional travel data of Japan. Finally, Section 5 summarizes the paper and indicates the direction for further research.

2. MODEL

2.1. Derivation of VTTS from the time allocation model

Consider an individual who derives utility from the consumption of a composite good and the consumption of travel service, leisure time, and travel time. Assume that the individual maximizes her/his utility with respect to time and expenditure under the constraints of time budget, monetary budget, and minimum travel time. Since we expect interregional leisure-purpose travel to be done on nonworking days, it is assumed that the individual’s income is fixed and given. Let the individual’s utility be \( U \). Then, following DeSerpa (1971, 1973), the time allocation model can be formulated as

\[
\begin{align*}
\text{Maximize } & U(X, T, x, t) \\
\text{subject to } & PX + \sum c_i x_i = I [\lambda] \\
& T + \sum t_i x_i = T^0 [\mu] \\
& t_i \geq \hat{t}_i \quad \text{for } \forall i [\kappa_i],
\end{align*}
\]

where \( U(\cdot) \) is the utility function, \( X \) is the composite good, \( T \) is time available for leisure, \( x \) is a vector of travel frequency, \( t \) is a vector of travel time, \( P \) is the price of the composite good, \( c_i \) is the travel cost of transport service \( i \), \( x_i \) is the travel frequency of transport service \( i \), \( I \) is the monetary budget, \( T^0 \) is the available time, \( t_i \) is the travel time of transport service \( i \), and \( \hat{t}_i \) is the minimum travel time of transport service \( i \). \( \lambda, \mu, \) and \( \kappa_i \) are the Lagrange multipliers corresponding to Equations (1b), (1c), and (1d), respectively. It is assumed that the marginal utility (MU) with respect to composite good consumption is positive, whereas the MU with respect to travel time is negative.

The Lagrange function corresponding to this time allocation model is described as

\[
L = U(X, T, x, t) + \lambda \left( I - PX - \sum c_i x_i \right) + \mu \left( T^0 - T - \sum t_i x_i \right) + \sum \kappa_i \left( \hat{t}_i - t_i \right). \tag{3}
\]

The first-order conditions of optimality are derived as
\[
\frac{\partial U}{\partial X} = \lambda P, \quad \frac{\partial U}{\partial T} = \mu \tag{4a, b}
\]

\[
\frac{\partial U}{\partial x_i} = \lambda c_i + \mu t_i, \quad \text{for } \forall i, \quad \frac{\partial U}{\partial t_i} = \mu x_i - \kappa_i \tag{4c, d}
\]

\[
\kappa_i(t_i - \hat{t}_i) = 0 \quad \text{and} \quad \kappa_i \geq 0 \quad \text{for } \forall i \tag{4e, f}
\]

and Equations (2a) to (2c).

Next, let the indirect utility function of the individual be \( v_k(i, t, T) \). By applying the envelope theorem (Varian, 1987) to the above utility maximization problem, we obtain

\[
\frac{\partial v}{\partial t_i} = \frac{\partial U}{\partial t_i} + \kappa_i^* \frac{\partial (t_i - \hat{t}_i)}{\partial t_i} = -\kappa_i^{**} \tag{5}
\]

\[
\frac{\partial v}{\partial t} = \frac{\partial U}{\partial t} + \lambda \frac{\partial (I - PX - \sum c_i x_i)}{\partial t} = \lambda^* \tag{6}
\]

As the VTTS is defined as the WTP for travel time savings, it is derived from Equations (5) and (6) as

\[
VTTS_i = -\frac{\partial v/\partial t_i}{\partial v/\partial t} = \frac{\kappa_i^{**}}{\lambda^*}. \tag{7}
\]

On the other hand, from the first-order optimality conditions, we obtain the VTTS as

\[
\frac{\kappa_i^{**}}{\lambda^*} = x_i^* \frac{\mu^*}{\lambda^*} - \frac{\partial U/\partial t_i}{\lambda^*}. \tag{8}
\]

DeSerpa (1971) shows the VTTS in the case of \( x_i^* = 1 \). He terms the first term on the right-hand side of Equation (8) as the value of time as a resource, and the second as the value of time as a commodity.

