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STUDY OF WILLINGNESS TO PAY FOR REDUCING LOST TIME OF RAILWAY USERS

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Abstract: This paper analyzed the willingness to pay (WTP) for reducing the lost time of railway users in Tokyo Metropolitan Area. A questionnaire survey was conducted to obtain the data for the analysis. Contingent valuation method (CVM) was applied to inquire their WTP in the survey. A statistical method for survival data analysis was applied to estimate the WTP function. As the results of the estimation, some significant factors which influence on the WTP were detected. Meanwhile, the expectation of the WTP was calculated using the estimated function. Then, it became clear that the expectation of the WTP was proportional to the amount of the lost time and that the expectation changed in accordance with the amount of the reducing of the lost time.

Key Words: *travel time reliability, willingness to pay, survival analysis*

1. INTRODUCTION

There are many causes to make schedule of railway service delayed. To investigate the current condition of the delay in Tokyo Metropolitan Area (TMA), a statistics by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) can be utilized. This statistics compiles the notifications of every railway accidents, and troubles with more than 30 minutes delay. According to this statistics, we can know when and where accident happened, what a cause was, how large the influence was, and etc...

Figure 1 shows the transition of the number of railway accident. It had decreased until 2003. The reason is that MLIT devised measures to reduce the number of railway accidents. For example, MLIT indicated railway companies to install emergency stop buttons in platforms, fall detection mats into railroads, and evacuation spaces under platforms.

Figure 2 shows the site of railway accidents. Many railway accidents have occurred at large stations such as Tokyo, Ueno and Shinjuku. On the other hand, many railway accidents also occurred at suburban area. This indicates that if a railway accident occurs on a railway line which connects city-center and suburban area, many railway users' movement are disturbed.

