BENEFIT EVALUATION OF ROAD SNOW REMOVAL IN THE TOHOKU REGION

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1. Introduction

During the winter, accumulated snow obstructs traffic, seriously disrupting people's private lives and their social and economic activities. To prevent these problems, the Ministry of Land, Infrastructure, and Transport (MLIT) and regional governments carry out snow removal works to guarantee safe, smooth, and comfortable traffic conditions during every winter. But under tight financial conditions in Japan, snow removal should be conducted efficiently and its effectiveness must be quantitatively clarified.

This research stands on the view that its efficiency should be evaluated by cost benefit analysis and the benefit should be evaluated using consumers' surplus analysis that is used by all traffic project evaluation manuals. There are two reasons for this position. First, if a general equilibrium traffic demand curve is used, it is possible to measure the repercussion effects through market mechanisms. Secondly, by introducing items such as punctuality, comfort etc. to generalized travel cost, it is possible to represent the benefits as the reduction of generalized travel cost. If the previous researches surveyed by Tanabe et. al. [1)] can be categorized from this perspective into the following. Research performed to measure repercussion effects based on a numerical model includes research by Igarashi [2)], by Chiba et. al. [3)], and by McBride and Joseph [4)]. Morohashi and Umemura [5)] measured the snow removal effect by land prices. One problem with their research is the arbitrary character of these models that are set without any linkages to the principles of individual action. Models linked to traffic volumes are desirable, Research that attempts to represent the effects of snow removal as generalized travel cost saving includes that by Sakai [8)], Karl Moriz [7)], the Hokkaido Development Bureau, [8)] and McBride and Joseph [4)]. These all measure delay loss, the effect of snow removal on lowering direct damage, and so on. But they have not succeeded in converting the effects of snow removal on punctuality and driving comfort into monetary values. Hayashiyama et. al. [9)] have measured snow removal benefits based on CVM, but they have not linked them to traffic activities, which means that the reliability of their results might be low. As far as the author's know, no research has successfully measured snow removal benefits based on consumers' surplus analysis that accounts for comfort and punctuality in this way. The problems to be solved are the estimation of generalized travel cost and changing traffic volume due to the snow removal. Assuming that the latter has little elasticity and changes little, this research focuses on the former problem. Morikawa [10)] explains that SP data is suitable for the evaluation of qualitative attributes such as comfort and safety, and this research was performed by carrying out questionnaire surveys concerning route selection among drivers and collecting SP data to measure generalized travel cost.

2. Concepts of this research

(1) Form of the questions

The survey adopts the pair comparison format questionnaire shown in Figure 1 under conditions set as explained below to obtain vehicle user's utility function and estimate their value consciousness. Figure 1 shows a question regarding the trade-off between required time and toll fees, but other questions compared punctuality and comfort for each level of snow removal. The pair comparison format questionnaire survey has been used by Kono et. al. [11] to measure uncertainty regarding required time on the Metropolitan Expressway system, and its benefits are that it can clearly account for the trade-off relationship and the respondents can answer it easily. Another strong point is that because this method can use a partial profile that shows only differing attributes, it can be used to evaluate a relatively large number of attributes [12].

Route A: No toll is charged but packed snow remains and driver feels the strain due to snow
Route B: A toll of ¥100 is charged and paved surface is completely exposed just as it is when there is no snow

When you have a choice of the above pair of hypothetical routes, which of 1 to 3 below would you choose?

1. Route A
2. Cannot decide
3. Route B

Figure 1. Pair Comparison Question Format

(2) Common conditions for answering

[1] The car the respondent is riding is an FF passenger car equipped with skid resistance equipment (studless tire, chains).
[2] The respondent drives the vehicle and has no other passengers.
[3] The road is a two-lane road with one lane in each direction.
[4] The roads in the region are continuously flat.

(3) Types of hypothetical conditions

Five groups of questionnaires were prepared by setting the sets of conditions in Table 1 regarding driving time period, weather and visibility, purpose of trip, possibility/impossibility of delayed arrival.