### 2.2 Variation in the VTTS over travel time

In order to study the variation in the VTTS over travel time, we should discuss the relationship between each component of the VTTS and travel time. In this section, we will examine this relationship based on Equation (8), in terms of the following two cases: the first case involves the condition that the MU with respect to income is constant and the second case involves the condition that the MU with respect to income is nonconstant.

If the MU with respect to income \( \lambda^* \) is constant, we need to examine the impacts of changes in travel time on the MU with respect to time as a resource \( \mu^* \) and on the MU with respect to travel time \( \partial U/\partial t_i^{**} \). First, with regard to the impact of changes in travel time on \( \mu^* \), the utility level changes in response to the changes in leisure time that occur due to changes in travel time. This
change depends upon the form of utility function. If the MU with respect to leisure time is decreasing, \( \mu^* \) increases as travel time increases. On the contrary, if the MU with respect to leisure time is increasing, \( \mu^* \) decreases as travel time increases. Second, the impact of change in travel time on \( \frac{\partial u}{\partial \tau} \) depends on whether the MU with respect to travel time is increasing or decreasing. An increasing MU with respect to travel time implies that a traveler derives greater disutility such as fatigue and boredom as travel time increases, whereas a decreasing MU with respect to travel time implies that travelers gradually begin to feel neutral about the disutility as travel time increases. Although we expect the MU with respect to travel time to be negative, we cannot specify whether it is increasing or decreasing \textit{a priori}. Hence, it may be impossible to judge \textit{a priori} the clear tendency on the variation in the VTTS over travel time even under the assumption of a constant MU with respect to income.

If the MU with respect to income is nonconstant, we should consider the change in the MU with respect to income in addition to the discussion of the case of a constant \( \lambda^* \). The travel cost is expected to increase as travel time increases. The increase in travel cost causes a decrease in the monetary budget available for composite good consumption. However, we cannot predict \textit{a priori} whether the MU with respect to income \( \lambda^* \) is increasing or decreasing. In most cases, \( \lambda^* \) is considered to be constant or decreasing. If \( \lambda^* \) is decreasing, \( \lambda^* \) increases as travel time increases. If \( \lambda^* \) is constant, \( \lambda^* \) is neutral over travel time. This unpredictability makes the results more complicated.

Consequently, from a theoretical viewpoint, we find many patterns of variation in the VTTS over travel time. There is no simple condition to explain the monotonic change in the VTTS over travel time. This implies that the characteristics of VTTS variation over travel time are highly dependent on the form of utility function. In order to specify the pattern of the variation, we may be required to examine it using empirical data. Therefore, in the following section, we empirically analyze the variation in the VTTS over travel time by using an approximated utility function. Although this approximation may relax the strictness of the analysis, it should yield richer and more useful implications.
3. EMPIRICAL ANALYSIS

3.1 Derivation of VTTS in a discrete choice model system
Consider a situation wherein a traveler selects only one transport service \( i \) by excluding the other services. In addition, the traveler consumes a single unit of service \( i \) in the time allocation model shown earlier. This means that both \( x_i = 1 \) and \( x_j \neq 1 (\forall j \neq i) \) are satisfied in Equation (1). Then, as Train and McFadden (1978) show, the utility maximization under the condition that an individual discretely chooses the transport service \( i \) is described as follows:

\[
\begin{align*}
\max_{X,T,t_i} U_i &= U_i(X,T,t_i) \\
\text{subject to} & \quad PX + c_i = I \quad \left[\lambda\right] \\
& \quad T + t_i = T^0 \quad \left[\mu\right] \\
& \quad t_i \geq \hat{t}_i \quad \left[\kappa^t\right].
\end{align*}
\]

where \( U_i \) denotes the conditional utility function for transport service \( i \).