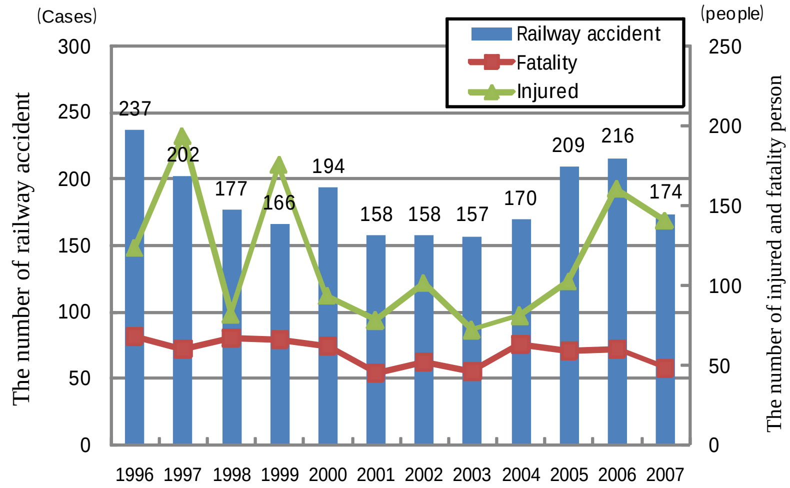

Figure 1 Transition of the number of railway accident in TMA

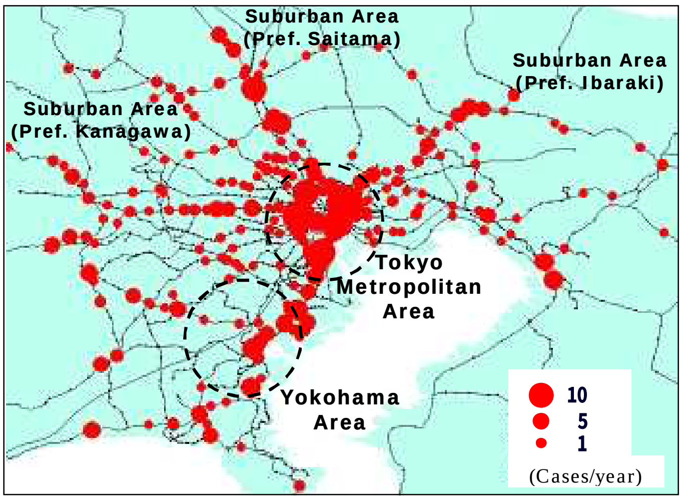

Figure 2 Site of accident in TMA

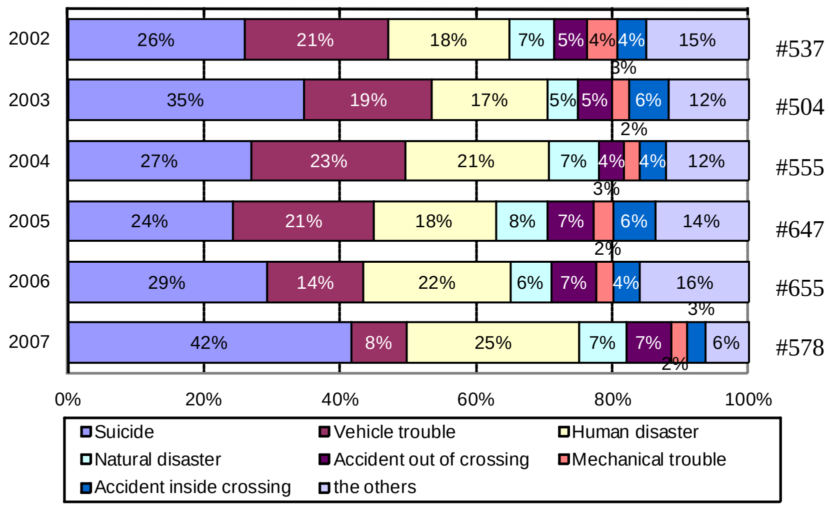

Figure 3 Share of the causes of railway accident

Figure 3 shows the causes of railway accidents. Obviously, the share of suicide has recently increased. Concerning the cause in 2007, suicide was dominant and it occupied about 42%. Recently, more than 30,000 people commit suicide a year in Japan and some of them jump to railway as the method of committing suicide.

As shown in the above, there are many railway accidents have occurred everywhere in TMA. And it has generated not only actual time loss but also opportunity cost. So far, railway network developments in TMA have been done mainly to achieve reducing travel time and easing congestion, and not raising reliability of travel time. However, railway user generally wants to arrive at his/her destination on schedule. Therefore, it is required to consider the raising reliability of travel time as one of the benefit of railway development.

However, there is little information on economic value of the reliability of travel time of railway. Therefore, this study aims to evaluate it by applying contingent valuation method (CVM) which is a survey-based technique to examine the economic valuation of non-market resources. Moreover, expectation of the willingness to pay (WTP) for raising the reliability is derived by using WTP function estimated in this study.

2. REVIEW OF PREVIOUS STUDIES

Over the past few decades, a considerable number of studies have been conducted concerning the railway in TMA. These studies have focused on railway service such as evaluation of the railway service. Little attention has been given to reduce the lost time in the railway network. There is no study to estimate WTP for reducing the lost time. Therefore, we will concentrate on the following issues: evaluation of the railway service, the transport service reliability and the time reliability analysis.

From the view point of the evaluation of the railway service, Terence *et al.* (2001) pointed out that stay at the stage of the research of the reliability of railway service of qualitative assessment. And it demonstrates that the passenger has a willingness to pay for the improvement of the reliability of arrival time. Through the qualitative analysis, it is also possible to include this effect in user's benefit of railway service. However, due to the constraint of data, the quantitative analysis on the lost time of railway passenger has not been done.

From the view point of the reliability of railway network, Terence *et al.* (1994) described that when time-table of public transportation is scheduled, the reliability and robustness of services should be considered. Then he defined that total travel cost is summation of the required time, the transit time, the delay time, the early arriving time and the departure delay time, and he thought that these time were probabilistic. In order to create the time-table with high reliability, it is necessary to solve a total cost minimization problem.

Furthermore, Higgins *et al.* (1998) constructed the models which can estimate an expectation of the delay time of railway service. Delay time divided into “Direct Delay to Trains”, “Knock-on Delay” and “Delay due to late connection”. So, they reflected on the construction of the model. On the other hand, Reitveld *et al.* (2001) defined that uncertainty of arrival time as the reliability. The probability distribution of arrival time and departure time were specified for each transport mode and also the policy option for the improvement of reliability was evaluated through the simulations.

These three researches focused on the improvement of reliability of railway services in normal conditions. On the other hand, Takada *et al.* (2004) analyzed the railway accident using railway accident statistics issued by MLIT. The probability distribution of railway accident was specified. Moreover they built a simulation system, and estimated lost time caused by railway accidents.

The research of evaluation of railway service, the transport service reliability and the time reliability analysis has been reviewed. However, there is no research which examined the WTP for reducing the lost time for railway service.