Table 1 Hypothetical Conditions and Questionnaires

Category	I	II	III	IV	V
Driving time period	Daytime	Nighttime	Daytime	Daytime	Daytime
Weather and visibility	Clear and good visibility	Clear and good visibility	Raining and poor visibility	Clear and good visibility	Clear and good visibility
Purpose of trip	Business	Business	Business	Private travel	Private travel
Possibility/impossibility of late arrival	Delayed arrival impossible	Delayed arrival impossible	Delayed arrival impossible	Delayed arrival impossible	Delayed arrival possible

(4) Setting the snow removal level

The snow removal level was set at the six ranks in Table 2. But the state of road surfaces under the present snow removal level is hypothetically set at 3.

Table 2. Set Snow Removal Levels

Snow removal level	Conditions
1	Paved surface is completely exposed just as it is when there is no snow (if it is asphalt, the road is completely black).
2	A faint coating of snow remains (if it is asphalt, the road is gray).
3	Packed snow remains, but it is free of ruts.
4	Conditions in 2 and 3 above when the road surface is frozen (ice burn state).
5	Snow has been removed and the pavement is visible, but the road surface is frozen.
6	No snow removal or snow melting has been done.

(5) Setting the utility function

A linear utility function was set so that is as shown in equation (1).

$$U=\alpha_1 X_1+\alpha_2 X_2+\alpha_3 X_3+\beta_2 D_2+\beta_3 D_3+\beta_4 D_4+\beta_5 D_5+\beta_6 D_6 \quad (1)$$

X_1 : fee (yen)

X_2 : required time (minutes)

X_3 : punctuality (X_3% delay from required time X_2 with 50% probability)

D_i : road surface dummies for the level i(if snow removal levels i, D_i=1,otherwise 0)

α, β : coefficients to the attributes

Assuming that the respondents would judge the difference between the utility of route A and route B to select a route, the variable z that represents the utility difference is introduced to account for judgement error as shown in equation 2 to construct a logit model and estimate the weight α's and β's.

$$z = U^A\text{-}U^B = \sum_{i=1}^{3}\alpha_i\left(X_i^A - X_i^B\right)+\sum_{j=2}^{6}\beta_j\left(D_j^A - D_j^B\right)+\varepsilon \quad (2)$$

U^A, U^B : utility of route A and route B

ε : probability variable with gumbel distribution

Then the probability P_A to choose route A can be expressed by

$$P_A = \frac{1}{1+\exp(\mathrm{U_B} - \mathrm{U_A})} \quad \text{.........(3)}$$

3. Outline and results of the survey

(1) Regions surveyed

Table 3. Regions Where the Survey Was Performed

Case study locations			Travel time	Average traffic volume (vehicles/day)
No.	Road name	Section	Driving speed	
[1]	National Highway Route 7	Hirosaki City – Aomori City 38.1km	57 min. 40.1 km/h	22,205
[2]	National Highway Route 13	Yamagata City – Shinjo City 61.2km	84 min. 43.7 km/h	30,564
[3]	National Highway Route 13	Yuzawa City – Yokote City 17.5km	28 min. 37.5 km/h	15,742
[4]	National Highway Route 49	Koriyama City – Aizuwakamatsu City 60.6km	76 min. 47.8 km/h	14,686
[5]	National Highway Route 113	Oguni Town – Nanyo City 43.2km	55 min. 47.1 km/h	8,209

The five regions in the Tohoku area that are shown in Table 3 were selected for the survey. They were chosen because they are in snowfall regions and do not include mountain passes, and based on the distance between the cities. The travel times and traveling speeds in Table 3 are those in seasons other than the winter.

(2) Results of the parameter estimations

Table 4 shows the results of the parameter estimations for the linear utility functions.