The following first-order optimality conditions are derived from the Kuhn-Tucker theorem:

\[
\begin{align*}
\frac{\partial U_i}{\partial X} &= \lambda P, \quad \frac{\partial U_i}{\partial T} = \mu, \quad \frac{\partial U_i}{\partial t_i} = \mu - \kappa^t_i \\
\kappa^t_i \left( \hat{t}_i - \tilde{t}_i \right) &= 0 \quad \text{and} \quad \kappa^t_i \geq 0 \\
PX + c_i &= I, \quad T + t_i = T^0.
\end{align*}
\]

Let the conditional indirect utility function be \( v_i = v_i\left(c_i, \hat{t}_i, I, T^0\right) \). The following equations are derived from the envelope theorem:

\[
\begin{align*}
\frac{\partial v_i}{\partial c_i} &= \frac{\partial U_i}{\partial c_i} + \lambda^* \frac{\partial (I - PX - c_i)}{\partial c_i} = -\lambda^* \\
\frac{\partial v_i}{\partial t_i} &= \frac{\partial U_i}{\partial t_i} + \kappa_i^t \frac{\partial (t_i - \hat{t}_i)}{\partial t_i} = -\kappa_i^t.
\end{align*}
\]

Consequently, we obtain the VTTS in the discrete choice model system as follows:

\[
\frac{\kappa_i^t}{\lambda^*} = \frac{\partial v_i}{\partial t_i} / \frac{\partial v_i}{\partial c_i}.
\]

3.2 Approximation of the utility function
We approximate the utility function using the method demonstrated by Blayac and Causse (2001). In the present analysis, we use the following four approximations: the first-order approximation, the second-order approximation, the second-order approximation with a constant MU with respect to income,
and the third-order approximation with a constant MU with respect to income. First, we apply the Taylor expansion to the conditional direct utility function at \((X, T, t_i) = (0,0,0)\). We obtain the following first-order approximation as

\[
U_i(X, T, t_i) = \frac{\partial U_i}{\partial X} X + \frac{\partial U_i}{\partial T} T + \frac{\partial U_i}{\partial t_i} t_i + Z_{1,i}.
\]  

(13)

By substituting the first-order optimality conditions shown in Equation (10) into Equation (13), the first-order approximated conditional indirect utility function is derived as follows:

\[
v_i(c_i, t_i, I, T^o) = \lambda (I - c) + \mu^*(T^o - t_i) + \left( \mu^* - \kappa_{T^o}^i \right) t_i + Z_{1,i}.
\]  

(14)

This is the same result as that shown by Bates (1987). In the empirical analysis shown later, we apply the multinomial logit (MNL) model to travel mode choice. As Ben-Akiva and Lerman (1985) show, in the MNL model, the probability of choosing a specific mode is described as the function of the difference of indirect utility functions between modes. Thus, generic variables such as \(\lambda I\) and \(\mu^* T^o\) in Equation (14) cannot be identified in our analysis. Thus, we rewrite the conditional indirect utility function without the generic variables as follows:

\[
v_{1,j} = -\lambda c_i - \kappa_{T^o}^i t_i + z_{1,j} = \theta_{1,j} c_i + \theta_{1,j} t_i + \theta_{1,j}.
\]  

(15)

This is the linear indirect utility function that is widely used in practical transport planning.

Next, we obtain the second-order direct utility function in the same way as the first-order approximation as follows:

\[
U_i(X, T, t_i) = \frac{\partial U_i}{\partial X} X + \frac{\partial U_i}{\partial T} T + \frac{\partial U_i}{\partial t_i} t_i + \left( \frac{\partial^2 U_i}{\partial X^2} X^2 + \frac{\partial^2 U_i}{\partial T^2} T^2 + \frac{\partial^2 U_i}{\partial t_i^2} t_i^2 \right) + \left( \frac{\partial^2 U_i}{\partial X \partial T} X T + \frac{\partial^2 U_i}{\partial X t_i} X t_i + \frac{\partial^2 U_i}{\partial T t_i} T t_i \right) + Z_{2,i}.
\]  

