MONETARY EVALUATION OF VARIOUS SNOW REMOVAL ATTRIBUTES BY CONJOINT ANALYSIS

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1. Abstract

Snow removal projects incur considerable cost every year, they aim to minimize the effect of snow on road transportation. However, purpose of operation and operation method differ according to snow removal attributes. Therefore, it is important to measure the individual effect of various attributes of snow removal, for efficient implementation of snow removal projects. This study attempts to measure the marginal benefit of each attribute by conjoint analysis, toward evaluation the effect of snow-removal for each attribute.

In this study, various procedures of investigation and analysis were developed for conjoint analysis, which is a technique used in marketing. A logit model theory developed using random utility was used in this analysis. Snow removal projects were classified into the 5 attributes of frequency of operation, road width, sight distance, frozen road surface, bumps on road; and 2 or 3 levels were set for each. In addition, donation amount based on actual operation cost was set at 5 profiles. A questionnaire survey on Willingness to Pay was conducted on Sapporo citizens by postage-paid card in June 2000.

It was shown to be possible to use the voluntary profile for conjoint analysis. It also was shown to be possible to estimate the marginal willingness to pay of snow removal. Results of this study can be expanded for the policy statement by application of the environment economical evaluation theory, when the snow removal project is evaluated.

2. Introduction

Snow removal projects incur considerable cost every year, they aim to minimize the effect of snow on road transportation. However, purpose of operation and operation method differ according to snow removal attributes. Therefore, it is important to measure the individual effect of various snow removal attributes, for efficient implementation of snow-removal projects. This study attempts to measure the marginal benefit of each attribute by conjoint analysis, toward evaluation the effect of snow removal for each attribute.

This study surveyed willingness to pay for snow removal of various attributions and levels, and it evaluated the benefit of each attribution by conjoint analysis. The results express the marginal benefit of attribution. If we are able to calculate the marginal costs of each operation, we can determine optimal service level of snow removal operations by optimal supply condition of public goods, which is called the Bowen-Samuelson condition. This paper reviews existing research (Chapter 3), develops a framework for conjoint analysis (Chapter 4), provides an estimation model for willingness to pay (Chapter 5) and closes with conclusions (Chapter 6).

3. Review of existing research

In most studies on evaluation of snow removal, the evaluation method focuses on user benefit, such as cumulation of cost as benefit, reduction of travel time and reduction of travel cost. Tanabe et al. (1998)[1], Morisugi et al. (2000)[2] and Hayashiyama et al. (2001)[3] tried to evaluate the quality of life by Contingent Valuation Method (CVM) based on welfare economic theory. We were unable to evaluate goods and services that have many attributions, because it is characteristic of CVM that goods and services are evaluated as a bundle. We are able to evaluate attributions of goods and services not by CVM but by conjoint analysis. Conjoint analysis was developed to promote commodities efficiency. Recently there are many examples (e.g., Takeuchi (1998)[4]) in which this method is used to evaluate investment in environmental improvement. In infrastructure planning, there are examples in which the method is applied by Yuzawa et al. (1990, 1995)[5][6] to the modal split choice model. Conjoint analysis applies not only not to research, but also to actual policy.

4. Framework of conjoint analysis

This chapter discuses the framework for evaluating snow removal projects by conjoint analysis.

4.1 Selection of conjoint analysis method

Conjoint analysis was developed by Luce and Tukey (1964)[7]. The method is used to evaluate the various values of goods and services by stated preference data. It can be classified as Rating-based Conjoint or Choice-based Conjoint, depending on the questioning method. In the former, the respondent gives optional points and arranges the profiles in order preference. In the later, the respondent chooses a primary profile in the bundle of attributes. Rating-based conjoint is subclassified as Full-profile Rating-based Conjoint or Pair-wise Rating-based Conjoint. In Full-profile Rating-based Conjoint, the respondent evaluates various profiles under understanding of all profiles. Respondents are confused by this method, in that it is difficult to understand the questionnaire. Thus, in Pair-wise Rating-based Conjoint, the Full-profile Rating-based Conjoint is simplified for respondents. There are many methods of conjoint analysis. However, when consumers buy goods and services, they choose goods and services not to so much by evaluating them on absolute terms as by comparing them. Thus, we use Choice-based Conjoint in this study.