Table 4. Parameter Estimation Results

No.	Type	Location	Characteristic	α_1		α_2		α_3		β_2		β_3		β_4		β_5		β_6		Corrected for Likelihood	Accuracy (%)
				Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value		
1	I	①R7	46	-0.003	-28.00	-0.118	-9.35	-9.049	-44.83	-0.013	-0.09	-1.229	-9.95	-3.119	-24.24	-3.451	-23.03	-5.037	-29.87	0.3889	81.84%
2	II	Hirosaki	65	-0.003	-33.67	-0.060	-5.87	-6.651	-44.59	-0.229	-1.88	-1.352	-12.90	-3.094	-28.18	-3.157	-25.54	-4.727	-35.51	0.3927	80.98%
3	III	~	55	-0.003	-31.58	-0.042	-3.81	-6.433	-37.52	-0.198	-1.51	-1.526	-13.26	-3.715	-30.88	-3.503	-25.37	-5.155	-34.48	0.3910	82.32%
4	IV	Aomori	50	-0.002	-27.96	-0.007	-0.59	-3.697	-22.78	-0.235	-1.77	-1.075	-9.68	-2.647	-22.61	-2.979	-22.20	-3.977	-27.47	0.3438	79.06%
5	V		78	-0.002	-35.30	-0.022	-2.48	-3.277	-23.97	-0.255	-2.40	-1.238	-13.67	-3.114	-32.69	-3.313	-29.93	-4.518	-37.50	0.3520	80.26%
6	I	②R13	54	-0.002	-34.21	-0.084	-18.18	-4.004	-38.26	-0.114	-0.95	-1.830	-17.46	-3.821	-34.82	-4.241	-34.41	-5.811	-46.23	0.4740	85.72%
7	II	Yamagata	67	-0.002	-32.51	-0.064	-16.68	-4.144	-37.54	-0.134	-1.16	-1.885	-18.28	-4.226	-39.40	-4.058	-32.15	-6.120	-45.77	0.4667	85.92%
8	III	~	68	-0.002	-34.88	-0.049	-14.64	-3.055	-37.38	-0.061	-0.59	-1.379	-16.00	-3.362	-36.82	-3.247	-31.46	-4.475	-43.34	0.3779	82.92%
9	IV	Shinjo	73	-0.002	-31.79	-0.046	-14.14	-2.412	-32.15	-0.113	-1.13	-1.226	-14.75	-2.870	-32.36	-3.033	-30.06	-3.907	-39.12	0.3215	80.43%
10	V		73	-0.003	-39.05	-0.062	-17.01	-4.111	-44.42	-0.561	-4.90	-2.234	-22.13	-4.616	-43.84	-4.993	-42.21	-6.323	-53.28	0.4936	86.51%
11	I	③R13	69	-0.003	-34.18	-0.052	-7.68	-3.125	-31.46	-0.253	-2.27	-1.020	-11.58	-2.599	-27.73	-2.553	-25.14	-4.881	-46.54	0.4012	82.50%
12	II	Yuzawa	73	-0.003	-34.94	-0.069	-10.25	-4.142	-41.41	-0.076	-0.70	-0.955	-11.01	-2.556	-27.73	-2.641	-26.50	-4.139	-40.57	0.4117	83.19%
13	III	~	72	-0.004	-36.84	-0.097	-13.56	-5.457	-49.99	-0.113	-1.00	-1.470	-15.42	-3.432	-34.17	-3.425	-31.38	-5.464	-48.62	0.4619	84.23%
14	IV	Yokote	68	-0.003	-36.38	-0.070	-10.15	-4.199	-40.23	-0.274	-2.45	-1.473	-15.80	-3.424	-34.70	-3.697	-34.44	-5.187	-47.23	0.4371	84.60%
15	V		53	-0.003	-28.69	-0.036	-4.71	-2.973	-26.70	-0.168	-1.31	-0.789	-7.94	-2.215	-20.86	-2.366	-20.60	-3.732	-32.00	0.3730	81.69%
16	I	④R49	53	-0.002	-31.36	-0.069	-15.77	-3.572	-33.80	-0.225	-1.80	-1.941	-17.40	-4.489	-38.66	-4.732	-34.46	-6.325	-44.54	0.4812	86.83%
17	II	Koriyama	60	-0.002	-32.05	-0.072	-17.11	-3.754	-34.87	-0.203	-1.67	-2.126	-19.45	-4.775	-41.90	-4.653	-34.72	-5.887	-43.25	0.4805	86.24%
18	III	~	57	-0.002	-27.74	-0.069	-15.92	-3.171	-29.72	-0.371	-2.92	-2.039	-17.88	-4.271	-35.87	-4.538	-32.27	-5.813	-40.38	0.4471	84.68%
19	IV	Aizu	56	-0.002	-28.38	-0.066	-16.12	-3.488	-32.28	-0.144	-1.16	-1.900	-17.09	-4.566	-39.53	-4.359	-31.42	-6.164	-42.50	0.4745	85.85%
20	V		43	-0.001	-24.27	-0.063	-14.01	-3.091	-25.73	-0.364	-2.70	-1.795	-15.11	-4.039	-32.46	-3.719	-25.35	-5.446	-35.98	0.4070	83.31%
21	I	⑤R113	80	-0.002	-33.37	-0.056	-6.28	-5.102	-36.76	-0.190	-1.80	-1.038	-11.59	-2.414	-25.67	-2.613	-24.29	-3.981	-33.89	0.3033	77.77%
22	II	Oguni	77	-0.002	-31.88	-0.018	-1.91	-5.701	-34.75	-0.293	-2.62	-1.287	-13.33	-3.192	-31.62	-3.103	-25.99	-5.152	-38.75	0.3494	81.44%
23	III	~	77	-0.002	-34.05	-0.051	-5.40	-5.943	-39.87	-0.110	-1.00	-1.277	-13.47	-3.024	-30.39	-2.802	-24.32	-4.854	-38.65	0.3433	79.94%
24	IV	Nanyo	82	-0.002	-35.89	-0.059	-6.40	-8.403	-54.89	-0.281	-2.54	-1.320	-13.72	-3.170	-31.62	-3.164	-27.22	-5.186	-40.37	0.3710	81.82%
25	V		72	-0.003	-33.95	-0.055	-5.39	-4.112	-27.17	-0.282	-2.36	-1.475	-14.24	-3.464	-31.91	-3.230	-26.25	-5.580	-41.84	0.3951	81.44%