(16)

By substituting the first-order optimality conditions into Equation (16), we derive the following second-order approximated conditional indirect utility function as

\[
v_i(c_i, t_i, I, T^o) = \left( \alpha^T + \frac{\alpha_T}{2} - \alpha_{TT} \right) t_i^2 + \left( \alpha_X - \frac{\alpha_X}{2p^2} \right) c_i^2 + \left( \alpha_{TT} - \alpha_T \right) t_i + \left( \alpha_{XX} - \alpha_{XT} \right) T^o + \left( \alpha_{TT} - \alpha_{TT} \right) t_i - \lambda \frac{\alpha_T T^o}{p^2} \frac{\alpha_T c_i}{p} + \left( \alpha_{TT} - \alpha_{TT} \right) t_i + Z_{2,i}.
\]  

(17)

where the parameters are defined as follows:
Similar to the first-order approximation, we obtain the following indirect utility function without the generic variables as

\[ v_{2,j} = \theta_{2,j}(l,T)\hat{c}_i + \theta_{2,j}(l,T)\hat{t}_i + \theta_{2,c}\hat{c}_i^2 + \theta_{2,t}\hat{t}_i^2 + \theta_{2}\,c_i\hat{t}_i + \theta_{2,j}. \]  

(19)

The parameters associated with travel cost and (minimum) travel time follow the functions of income and available time, respectively. Since it is assumed that both the income and available time are given and constant, these parameters can be estimated in the same way as the other parameters.

With regard to the case of a constant MU with respect to income under the second-order approximation of the utility function, the utility function satisfies the following equations:

\[ \frac{\partial^2 U_i}{\partial X^2} = 0, \quad \frac{\partial^2 U_i}{\partial T^2} = 0, \quad \frac{\partial^2 U_i}{\partial X\partial T} = 0. \]  

(20)

By substituting Equation (20) into Equation (19), we derive the indirect utility function in the case of a constant MU with respect to income as follows:

\[ v_{2e,j} = \theta_{2e,c}\hat{c}_i + \theta_{2e,t}\hat{t}_i + \theta_{2e}\,c_i\hat{t}_i + \theta_{2e,j}. \]  

(21)

Finally, we can derive the third-order approximation in the same way as the first- and the second-order approximations as follows:

\[ v_{3e,j} = \theta_{3e,c}\hat{c}_i + \theta_{3e,t}\hat{t}_i + \theta_{3e}\,c_i\hat{t}_i + \theta_{3e,j}. \]  

(22)

### 3.3 VTTS Estimation

The data used for parameter estimation is derived from the Third Inter-regional Transport Survey, Japan. This survey was conducted in 2000 by the Ministry of Land, Infrastructure and Transport, Japan. The data includes traveler’s origin zone, destination zone, chosen travel mode and route, and socio-demographic information. The zone is defined as a daily transport area within which most of population commute, shop, and travel to school in the course of a day. There are 207 such zones defined in Japan. The survey covers interzonal journeys for the following three purposes: business, leisure, and other purposes.

In our analysis, we selected only leisure-purpose travel. For the preparation of the data of the level of transport service, we follow the method used in the formal travel demand analysis for the long-term transport plan of Japan that was conducted in 2000 (Ministry of Land, Infrastructure and Transport, 2000; Inoue et al., 2001). We randomly selected 3,000 sample data from the master data set.
Presented at ETC 2006, Strasbourg, September 2006

The MNL model is used for the parameter estimation of travel mode choice. The following four models are estimated: the first-order approximation model, the second-order approximation model, the second-order approximation model with a constant MU with respect to income, and the third-order approximation model with a constant MU with respect to income. The same data set is used for all the models. Although the parameter corresponding to minimum travel time should depend on the travel mode as per Equation (15), it is assumed that the parameter is generic across travel modes. The estimation results are shown in Table 1. This shows that all the parameters of all the models pass the statistical test at the significance level of 99%. The signs of the parameters also appear to be reasonable.

