EVALUATION OF LOW-FLOOR LIGHT RAIL VEHICLE BASED ON CONTINGENT VALUATION METHOD

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Abstract: This paper aims to monetarily evaluate customers' subjective values including satisfaction with Low-Floor Light Rail Vehicle (LRV) by applying Contingent Valuation Method (CVM). Original surveys were conducted in Hiroshima targeted on tram users and residents along the tram route. A new method correcting the biases inherent in willingness-to-pay responses is proposed. As a result, it is found that the customer satisfaction for getting on and off the LRT would be improved by the introduction of the LRV. Moreover, a new method proposed in this study has capability to correct biases caused by survey design and to indicate the interval of the true subjective values.

Key Words: Light Rail Vehicle, Contingent Valuation Method, subjective values

1. INTRODUCTION

Increasing automobile traffic becomes major cause of environmental deterioration such as air and noise pollution, traffic congestion, and decline of downtown area. One of the measures against such problems is to shift passenger traffic to public transport by improving its level of services. Above ail, LRT (Light Rail Transit) systems have advantages over other transit modes in low emission and user-friendliness. High-performance vehicles called LRV (Light Rail Vehicle) are extensively introduced in tram systems in many cities. LRV excels in acceleration, deceleration, maximum speed and low noise and vibration level. Besides, LRV has large capacity because the length of a unit is longer than that of conventional streetcar. The height of the vehicle floor from the ground is much lower in most of new type LRVs. Passengers, particularly for elderly and disabled people, can easily get on and off the vehicle. Most popular type is partly low-floor vehicle (low-floor 70%) and some of the LRV has complete low floor (low floor 100%).

Nowadays, many local governments and transit firms in Japan are also planning to introduce LRT systems or replace conventional rolling stocks by LRV. Low floor type LRV was firstly introduced in 1997 in Kumamoto city, and next in Hiroshima in 1999. However, there are many obstacles for this innovation, such as obsolete technical regulations, poor financial resources. One of the largest barriers is the difficulty to evaluate the effects of LRV because there are various non-monetary effects in LRV - these effects are exactly the characteristics of LRV such as option value, vicarious value. For that reason, these kinds of effects are not

considered in the manual of cost benefit analysis for railway projects established by Japanese Ministry of Transport (1999). Such non-monetary effects should be considered more explicitly in cost benefit analysis in order to realize better quality of public transport.

Contingent Valuation Method (CVM) is one of the economic measurements to evaluate the value of environment and other no-monetary goods. In this method, researchers directly ask willingness to pay (WTP) or willingness to accept (WTA) for the change of environment quality to the respondents and evaluate its value. CVM enables to evaluate the benefits regarding hypothetical environment quality as well as that of the real environment quality. Furthermore, this method has such a great advantage that can measure non-use value of environment quality. However, various kinds of biases are existed in stated WTP or WTA in questionnaires.

This research focuses on the subjective values of LRV resulted from lowering floor in the case of Hiroshima by Contingent Valuation Method (CVM). The data for the analysis were collected by original questionnaire surveys targeting on passengers and residents living along the tram route (chapter 2). In chapter 3, passengers' satisfaction scores and observed willingness to pay are shown as the results of the surveys. Chapter 4 and 5 propose a new method correcting the biases inherent in willingness-to-pay responses and show that the new method has capability to correct biases caused by survey design and to indicate the interval of the true subjective values of LRV.

2. QUESTIONNAIRE SURVEY IN HIROSHIMA

2.1 Outline of LRV in Hiroshima

The Low-Floor Light Rail Vehicles introduced in Hiroshima is given the nickname "GREEN MOVER". In June 1999, the first unit was introduced. In October 2000, four units have been introduced. The unit has complete low flat floor and has 5 bodies with 3 bogies. The floor height from the ground is 33cm; on the other hand, 78cm of the conventional vehicles. The floor height from the platform is only 3cm. There are 52 seats and space for wheelchair is assigned. The expected effects through introducing the vehicles are below.
1. Easy to get on and get off not only for ordinary people but for disabled and elderly people.
2. Shorten the stoppage time resulted from smoother boarding.
3. Better comfort by lowering noise and vibration in the vehicle.