For notation of α and β see eq.(1)

Table 5. Parameter Estimation Results (Case of level 2 Dummy Removed)

No.	Type	Location	Characteristic	α_1		α_2		α_3		β_3		β_4		β_5		β_6		Corrected for Likelihood	Accuracy (%)
				Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value	Estimated Value	t value		
1	I	①R7	46	-0.002	-27.80	-0.113	-9.06	-8.729	-65.93	-1.170	-13.26	-3.003	-39.98	-3.323	-35.88	-4.848	-52.74	0.389	0.822
2	II	Hirosaki	65	-0.003	-33.45	-0.054	-5.37	-6.279	-64.14	-1.060	-14.85	-2.738	-43.85	-2.781	-36.77	-4.275	-62.96	0.380	0.808
3	III	～	55	-0.002	-30.82	-0.037	-3.36	-6.050	-54.60	-1.258	-15.88	-3.359	-50.77	-3.141	-37.55	-4.704	-59.36	0.377	0.819
4	IV	Aomori	50	-0.002	-27.57	-0.003	-0.23	-3.449	-30.80	-0.790	-10.14	-2.314	-31.94	-2.607	-31.40	-3.568	-46.50	0.336	0.790
5	V		78	-0.002	-34.58	-0.018	-2.00	-3.047	-32.56	-0.925	-14.58	-2.740	-47.29	-2.894	-42.98	-4.063	-61.00	0.345	0.805
6	I	②R13	54	-0.002	-33.10	-0.080	-17.83	-3.814	-44.74	-1.634	-23.02	-3.551	-59.06	-3.918	-52.18	-5.422	-67.39	0.472	0.856
7	II	Yamagata	67	-0.002	-30.87	-0.061	-16.23	-3.967	-45.15	-1.665	-24.04	-3.925	-70.07	-3.726	-51.17	-5.722	-61.91	0.469	0.859
8	III	～	68	-0.002	-33.43	-0.047	-14.17	-2.936	-42.63	-1.255	-20.94	-3.172	-55.87	-3.027	-47.25	-4.225	-59.46	0.376	0.829
9	IV	Shinjo	73	-0.002	-30.20	-0.044	-13.68	-2.326	-35.51	-1.057	-18.34	-2.651	-46.57	-2.779	-44.73	-3.642	-51.63	0.319	0.799
10	V		73	-0.002	-37.92	-0.060	-16.66	-3.959	-51.16	-1.615	-24.22	-3.940	-70.12	-4.258	-60.70	-5.549	-72.60	0.489	0.861
11	I	③R13	69	-0.003	-33.13	-0.047	-7.03	-2.937	-37.87	-0.692	-10.78	-2.193	-33.56	-2.117	-30.54	-4.311	-62.65	0.389	0.823
12	II	Yuzawa	73	-0.003	-34.60	-0.064	-9.71	-3.963	-51.47	-0.814	-13.11	-2.356	-39.25	-2.403	-35.91	-3.850	-64.17	0.402	0.828
13	III	～	72	-0.003	-36.62	-0.092	-13.04	-5.216	-63.44	-1.281	-19.08	-3.178	-52.98	-3.131	-43.63	-5.078	-76.21	0.454	0.839
14	IV	Yokote	68	-0.003	-35.78	-0.065	-9.60	-3.999	-48.96	-1.124	-17.24	-3.002	-50.00	-3.226	-46.10	-4.644	-71.97	0.426	0.846
15	V		53	-0.003	-28.03	-0.032	-4.22	-2.811	-31.76	-0.558	-7.80	-1.922	-26.23	-2.032	-26.16	-3.348	-46.37	0.359	0.803