Then, we evaluate each VTTS corresponding to the above four models. These are derived from the approximated utility functions of Equations (15), (19), (21), and (22), respectively, as follows:

First-order approximated VTTS:

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<th>t-statistics</th>
<th>parameter</th>
<th>t-statistics</th>
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</tr>
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<td>(9.13)</td>
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</table>

Initial log-likelihood: -3394.3
Final log-likelihood: -2218.8
Adjusted likelihood ratio: 0.346
Number of observations: 3,000

The second-order approximated VTTS:

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Initial log-likelihood: -3394.3
Final log-likelihood: -2164.1
Adjusted likelihood ratio: 0.362
Number of observations: 3,000

The third-order approximated VTTS:

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Table 1 Parameter Estimation Results

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<td>(travel time)^3*10^-6</td>
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<td>-0.00294</td>
<td>(-5.53)</td>
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</table>

Initial log-likelihood: -3394.3
Final log-likelihood: -2164.1
Adjusted likelihood ratio: 0.362
Number of observations: 3,000

The third-order approximated VTTS:

<table>
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<th>Variables</th>
<th>Unit</th>
<th>parameter</th>
<th>t-statistics</th>
<th>parameter</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>travel cost*10^-2</td>
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<td>(-6.08)</td>
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<td>(travel cost)^2*10^-6</td>
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<tr>
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<td>minute*yen</td>
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<td>(-12.7)</td>
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<tr>
<td>(travel time)^3*10^-6</td>
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<td>-0.00294</td>
<td>(-5.53)</td>
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</tr>
</tbody>
</table>

Initial log-likelihood: -3394.3
Final log-likelihood: -2164.1
Adjusted likelihood ratio: 0.362
Number of observations: 3,000
Second-order approximated VTTS:

\[ VTTS_{2, i} = \frac{\theta_{2, i} + 2\theta_{2, c}i + \theta_{2, c}c_i}{\theta_{2, c} + 2\theta_{2, c}c_i + \theta_{2, c}i} \]  \hspace{1cm} (24)

Second-order approximated VTTS with a constant MU w.r.t. income:

\[ VTTS_{2c, i} = \frac{\theta_{2c, i} + 2\theta_{2c, c}i}{\theta_{2c, c}} \]  \hspace{1cm} (25)

Third-order approximated VTTS with a constant MU w.r.t. income:

\[ VTTS_{3c, i} = \frac{\theta_{3c, i} + 2\theta_{3c, c}i + 3\theta_{3c, c}i^2}{\theta_{3c, c}}. \]  \hspace{1cm} (26)

First, the first-order approximated VTTS is estimated at 165.9 yen/minute with Equation (23). Second, the second-order approximated VTTS with a constant MU with respect to income is estimated as shown in Figure 1. This indicates
that the VTTS decreases as travel time increases. Third, the third-order approximated VTTS with a constant MU with respect to income is estimated as shown in Figure 2. This also indicates that the VTTS decreases as travel time increases.

Fourth, we estimate the VTTS from the second-order approximated model with a nonconstant MU with respect to income. As Equation (24) shows, we should use both travel time and travel cost in order to obtain the VTTS. The relation
between travel time and travel cost may depend on the travel mode. The relationships between travel time and travel cost of sample travelers choosing the travel modes of rail, airplane, and automobile are shown in Figures 3, 4, and 5, respectively. These figures indicate that travel cost increases as travel time increases, but travel cost is not always proportionate to travel time. Even in the case of automobile users, the travel cost corresponding to a specific travel time varies considerably because it depends on whether or not drivers use tolled expressways. In this case, we estimate each VTTS based on Equation (24). The estimated VTTS for the rail, airplane, and automobile users are shown in Figures 6, 7, and 8, respectively. In the estimation, we use the actual data of travel time and travel cost. Figures 6 and 7 show that the variations in the estimated VTTS over travel time appear neutral in the case of rail and airplane users; on the other hand, Figure 8 shows that in the case of automobile users, the estimated VTTS appears to decrease as travel time
3.4 Discussion