4.2 Classification of attributions and levels of snow removal

Figure 1 and Table 1 show the attributions and levels of snow removal in this study. These are the materials used to make the profiles. We established 6 attributions and 2 or 3 levels of snow removal, by referring to snow removal standards. These attributions are frequency of operation, effective road width, height of snow piled at the shoulder, stopping distance, bumps on road, and willingness to pay based on cost of operation. We referred to Hokkaido Development Bureau data (1998)[8] for stopping distance. We established three levels of classification; the present level, the improved level, the deteriorated level. The attributions cover most snow removal operations, making it possible for respondents to evaluate and choose the profile made from these attributions and levels.

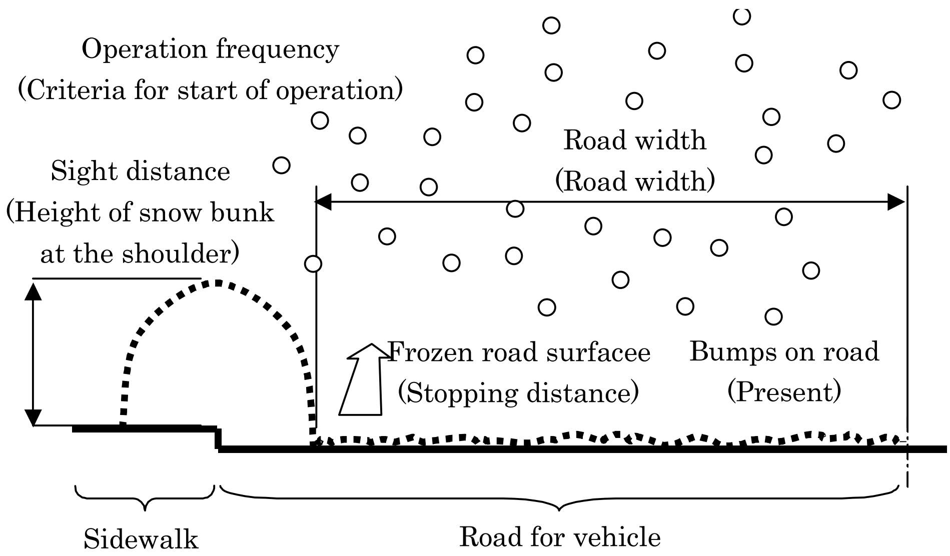

Figure 1 Attributes of Projects for Removal of Snow from Roads

Table 1 Attributions and Levels of Projects for Snow Removal from Roads

Attribute (Level index)	Level	Description
Frequency of operation (Criteria for start of operation)	5 cm 10 cm 20 cm	Snow depth under ankle Snow depth at ankle Snow depth under shin
Road width (Road width)	90% (7.7 m) 80% (6.8 m) 60% (5.1 m)	Shoulder is not covered Shoulder is covered Width of road reduce half
Sight distance (Height of snow bunk at the shoulder)	0.5 m 1.5 m 2.0 m	No problem Hidden children for bunk Hidden adults for bunk
Frozen road surface (Stopping distance /(40 km/h))	90 m (μ=0.10) 50 m (μ=0.25) 40 m (μ=0.45)	Slippy surface Covered snow Jamming snow
Bumps on road (Present)	High (Present) Low (Absent)	Present Absent
Willingness to pay (Operating cost)	------	Based on operating cost

4.3 Production of Profiles and Data Collection

In this study, we choose there are some profiles in 162 combinations of profiles. We tried to produce five profiles by using two methods, which were developed by voluntary. This method produces profile combinations through brainstorming by road administrators, and enables the inclusion of profiles that can be manipulated by surveyor.

Respondents are the head of household in Sapporo. We asked 249 persons and effective responses are 242, for an effective response rate of 97.2%.