3. DATA

In this study, a questionnaire survey was executed to collect the data of railway passengers' consciousness for improving the railway service. The survey was conducted in February, 2006. The questionnaire was distributed in front of the ticket gates of four stations such as Kawaguchi, Omiya, Musashi-Koganei, and Shiki which located suburban in TMA.

The questionnaire with an answer sheet was randomly distributed to a person who was supposed to be come out from the gate. Totally, 1418 questionnaires were distributed and 392 answers were returned. The reasons why the return ratio stayed in about 28% are the questionnaires were distributed to the person in the open air, and furthermore the collection of the answer sheet was done by postal mail, which are usually thought to be inefficient survey methods.

In the questionnaire, level of satisfaction for railway service, current situation of railway use, frequency in encounters of service delay, stated preference for change of behavior during the railway service was suspended, and the willingness to pay for improving the punctuality (WTP) were asked to each correspondent.

In this study, contingent valuation method (CVM), which is a survey-based technique to examine the economic valuation of non-market resources, is applied to examine the WTP. The Question about the WTP is shown in the Figure 4.

It is assumed that the WTP depends on largeness of change in condition before and after the improvement of service. Therefore, three set of questions with different conditions were prepared as seen in Table 1. Each set has two questions with different reduction ratio of the lost time. Reduction ratio was set 50% and 100%, and "100%" means that the lost time would be completely resolved.

One question set was printed on the questionnaire, and each correspondent was required to fill in his/her WTP on the answer sheet under the given conditions.

You lost six hours every year because of the delay of railway services. However, it becomes cleared that the improvement of railway system could reduce your lost time. Consequently, please answer the following Question-A and -B.

Question-A: If this improvement reduces 3 hours of your lost from 6 to 3 hours.
How much can you support this improvement?

I can support it by JPY [ ] for this improvement per year.

Question-B: If this improvement reduces 6 hours of your lost from 6 to 0 hours.
How much can you support this improvement?

I can support it by JPY [ ] for this improvement per year.

Figure 4 Example of questionnaire of WTP survey

Table 1 Condition of the WTP survey

Title of question set	Condition setting			
	Reduction Ratio of lost time (%)	Lost time at current situation	Reduced time of lost time	Lost time at post-situation
A	50	2	1	1
	100	2	2	0
B	50	6	3	3
	100	6	6	0
C	50	12	6	6
	100	12	12	0

4. WILLINGNESS TO PAY FOR REDUCING THE LOST TIME

4.1 Characteristics of Willingness to Pay

In this section, the WTP data obtained by the survey is used.

Figure 5 shows the share of the WTP for reducing one hour of lost time. The mean of WTP is JPY 1,958 and the standard deviation is JPY 4,300. In case of excluding the data whose WTP is JPY 0, the mean of WTP is JPY 3,286 and the standard deviation is JPY 5,178.

There were some data with its WTP was JPY 0 and the data was excluded from the data set.

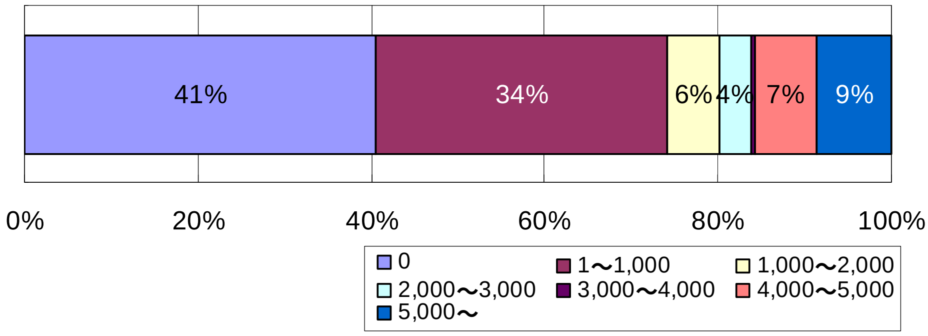

Figure 5 Share of WTP for lost time per year (#=392)