First, we will discuss the magnitude of the estimated VTTS corresponding to each model. The average wage rate in Japan as of 2000 is 37.6 yen/minute. The estimated VTTS for the first-order approximation, the second-order approximation with a constant MU with respect to income, and the third-order approximation with a constant MU with respect to income exceeds 150 yen/minute for travelers with average travel time (248.9 minutes) travelers. On the other hand, the VTTS of the average travel time of rail and automobile users estimated using the second-order approximation are less than 80 yen/minute. Since long-distance travelers may earn higher income, their VTTS may be higher. However, a VTTS above 150 yen/minute appears rather high. From the viewpoint of the VTTS magnitude, the assumption of a constant MU with respect to income may be inappropriate.

Second, we will compare the VTTS with respect to the travel modes. In general, travelers who use higher-speed travel modes have higher WTP for travel time saving. The empirical analysis with the second-order approximation shows that airplane users have the highest VTTS, followed by rail users and automobile users who have the lowest VTTS. This shows that the estimated results are quite reasonable.

Third, we will consider the variation in the VTTS over travel time. In order to discuss it from a realistic viewpoint, we should consider various factors in addition to the theoretical analysis shown earlier. For example, in the theoretical analysis, we assumed that the available time and monetary budget increases.
are given and fixed. However, in reality, travelers may control these constraints by changing their available time and monetary budget. We did not explicitly consider the destination choice in the theoretical analysis; however, in reality, travelers may choose their destinations. Furthermore, long-distance travel offers various services for reducing the disutility derived from travel, but this influence was not considered in the theoretical analysis. We will discuss it in the following two cases: the case of a constant MU with respect to income and the case of a nonconstant MU with respect to income.

The results of the empirical analysis indicate that the VTTS decreases as travel time increases under the assumption of a constant MU with respect to income. We discuss the reason for this result from the following two viewpoints: the changes in the MU with respect to time as a resource \( \mu^r \) and the change in the MU with respect to time as a commodity \( \partial U / \partial t \). As regards the change in the MU with respect to time as a resource \( \mu^r \), there are three hypothetical situations that should be considered. The first situation is that the individual's available time and her/his destination are both fixed. In this situation, the increase in the travel time reduces the time available for leisure activity. If it is assumed that the MU with respect to leisure time is decreasing, then the MU with respect to leisure time increases as travel time increases. This has been already pointed out by Jiang and Morikawa (2000). However, we cannot assume a priori that the MU with respect to leisure time is decreasing. If it is increasing, the opposite result can be obtained. The second situation is that the individual's available time is fixed while she/he can choose the destination. If people can choose the destination for leisure activity, they will choose one where they can derive the highest utility through the leisure activity. A journey involving a lengthy travel time implies that the destination chosen is attractive enough to spend leisure time there. If this is so, it is possible that the longer the travel time, the higher the MU with respect to time as a resource. The third situation is that the available time can be changed. We sometimes observe that people enjoy a longer stay for leisure activities if they visit places farther from their home. For example, they enjoy one-day leisure activities at a nearer destination, whereas they stay overnight at farther destinations. This implies that they relax their constraint of available time as travel time increases. If this holds true, then the MU with respect to time as a resource may decrease as travel time increases. Next, with regard to the MU with respect to time as a commodity \( \partial U / \partial t \), we can point out the following two factors. One is the influence of disutility caused by travel time. The other is the influence of traveler's choice that is aimed at reducing the travel disutility. For
example, automobile drivers may take additional rest as they travel longer. If the duration of the rest taken is included in the travel time, then the MU with respect to travel time may decrease as travel time increases. Consequently, we can summarize the following two hypothetical reasons why the VTTS decreases as travel time increases: One is because \( \mu \) decreases as travel time increases due to the decrease in the MU with respect to leisure time or due to the relaxation of the constraint of available time. The other is because \( \partial U/\partial t_i \) decreases as travel time increases due to the decrease in the MU with respect to travel time or due to the change of the traveler’s behavior for reducing the travel disutility. Although we point out the hypothetical reasons for the decrease in VTTS, we cannot judge which reason is the most appropriate from the data set. In order to do so, we need to collect data on individuals’ leisure behavior.