2.2 Design of The Survey

Original questionnaire surveys were conducted in May and October 1999 in Hiroshima, before and after introduction of the LRV. Respondents are targeted on both passengers (users) and residents living along the tram route. The reason why two types of respondents are chosen is that evaluation of the streetcar may differ from their frequency of using the tram. In the questionnaire survey to residents, as samples with less opportunity to use the tram, the samples were picked up by home visits in several residential area where one to three kilometers distant from the tram stops. In the survey to the passengers, as samples with more opportunity to use, questionnaires were directly distributed to passengers at main tram stops and were returned by mail. The result of collection is shown in table 1.

Table 1. Distribution and collection of questionnaire sheets

	Attribute	Number of distribution	Number of collection	Number of valid respondents
Before infroduction of LRV	User	3000	391	390
	Resident	994	878	730
After infroducion of LRV	User	1342	383	383
	Resident	780	704	570

On the two surveys, the authors collected personal attributes, respondents' satisfactory score

for several service quality items concerning the transit system and the new vehicle. And on the first survey, that was conducted before introduction of LRV, the authors also asked "Willingness to pay" for replacing conventional type vehicles by low- floor LRV in several situations. WTP concerning direct use value, option value and vicarious value of lowering vehicle floor were asked in the questionnaire by open-end type question.

In the question concerning WTP, double stages questions are designed to remove 'refused bid' in later analysis. First of all, the introduction plan of LRV was explained to respondents and they were firstly asked whether respondents approved or not the plan. Next, respondents are asked their WTP, that how much money respondents had a willingness to pay for replacing conventional vehicle by LRV in a hypothetical case: replacing half of total conventional vehicles by new Low-Floor LRV, and asked their WTP to respondents who answered "approval for the policy" and "I have no idea" in order to remove 'protest bid'.

Furthermore, two ways for payment were set in order to observe the difference between the payment ways for improving rolling stocks; one is by increasing the train fare (Group A/B), and the other is by increasing citizens' tax (Group C/D). The authors also asked WTP in following two cases in order to observe option value; one is considered the value of LRV not only respondents themselves but also others such as the elderly persons (Group B/C/D) and another is considered the value of only respondents themselves (Group A). The grouping is shown in table 2.

Table 2. Grouping for CVM analysis

Group	A	B	C	D
Attribute	User	User	User	Resident
Payment	Fare	Fare	Tax	Tax
Beneficiary	Respondent only	Respondent and others	Respondent and others	Respondent and others
Sample size	149	147	233	694

3. CUSTOMERS' SATISFACTION AND OBSERVED WILLINGNESS TO PAY ON LRV

3.1 Results of Customer Satisfaction on LRV

In the first survey, 24 items of questions were set concerning the services of the vehicle and respondents were asked in the questions by rating a 5 stages evaluation which concerns the service quality of conventional type vehicle in the all samples. In the second survey, 5 items of questions were set concerning new LRV targeted respondents who experienced to ride the new vehicle. The authors calculated the average values of evaluation of the all customer satisfaction scores on both conventional vehicle and new LRV and picked up 6 question items of customer's satisfaction scores that were expected to change by introduction of LRV. The results are shown in figure 1.

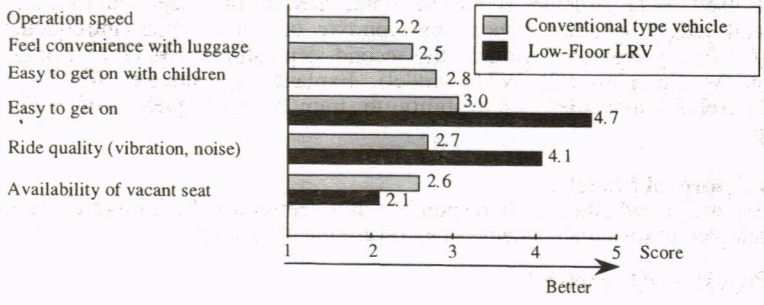

Figure 1. Average customer satisfaction scores on the two vehicle types (in the case of residents)

The satisfaction scores concerning comfort such as 'easy to get on', 'ride quality' increased by introducing new LRV. The reason why 'availability of vacant seat' was dropped in new LRV is that number of the seat of new vehicle decreased because of the change of seats allocation design caused by the existence of truck box on the floor.