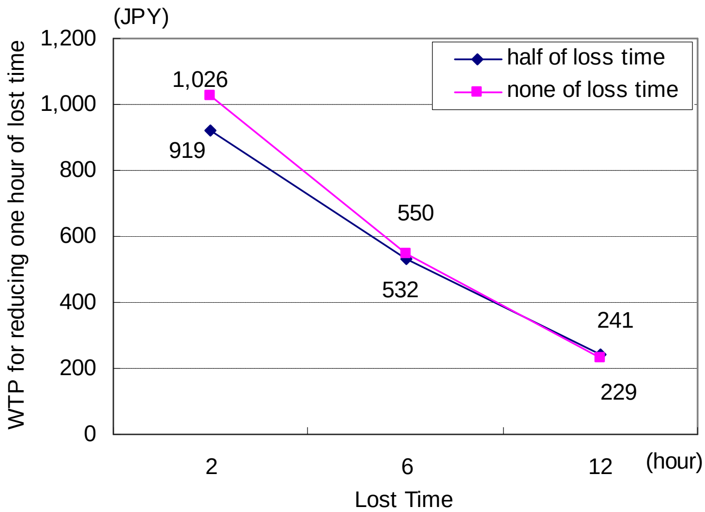

Figure 6 Average WTP for lost time

There are some reasons to exclude the data. One reason is that in spite of improving railway system which can reduce lost time, some user does not have intention to support this by money. Another reason is that they are not interested in this donation from the beginning.

Figure 6 shows the mean of WTP under the specific conditions as described in chapter 4. This figure demonstrates two phenomena. One is that the mean of WTP for reducing one hour of lost time decrease in accordance with the amount of lost time. The other is that the WTP for reducing one hour of lost time is almost equal at any current lost time.

4.2 Analysis on Reduction of Lost Time

4.2.1 Survival Analysis Model

Survival analysis is a collection of statistical procedures for data analysis for which the outcome variable of interest is time until an event occurs. By time, we mean years, months, weeks, or day from the beginning of follow-up of an individual until an event occurs; alternatively, time can refer to the age of an individual when an event occurs. By event we mean death, disease, incident, relapse from remission, recovery (e.g., return to work) or any designated experience of interest that may happen to an individual.

Although, more than one event may be considered in the same analysis, we assume that only one event is of designated interest. When more than one event is considered (e.g., death from any several causes), the statistical problem can be characterized as either a recurrent events or a competing risk problem.

In the survival analysis, we usually refer to the time variables as survival time, because it gives the time that an individual has “survived” over some follow up period. We also typically refer to the event as a failure, because the event of interest usually is death, disease incidence, or some other negative individual experience. However, survival time may be “time to return to work after an elective surgical procedure”, in which case failure is positive event.

In this research, Maximum WTP for each respondent was considered as explained variables of survival analysis. The survival analysis is applied to estimate a WTP function. The survival analysis is explained as follows.

The survival analysis is an analytical procedure that has been used to in the medicine field and the mechanical engineering field. The analysis intended for the relapse of the disease and the event of the death has been done by Nelson (1982) and the analysis intended for the breakdown of the mechanical system has been done. Meanwhile, survival time model is applied in the traffic engineering field by Hensher *et al.* (1994).

The survival analysis model is classified into three types. One type, whether it being assumed to be distribution at the survival time whether the covariate that influences at the survival time has been introduced into the model as a parameter. The covariate is not included into the model as Non-Parametric model, and the distribution type is not assumed. Second type, Semi-Parametric model (proportional hazard model), the covariate is included into the model and the distribution form is not assumed. Third type, parametric model (acceleration failure model) is included after the model of the covariate and the distribution type assumes a specific distribution.

4.2.2 Proportional Hazard Model (Parametric Model)

In this research, the analysis was done by applying proportional hazard model with covariate which increase or decreased its hazard. The proportional hazard model is defined by equation (1). Weibull distribution was assumed in this research as a distribution of base hazard.

$$h(t) = h_0(t)\exp\left(\sum_{i=1}^{m}\beta_i x_i\right) \quad (1)$$

$h(t)$ as hazard function, $h_0(t)$ as base hazard function, λ as shape parameter, γ as scale parameter, β_i as covariate parameter.

Then, the basic hazard function is shown by equation (2).

$$h_0(t) = \gamma\lambda t^{\gamma-1} \quad (2)$$

Therefore, the hazard function $h(t)$ is shown from equation (1), (2) by equation (3).

$$h(t) = \gamma\lambda t^{\gamma-1} \exp\left(\sum_{i=1}^{m} \beta_i x_i\right) \quad (3)$$

The survival function $S(t)$ is led from equation (3), it is equation (4).

$$S(t) = \exp[(-\lambda t^{\gamma}) \exp\left(\sum_{i=1}^{m} \beta_i x_i\right)] \quad (4)$$

Formulation of 4.2.2 referred to Hougaard(2001), Kitamura *et al.*(2002), Uchinami *et al.*(2005), and Kin *et al.*(2008).