Next, the results of the empirical analysis under the assumption of a nonconstant MU with respect to income show that the VTTS of automobile users decreases as travel time increases, whereas the variations in the VTTS of rail and airplane users are neutral over travel time. We will discuss this based on a consideration of the case of a constant MU with respect to income that was shown earlier.

Following the classical microeconomic theory, it is assumed that the MU with respect to income is decreasing. Then, the results of the empirical analysis require that the income constraint become more rigid as the travel time increases for automobile users while the income constraint become more relaxed as travel time increases for rail and airplane users. We will point out the following three hypothetical reasons for the above requirements. The first hypothetical reason is that the marginal expenditure for leisure activity with respect to leisure time is smaller than the marginal travel cost with respect to travel time for automobile users. The second hypothetical reason is that automobile users do not change their budget constraint as travel time increases whereas rail and airplane users will relax their budget constraint as travel time increases. The third hypothetical reason is that there is no relation between travel time and the income of automobile users, whereas rail and airplane users with higher income tend to travel for longer durations. The reasons provided above are, however, hypothetical. Verifying these reasons necessitates further analysis with other empirical data including the relation between income and travel time.
4. CONCLUSIONS

We have examined the variation in the VTTS over travel time. The theoretical consideration shows that it is impossible to identify the conditions determining the monotonic change in the VTTS over travel time. We then examine it with the empirical data of interregional travel mode choice in Japan. The empirical analysis results show that the VTTS decreases as travel time increases. We presented some hypothetical reasons for these results. However, since these reasons are hypothetical, verifying them necessitates further examination with more empirical data is needed in order to verify them.

Our analysis results may yield some policy implications. First, it is shown that the VTTS changes as the travel time changes. Although a constant VTTS has often been used for benefit evaluation in practical transport planning, it may not be appropriate at least for the economic evaluation of the interregional transport investment of Japan. We need to take into account the variation in the VTTS even for practical benefit calculation. Second, our empirical analysis results show that the variation in the VTTS over travel time may differ across travel modes. We should consider the difference in the VTTS across travel modes in terms of a cost-benefit analysis. Third, the variation in the VTTS over travel time may influence the transport investment policy. If we acknowledge that the VTTS decreases as travel time increases, the marginal benefit caused by marginal travel time saving would increase as travel time reduces. This implies that society will require additional travel time saving as travel time decreases.

Finally, we point out some further research topics relating to the present analysis. First, we analyzed the VTTS with data that was used in the formal long-term transport planning in Japan. However, the VTTS estimation is highly influenced by the data definition, particularly by the level of service data including the travel time and travel cost of the alternative travel mode. We should examine the sensitivity of these data to the estimation. Second, we used only two variables—travel time and travel cost—in the model estimation for analytical simplification. However, in reality, there are other variables that may influence the travel mode choice such as the number of transfers and the congestion and comfort of the vehicle. As Hess et al. (2005) point out, the inappropriate assumption of variables may bias the VTTS estimation results. We should verify the appropriateness of using two variables. Finally, we used the MNL model in the examination of travel mode choice. This model cannot consider the heterogeneity of individual preference. As Hess et al. (2005) and
Sillano and Ortuzar (2005) show, the mixed logit model may be applicable to the VTTS estimation.

Acknowledgement

This study was financially supported by the Obayashi Foundation, although some of the work was conducted after the original project was concluded. I am grateful to Mr. Keiichi Onoda (University of Tokyo) for his support of the model analysis.
References