16	I	④R49	53	-0.002	-29.69	-0.065	-15.35	-3.399	-37.89	-1.627	-21.55	-4.077	-66.08	-4.266	-53.68	-5.809	-59.16	0.481	0.865
17	II	Koriyama	60	-0.002	-30.57	-0.069	-16.69	-3.595	-40.02	-1.838	-25.06	-4.398	-77.25	-4.241	-54.95	-5.440	-59.52	0.478	0.858
18	III	～	57	-0.002	-26.32	-0.067	-15.55	-3.054	-33.32	-1.596	-21.12	-3.762	-61.19	-3.980	-49.88	-5.232	-52.79	0.445	0.846
19	IV	Aizu	56	-0.001	-27.00	-0.062	-15.61	-3.306	-36.39	-1.654	-21.91	-4.206	-70.05	-3.966	-50.02	-5.703	-54.66	0.474	0.857
20	V		43	-0.001	-23.07	-0.060	-13.61	-2.965	-30.05	-1.355	-16.99	-3.516	-50.50	-3.173	-37.56	-4.856	-44.61	0.405	0.833
21	I	⑤R113	80	-0.002	-32.22	-0.050	-5.65	-4.736	-52.13	-0.782	-12.62	-2.091	-35.96	-2.268	-34.46	-3.575	-53.96	0.290	0.777
22	II	Oguni	77	-0.002	-30.56	-0.013	-1.39	-5.351	-52.25	-0.933	-13.55	-2.767	-44.49	-2.657	-36.65	-4.623	-57.35	0.343	0.808
23	III	～	77	-0.002	-33.19	-0.045	-4.84	-5.555	-59.17	-1.098	-16.44	-2.776	-47.49	-2.539	-35.88	-4.490	-62.03	0.331	0.799
24	IV	Nanyo	82	-0.002	-35.84	-0.056	-6.15	-8.180	-85.54	-1.010	-15.21	-2.836	-48.39	-2.813	-40.32	-4.782	-66.91	0.372	0.823
25	V		72	-0.003	-33.20	-0.050	-4.94	-3.812	-39.02	-1.134	-15.74	-3.059	-49.74	-2.811	-36.88	-5.041	-70.19	0.385	0.810

The estimated parameters show that none of the signs are reversed to common sense and the t values of all parameters except for the level 2 dummy were good. An examination of the individual responses shows that because the responses for snow removal level 2 (faint covering) and for snow removal level 1 (completely removed) often tended to be similar, the t value of the snow removal level 2 (faint covering) is low. This is interpreted as the fact that if the snow removal level is level 2 (the pavement surface and center line are visible through a thin layer of snow), the users make judgements of value equal to that for level “1” that is snow removed until the pavement surface is completely visible. Because the t value of the dummy variable of snow removal level 2 is low and not significant as explained above, level 2 dummy was removed to set the parameters a second time. The results are shown in Table 5.