3.2 The Results of WTP Aggregation

The results of the policy approval or disapproval and WTP for lowering the vehicle floor are shown in table 3. From the view of option value the case of payment by train fare (Group A and B), WTP of group B, which considers other people's use, is higher than Group A. The rate of approval is also higher in Group A. The rate of disapproval in tax payment case is higher than that in fare payment case (Group B and C). Frequent users have higher WTP and approval rate (group C and D). Number of valid respondents in WTP calculation is smaller than total samples because some samples have blanks in WTP responses.

These results mean that payment by fare is more acceptable to the expense for introducing Low-Floor LRV in this case and that 'option value' and 'vicarious value' exist in Low-Floor LRV.

Table 3. The results of the policy approval or disapproval and WTP

Group		A	B	C	D
Approval		67(45%)	87(59%)	99(42%)	227(33%)
No idea		33(22%)	27(18%)	43(18%)	168(24%)
Disapproval		49(33%)	33(22%)	91(39%)	299(43%)
WTP	Median	30.0	20.0	500	500
	Mean(Gross)	39.8	40.6	980	824
	Mean(Net)	26.8	31.6	579	428
	Valid respondents	95	109	130	324
	unit	JPY/one ride		JPY/month	

4. DECISION FACTORS OF WTP DERIVED FROM WTP MODELS

4.1 Model Formulation

In this chapter, WTP for introducing low-floor LRV are estimated in order to grasp decision factors of respondents' WTP and to examine the methods of correcting biases (refused-bid') in survey data as a preparatory step for chapter 5. Considering that the results in the previous chapter show that subjective value of LRV is reflected their approval for policy as well as their WTP itself, WTP structure should be represented by two steps; the first step covers all samples and judges whether respondents approve or not the plan introducing low-floor vehicles ((1) Policy Approval Model), the second step estimates WTP of whom approve or not disapprove the plan ((2) WTP Model). Explanatory valuables for the models are personal/household attributes, accessibility to tram stop, frequency of using tram, car ownership.

(1) Policy Approval Model
This model judges whether each respondent has 'refused-bid'. Disaggregate binary logit model is adopted to formulate whether they refuse the plan or not.

$$\Pr(yes) = 1/[1+\exp(-V)] \quad (1)$$

$$V = \alpha + \beta \mathbf{x} \quad (2)$$

yes : 'approve' or 'no idea'

$\mathbf{x}$: explanatory valuables vector
α , β : unknown parameter

(2) WTP Model Based on Survival Analysis

WTP is estimated by survival analysis using accelerated-failure time model. Probability distribution of WTP t is formulated by survival distribution function $S(t, \mathbf{x})$.

$$S(t, \mathbf{x}) = \Pr(T > t \mid \mathbf{x}) = S_0[t \cdot \exp(-\beta \mathbf{x})] \quad (3)$$

T : random valuable
$\mathbf{x}$: explanatory valuables vector
S_0: baseline survival function

Weibull distribution is applied to S_0 in this study. The survival function is expressed as equation (4).

$$S(t, \mathbf{x}) = \exp[-\lambda \{(t + \xi) \cdot \exp(-\beta \mathbf{x})\} \gamma] \quad (4)$$

λ , ξ , γ : parameter

4.2 Results of Model Estimation

Estimation results are shown in table 4 and table 5. The lager parameter means higher WTP. The reason why sample size in both cases are different from table 1 is that some of the samples are omitted in estimation because of the blanks in the concerning questions.

The results of WTP estimation shows that respondents who live with elderly people have higher WTP in Group B/C/D which consider the option value in the questions. Income level has little influence on WTP in tax payment Group C/D. Higher frequent users in Group A/B, payment by fare, have likely to feel more approval for the plan, however, to respond lower WTP. In the case of C/D, payment by tax, goodness of fit in WTP model is lower. This suggests that there may be other unobservable factors or larger error variation. From this analysis, it is found that the difference of respondents' attributes, way of payment, beneficiaries which respondents considered are reflected to decision making of WTP structure.