4.2.3 Estimation Results of WTP Models

In this study, WTP per year is applied for the explained variable. Then, nine explanatory variables are employed for covariates as seen in table 2. The proportional hazard model was estimated by using the maximum likelihood estimation method. In this study, the explanatory power of the model is evaluated by AIC (Akaike's Information Criterion).

Table 2 shows basic statistic of the covariate used for the estimation.

Table 2 Basic statistics value of covariate

Covariate	Unite	Average	Standard Deviation
WTP per year	JPY	1,958	4,300
Times of use per month	Times	16.8	8.0
Times of delay per month	Times	3.0	2.8
Lost Time per year	Hour	6.7	4.3
Reduced Time per year	Hour	5.0	3.8
Encounter Ratio per month	-	0.2	0.3
Annual Income	Million yen	2.6	2.9
Age	Years old	4.5	1.5
Sex*	-	Male:31.3% ,Female:68.7%	
Number of Sample	sample	233	

* Male: 0 and Female: 1

Table 3 shows the result of parameter estimation. Model-1 is the model estimated with all covariates. Meanwhile, Model-2 is a model estimated with selected six covariates. Model-2 has most explanatory power by AIC.

Table 3 Parameter Estimation Results with the Proportional Hazard Model

Covariate		Model-1		Model-2	
Variables	Unit	coefficient	t-statistics	coefficient	t-statistics
Times of use per month	Times	-0.043	-3.91	-0.036	-4.00
Times of delay per month	Times	0.028	0.85	—	—
Lost Time per year	Hour	0.061	2.10	0.061	2.10
Reduced Time per year	Hour	-0.11	-3.24	-0.112	-3.29
Encounter Ratio per month	—	-0.878	-3.00	-0.685	-3.31
Annual Income	Million Yen	0.014	0.52	—	—
Age	Years old	-0.116	-2.52	-0.108	-2.45
Sex	—	0.252	1.58	0.216	1.52
Scale Parameter γ	—	0.859	17.53	0.856	17.47
Shape Parameter λ	—	0.0017	16.25	0.0016	16.82
AIC	—	4195		4192	
Number of Sample	Sample	233		233	

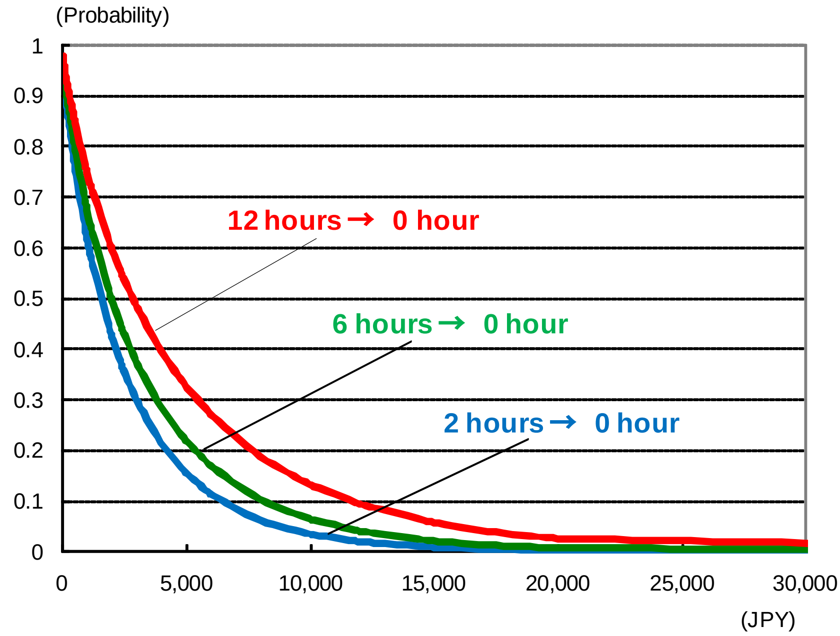

Figure 7 Distribution of survival function

Significant covariates of Model-1 and Model-2 are "Times of use per month", "Lost Time", "Reduced Time", "Encounter Ratio" and "Age". We utilize the Model-2 to calculate expectation of WTP.