(3)Generalized travel cost coefficients by road section

The users’ generalized travel cost in yen units are calculated by dividing the parameters(α_2, α_3, β_2 ～ β_6) that were set by the parameter for the toll fee(α_1). Equation (3) is the overall generalized travel cost C.

$$C = U/\alpha_1 = X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \delta_2 D_2 + \delta_3 D_3 + \delta_4 D_4 + \delta_5 D_5 + \delta_6 D_6 \quad (4)$$

where

$\gamma_i = \alpha_i / \alpha_1$, $\delta_i = \beta_i / \alpha_1$

γ_2: value of time (yen/minutes)

γ_3: value of punctuality(yen/%)

δ_i: cost of snow condition level i relative to the level 1 (yen) , ($i = 2$～ 6)

Table 6 shows the results of organizing the terms in equation (3).

Focusing on Questionnaire No. 1 in Table 6, it shows that the generalized travel cost is decreased by 2005.65 – 484.08 = 1521.57 (yen/vehicle•trip), if the level is, raised from no removal (level 6) to the present show removal level (level 3). This is the benefit of improving comfort per vehicle and per trip in survey region [1] (Hirosaki to Aomori) under hypothetical conditions I (daytime, clear and good visibility, business trip, late arrival impossible). The monetary value per unit of required time is an average of ¥29/minute, and comparing it with the time value (passenger car: ¥55.82) in the manual of the Road Bureau of the Ministry of Land, Infrastructure, and Transport, reveals that even accounting for differences in the numbers of passengers in the manual and hypothesized for this research (this research: 1 person, manual: 1.44 people), the value in this research tends to be smaller. This is assumed to be a result of the effects of the fact that the required level in the Tohoku Region is about 80% of the national average.

Table 6. Generalized cost coefficients by road section

No.	Type	Location	γ_2	γ_3	δ_3	δ_4	δ_5	δ_6
1	I	①R7	46.94	36.11	484.08	1,242.43	1,374.78	2,005.65
2	II	Hirosaki	19.13	22.22	375.04	968.82	984.23	1,512.85
3	III	～	15.77	25.74	535.21	1,428.92	1,335.89	2,000.80
4	IV	Aomori	1.18	15.51	355.18	1,040.76	1,172.73	1,605.25
5	V		8.18	13.93	422.77	1,252.93	1,323.32	1,857.95
6	I	②R13	38.10	18.12	776.47	1,686.92	1,861.27	2,576.09
7	II	Yamagata	35.21	22.72	953.78	2,247.91	2,134.22	3,277.06
8	III	～	26.55	16.53	706.40	1,785.79	1,703.79	2,378.53
9	IV	Shinjo	28.77	15.06	684.39	1,716.69	1,799.20	2,358.14
10	V		25.09	16.50	672.97	1,642.25	1,774.70	2,312.97
11	I	③R13	15.23	9.56	225.28	714.14	689.41	1,404.12
12	II	Yuzawa	20.19	12.43	255.31	739.34	753.84	1,207.87
13	III	～	26.60	15.14	371.84	922.22	908.51	1,473.58
14	IV	Yokote	20.78	12.78	359.48	959.76	1,031.32	1,484.74
15	V		11.83	10.51	208.63	718.39	759.50	1,251.58
16	I	④R49	36.20	18.86	903.04	2,262.19	2,366.96	3,223.46
17	II	Koriyama	38.58	20.21	1,032.86	2,472.04	2,383.53	3,057.94
18	III	～	43.32	19.88	1,039.29	2,449.45	2,591.48	3,406.80
19	IV	Aizu	43.17	22.94	1,147.58	2,918.33	2,751.28	3,956.69
20	V		44.32	21.81	996.53	2,585.72	2,333.70	3,571.24
21	I	⑤R113	26.56	25.32	418.10	1,118.08	1,212.81	1,911.39
22	II	Oguni	7.04	28.83	502.97	1,490.74	1,431.64	2,491.09
23	III	～	21.12	26.05	514.79	1,302.18	1,190.60	2,105.78
24	IV	Nanyo	24.43	35.40	437.05	1,227.27	1,216.98	2,069.05
25	V		18.08	13.73	408.32	1,101.87	1,012.45	1,815.74

(3) Generalized cost coefficient per vehicle ㎞

Table 7 shows the generalized cost coefficient per vehicle ㎞ by δ's in Table 6 by the distance in each survey section. The generalized cost coefficient per vehicle ㎞ in table 7 are the value gained per 1 minute of travel time, 1% of punctuality, and per 1 km of snow removal. In this case, it is hypothesized that the critical benefit for the section length is constant.