Table 4. Estimation results of Policy Approval Model

Explanatory valuables	Group A	Group B	Group C	Group D
Sex # (male:1)	0.312	0.151	-0.154	*-0.635
Age	0.014	-0.014	0.022	0.003
Vocation #	-0.622	-0.312	0.080	0.395
Living with babies#	0.003	-0.790	-0.534	-0.282
Living with children (<12 yrs old)#	-0.916	-1.335	-0.589	0.095
Living with elderly people(>64 yrs old)#	0.631	0.265	-0.400	0.226
Income (/year: JPY)	0.176	*0.228	-0.074	0.018
Car ownership#	-0.222	-0.425	-0.225	0.125
Accessibility to station # 1)	-0.198	-0.313	-0.045	0.084
Accessibility to station # 2)	1.302	0.279	-0.517	*0.588
Commuting#	-0.246	-0.282	-0.278	0.073
Frequency to ride tram in private purpose	*0.066	0.067	0.016	0.030
Constant	-0.786	0.962	0.094	-0.314
Sample size	112	110	172	498
Initial likelihood	-77.6	-76.2	-119.0	-342.0
Maximum likelihood	-59.1	-48.7	-107.0	-328.0
Likelihood ratio	0.239	0.361	0.104	0.041

*:significant at 5%
#: Dummy parameter
1) 1: less than 1km, 0:other 2): 1km～2km, 0:other

Table 5. Estimation results of WTP Model

Explanatory valuables	Group A	Group B	Group C	Group D
Sex # (male:1)	0.156	0.156	-0.067	-0.116
Age	0.0003	0.001	-0.002	-0.011
Vocation #	0.209	-0.107	0.423	0.402
Living with babies#	-0.208	-0.387	-0.100	-0.286
Living with children (<12 yrs old)#	0.386	0.466	-0.213	-0.098
Living with elderly people(>64 yrs old)#	-0.008	0.195	0.237	0.204
Income (/year: JPY)	-0.009	-0.005	0.049	-0.016
Car ownership#	*0.316	*0.439	0.009	0.060
Accessibility to station # 1)	-0.289	0.044	-0.448	0.214
Accessibility to station # 2)	-0.126	-0.132	0.061	**0.640
Commuting#	-0.054	-0.078	-0.185	*-0.398
Frequency to ride tram in private purpose	-0.014	-0.009	0.014	0.003
Constant	1.496	1.375	4.813	4.359
λ	0.075	0.104	0.185	0.075
γ	**1.356	**1.238	**1.078	**0.976
Sample size	73	86	104	239
Likelihood ratio	0.239	1.238	0.104	0.041

*: significant at 5%; **: significant at 1%
#: Dummy parameter 1): less than 1km, 0:others 2): 1km～2km, 0:others

5. VALUE OF LOW-FLOOR LRV: CORRECTING PROTEST BID BIAS

5.1 Correcting Process of Protest Bid Bias

The answer 'disapprove the plan' is defined as 'refused-bid' in this study. Refused-bid can be divided into two groups; the answer resulted from negative value on the plan, and the answer resulted from disapproval by non-economic reasons (against the way for payment etc.) although one has a positive value on the plan. The latter one is called 'protest bid bias' and it must be corrected by some methods in estimating WTP.

This chapter estimates a true interval of the value by lowering floor of LRV by the flow shown in figure 2. The following two ways for correcting refused-bid are proposed as a preparatory step of estimating WTP by applying survival analysis.

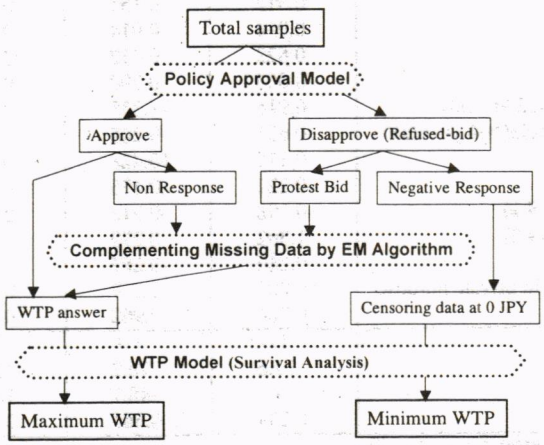

Figure 2. Estimation flow of the value of LRV

(1) All refused-bid answers are assumed to be resulted from negative value, and are regarded as left censoring data at 0 yen.
(2) All refused-bid answers are assumed to be resulted from protest bid, and are regarded missing data of WTP and are complemented by EM algorithm.