Figure 7 shows distribution of estimated survival function regarding to the WTP for reducing the lost time. Shape of survival function depends on the value of covariates as seen in Figure 7. Expectation of WTP is calculated by integration of survival function from 0 to infinity. When

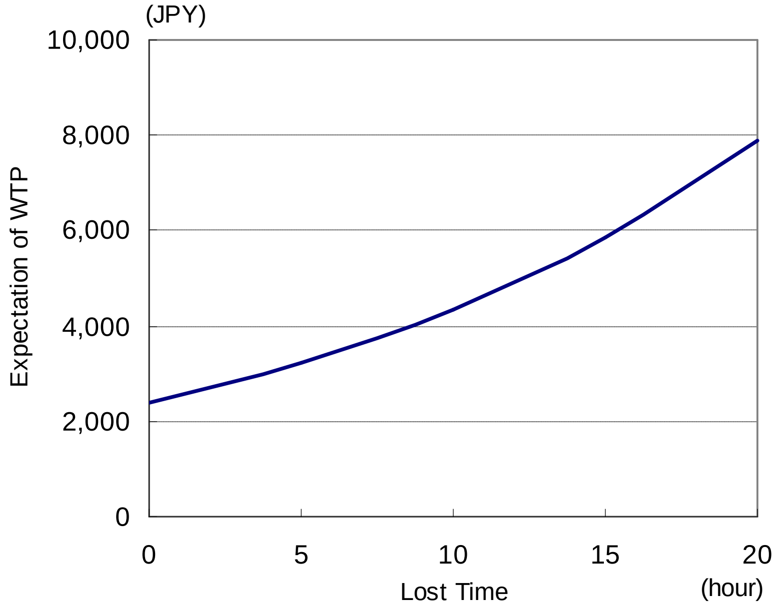

Figure 8 Expectation of WTP

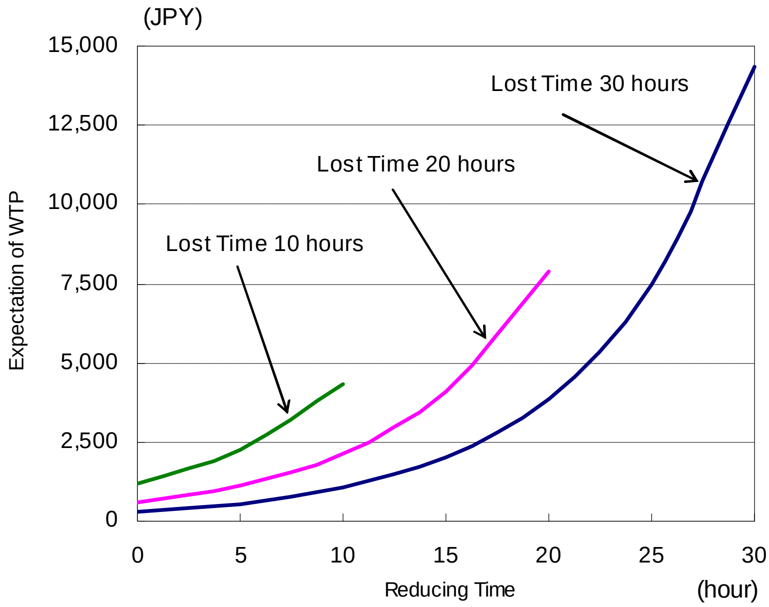

Figure 9 Expectation of WTP for reducing lost time

the expectation was calculated, the mean of each covariate was used.

Figure 8 shows the expectation of WTP when the current lost time is completely eliminated. It is comprehended that expectation of WTP is proportional to the amount of lost time.

Figure 9 shows expectation of WTP which change in accordance with reduced lost time. Meanwhile, the three curbs in the figure show the expectations of changing in proportion to the reducing lost time.

5. CONCLUSION

In this research, the questionnaire survey was conducted to collect the data on the user's preference for reducing lost time caused by the delay of railway service. To inquire the user's WTP for reducing lost time, CVM is applied. Moreover, the survival analysis is utilized to estimate coefficients of WTP function. The WTP function is also utilized to evaluate the expectation of the WTP.

As the results of this study, the WTP function which can consider the covariates is estimated. And it becomes clear covariates such as "Times of use per month", "Lost Time", "Reduced Time", and "Encounter Ratio" affect the expectation of the WTP. Meanwhile, expectation of the WTP depends on the largeness of his/ her current lost time, and also reduced lost time.

In future, we will estimate the user's benefit of reducing lost time using the estimated WTP function and a simulation system built by the authors.

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