Table 3 Voluntary profiles

	Operation frequency	Road width	Sight distance	Frozen road surface	Bumps on road	Willingness to pay
A	20 cm	60 %	2.0 m	Low	90 m	600
B	10 cm	80 %	0.5 m	Low	40 m	1,100
C	10 cm	60 %	2.0 m	High	50 m	1,300
D	20 cm	80 %	1.0 m	High	90 m	8,400
E	5 cm	90 %	0.5 m	Low	50 m	10,500

5. Model of estimation for willingness to pay

5.1 Outline of the model

When utility u_i of individual *i* expresses a utility function $u_i(\cdot)$, then utility under choosing profile *j* (1,2,3,…n) by individual *i* expresses a utility function $u_{ij}(\cdot)$.

$$u \equiv u_{ij}(\bullet) \qquad (1)$$

According to the theorem of random utility, the utility function $u_{ij}(\cdot)$ is expressed by fixed term $v(\cdot)$, probabilistic term ε, sets of road condition Q, and willingness to pay, from equation 2.

Here, the probability of individual *i* choosing profile *j* was expressed by assuming probabilistic term ε the Gumbel distribution as equation 3.

$$u_{ij} = v_{ij} + \varepsilon_{ij} = v_i\left(Q_j, y_{ij}, M\right) + \varepsilon_{ij} \qquad (2)$$

$$P_{ij} = \frac{exp(v_{ij})}{\sum_k exp(v_{ik})} \qquad (3)$$

4.2 Specification of the model and result of estimation structure

Generally, we use equation 4 as linear model for indirect utility function $v(\cdot)$.

The conversion of monetary benefit is expressed by equation 5 according to fixing utility level the beginning after indirect utility function is differentiated.

$$v_{ij} = \sum_{k=1}^{6} \beta_{ijk} x_{ijk} \qquad (4)$$

$\beta_{ij1} \ldots \beta_{ij5}$: the parameter of options of road condition for individual *i*
β_{ij6} : the parameter of options of willingness to pay for individual *i*
$x_{ij1} \ldots x_{ij5}$: road condition of options for individual *i*
x_{ij6} : willingness to pay of options for individual *i*

In this case, x_6 = y (income).

Here, because $x_1, \ldots, x_5$ are independent variables, equation 5 can be transformed into equation 6. These are the marginal benefit of every attribution.

$$\beta_6 dy = \sum_{i=1}^{5} \beta_i dx_i \qquad (5)$$

$$\frac{dy}{dx_1} = -\frac{\beta_1}{\beta_6} \quad \Rightarrow \quad \frac{dy}{dx_i} = -\frac{\beta_i}{\beta_6} \qquad (6)$$

Table 3 shows the result of estimation parameters by using maximum likelihood estimation, because t-value of each parameter, maximum likelihood ratio and hit ratio are statistically significant. Signs (+/-) of parameter mark agree with sign of each level. Accordingly, these results were statistically significant.

Table 3 Result of estimation parameters

i	Name of variables	Parameter (t-value)
1	Operation frequency	-0.642 (-9.54)
2	Road width	47.452 (2.60)
3	Snow bunk at shoulder	-15.318 (-7.94)
4	Bumps on road surface	-12.858 (-5.54)
5	Frozen road surface	28.198 (8.13)
6	Willingness to pay	-4.414×10^{-3} (-8.67)
	Likelihood ratio	0.356
	Hit ratio (%)	83.7
	No. of samples	1,210

5.3 Calculating benefit

Table 4 and figure 2 show the marginal willingness to pay for snow removal projects on arterial road (national road) per household in Sapporo.

1) The WTP for initiating removal of fresh snow at the first 1 cm is 145 yen.
2) The WTP for bringing the effective road width to within 10 % to that in summer is 10,750 yen.
3) The WTP for lowering the snow bunk height per 0.1 m is 3,470 yen.
4) The WTP for road surface correction is 2,913 yen.
5) The WTP for raising friction coefficient by 0.1 using anti-freezing agent is 6388 yen.

6. Conclusions

This study showed that the marginal benefit is able to evaluate the marginal willingness to pay by application of Conjoint Analysis for evaluating each attribution on snow removal projects. This study showed that, because the marginal benefit is equivalent to the marginal willingness to pay, we can apply conjoint analysis to evaluate each attribute of snow removal projects. People in Sapporo are particularly interested in the maintenance of effective road width and the spreading of de-icing and anti-icing agents. This method is considered useful in the difficult case of collecting preference data on winter traffic phenomena, although willingness to pay does not unique. In the future, development of methods for collection and analysis by substational traffic and behavior data will be important.

7. References

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