It can be seen that the generalized cost coefficient per vehicle ㎞ of the snow removal levels tends to be slightly higher when the set condition is assumed to be snow falling than when it is clear, and slightly higher when it is assumed to be nighttime than when it is assumed to be daytime. The benefits ratio of the snow removal levels when it is assumed to be a private trip (impossible to be late) is slightly higher than it is for a business trip, and the ratio of punctuality tends to be smaller in the case of a private trip where being late is possible than in the case of a private trip where it is impossible to be late.

Table 7. Generalized cost coefficient per vehicle ㎞

No.	Type	Location	Value of travel time(yen/minute)	Value of Punctuality (yen/%)	Level 3 dummy	Level 4 dummy	Level 5 dummy	Level 6 dummy
1	I	①R7	46.94	36.11	12.10	31.06	34.37	50.14
2	II	Hirosaki	19.13	22.22	9.38	24.22	24.61	37.82
3	III	～	15.77	25.74	13.38	35.72	33.40	50.02
4	IV	Aomori	1.18	15.51	8.88	26.02	29.32	40.13
5	V		8.18	13.93	10.57	31.32	33.08	46.45
6	I	②R13	38.10	18.12	12.94	28.12	31.02	42.93
7	II	Yamagata	35.21	22.72	15.90	37.47	35.57	54.62
8	III	～	26.55	16.53	11.77	29.76	28.40	39.64
9	IV	Shinjo	28.77	15.06	11.41	28.61	29.99	39.30
10	V		25.09	16.50	11.22	27.37	29.58	38.55
11	I	③R13	15.23	9.56	11.26	35.71	34.47	70.21
12	II	Yuzawa	20.19	12.43	12.77	36.97	37.69	60.39
13	III	～	26.60	15.14	18.59	46.11	45.43	73.68
14	IV	Yokote	20.78	12.78	17.97	47.99	51.57	74.24
15	V		11.83	10.51	10.43	35.92	37.98	62.58
16	I	④R49	36.20	18.86	15.05	37.70	39.45	53.72
17	II	Koriyama	38.58	20.21	17.21	41.20	39.73	50.97
18	III	～	43.32	19.88	17.32	40.82	43.19	56.78
19	IV	Aizu	43.17	22.94	19.13	48.64	45.85	65.94
20	V		44.32	21.81	16.61	43.10	38.90	59.52
21	I	⑤R113	26.56	25.32	10.45	27.95	30.32	47.78
22	II	Oguni	7.04	28.83	12.57	37.27	35.79	62.28
23	III	～	21.12	26.05	12.87	32.55	29.77	52.64
24	IV	Nanyo	24.43	35.40	10.93	30.68	30.42	51.73
25	V		18.08	13.73	10.21	27.55	25.31	45.39

There was little difference between the findings for snow removal level 4 (ice burn) and snow removal level 5 (black ice). Overall, no clear differences can be seen between estimation results depending on differences in hypothetical conditions, and if the snow removal level (road surface condition) is constant, it can be concluded that there is little difference depending on hypothetical conditions. It is undeniable that it is possible that the respondents were not clearly aware of differences in the hypothetical conditions. While there are differences in generalized cost coefficient per vehicle ㎞ in different regions, no clear differences in tendencies have been found.

4. Cost-Benefit Analysis

The value of benefits of the present snow removal level (level 3) over the no snow removal level (level 6) was calculated for region [1] (Hirosaki City to Aomori City). Table 8 shows the driving speed by road surface type in region [1].