The WTP derived from the first way will be a minimum of the true value of LRV because all refused bid respondents are supposed to have negative value. The WTP derived from the second way will be a maximum of the true value of LRV because all respondents with refused bid are supposed to have same value of LRV as other respondents.

5.2 Estimation of WTP

(1) Minimum Value of LRV

Survival analysis is applied to estimate the minimum value of LRV. In the case of left censoring data, the interval which has a possibility to happen event is expressed as [- ξ ,0] and probability to happen the event is expressed as equation (5) .

$$\Pr(T \leqq 0)=1-S(\xi) \tag{5}$$

$S(t)$: survival distribution function

Logarithmic logistic distribution is applied to $S(t)$ from the results in preparatory analysis.

(2) Maximum Value of LRV

As shown in figure 2, survey samples include two types of missing data; 'non response' from respondents who approve the plan and 'protest bid' from respondents who disapprove the plan. These missing data need to be complemented simultaneously in estimating more correct value.

In this study, EM algorithm is applied to complement the missing data. Five random numbers are generated in order to keep stability of random numbers and five patterns of complemented pseudo data are estimated from each case. WTP model are estimated from each case by applying Weibull distribution as survival function and average coefficient of parameter is derived.

(3) Value by Lowering Floor of LRV

Estimation results of the two values and distribution of WTP by Kaplan-Meier estimator are drawn in figure 3 (case of group D). Fitness can be visually checked whether minimum values are requested to close to Kaplan-Meier estimator. The true value of LRV will be located between the maximum curve and the minimum curve in figure 3.

Estimated means and medians are shown in table 6. WTP per month in Group A and B are converted values by 'WTP per one ride' and average frequency of using tram per month (13.9 times). It is found that minimum value of WTP by residents (Group D) has lower compared to the case of users (Group A/B/C). This is because all refused-bid are assumed to be negative value. WTP paid by tax is higher than that by fare in both mean and median in maximum case. It is also found that the difference of WTP per month (converted values) between A and B is larger than that between B and C. This means that effect of considering others' value is higher than that of difference of payment ways.

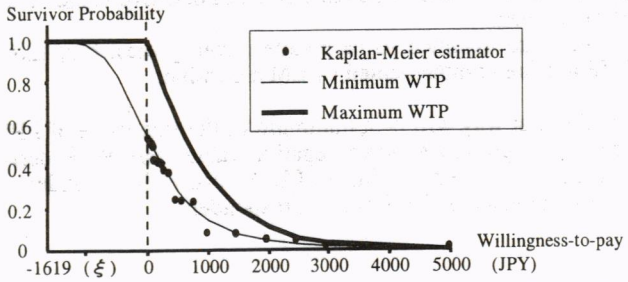

Figure 3. Estimation results of survival function (case of group D)

Table 6. Estimation results of the value of LRV

	Group	A	B	C	D
Mininum Value	Median	11.6(161)	18.4(255)	208	61
	Mean	16.9(234)	25.0(347)	423	241
Maximum Value	Median	35.1(486)	33.1(458)	807	672
	Mean	41.4(547)	41.2(571)	1065	905
	unit	JPY/one ride (JPY/month)	JPY/one ride (JPY/month)	JPY/month	JPY/month

6. CONCLUSIONS

This paper focuses on the subjective values of LRV resulted from lowering floor in the case of Hiroshima by using Contingent Valuation Method (CVM). It is found that the customer satisfaction for getting on and off the LRT would be improved by the introduction of the LRV. It is also found that payment by fare is more acceptable to the expense for introducing Low-Floor LRV in this case and that 'option value' and 'vicarious value' are also exist in Low-Floor LRV. A new method correcting the biases inherent in willingness-to-pay responses are proposed in chapter 5 and a true interval of the value by lowering floor of LRV are estimated by using survival analysis and EM algorithm.

The results of the surveys and correcting bias method proposed in this study can give suggestions to revise official evaluation methods and new financing system for improving public transport. Revising questionnaire design and conducting another survey are further subjects for this study.

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