Table 9 shows the results of the generalized travel cost for each snow removal level based on Equation (3), Table 6, Table 7, and Table 8. The generalized travel cost for the no snow removal (level 6) and the present snow removal level (level 3) per vehicle are obtained based on equation (3) and table 9 and the total benefits are calculated as shown below accounting for the number of days each condition is manifest and average traffic volume in Table 9.

$$\{(C_{level1} \times 294 + C_{level3} \times 1 + C_{level4} \times 26 + C_{level6} \times 44) - (C_{level1} \times 297 + C_{level3} \times 53 + C_{level4} \times 15)\} \times 22205 = 9.23 \text{ (billion yen/year)}$$

However,

$C_{level\ 1} = 1320$, $C_{level\ 3} = 1837.2$, $C_{level\ 4} = 4781.7$, $C_{level\ 6} = 5689$

Table 8. Setting the Driving Speed and Required time by Road Surface Condition (Hirosaki to Aomori)

Snow level	Set Speed (km/h)	Remarks
Level 1	40	Dry/wet
Level 3	36	Packed snow
Level 4,5	32	Frozen
Level 6	28	No snow removal

Source: Road Timetable 1999

Table 9. Generalized travel cost for Snow Removal Levels (Yen/vehicle)

	Snow Level	Required Time	Punctuality	Total	Difference (compared with 3)
Level 1	0.0	1320.0	0.0	1320.0	-617.2
Level 3	370.5	1466.7	0.0	1837.2	0.0
Levels 4, 5	1019.0	1650.0	2112.7	4781.7	2944.5
Level 6	1690.6	1885.8	2112.7	5689.0	3851.8

Table 10. Number of Days Each Road Surface Condition is Manifest Depending on Differences in Removal Level (Hirosaki to Aomori)

Removal Level \ Conditions manifest	Level 1	Level 3	Level 4	Level 6	Total
Level 1	365	0	0	0	365
Level 3	297	53	15	0	365
Levels 4, 5	294	1	70	0	365
Level 6	294	1	26	44	365

Table 11. Results of Cost-Benefits Analysis of the Present Level of Snow Removal (Level 3)

No.	Region	Benefits (billion yen/year)	Snow Removal Cost (billion yen/year)	Cost-Benefit Ratio	Net Benefits (billion yen/year)
[1]	Hirosaki City – Aomori City	9.23	0.16	58	9.08
[2]	Yamagata City – Shinjo City	10.78	0.16	69.5	10.63
[3]	Yuzawa City – Yokote City	1.38	0.07	19.3	1.31
[4]	Koriyama City – Aizuwakamatsu City	5.10	0.11	47.4	4.99
[5]	Oguni Town – Nanyo City	2.22	0.2	11.1	2.02

Table 12. Results of Cost-Benefits Analysis of Complete Snow Removal (Level 1)

No.	Region	Benefits (billion yen/year)	Snow Removal Cost (billion yen/year)	Cost-Benefit Ratio	Net Benefits (billion yen/year)
[1]	Hirosaki City – Aomori City	12.85	0.16	9.2	11.45
[2]	Yamagata City – Shinjo City	13.47	0.16	5.4	10.96
[3]	Yuzawa City – Yokote City	1.92	0.07	2.8	1.24
[4]	Koriyama City – Aizuwakamatsu City	6.41	0.11	3.2	4.38
[5]	Oguni Town – Nanyo City	2.70	0.20	1.3	0.58

Because the cost of snow removal in region [1] is about ¥0.16 billion, the net benefits are ¥9.08 billion/year and the cost benefits ratio is 58.0, showing that the efficiency standards are satisfied.

Table 11 shows the results of similarly calculating the benefits of the present snow removal level (level 3) as opposed to no snow removal (level 6) in the other four regions to perform a cost-benefits analysis. Table 12 shows the results of a cost-benefits analysis of complete snow removal (level 1).

Figure 11 reveals that in all the regions, the cost-benefit ratio is greater than 1 and the present snow removal level satisfies the efficiency standards. To completely remove snow, road heating must be installed at great expense, but Table 12 shows that the cost-benefits ratio exceeds 1 and the efficiency standards are satisfied even where total snow removal of this kind has been performed.

5. Conclusion

This research has obtained estimated values of generalized travel cost including comfort and punctuality provided by snow removal by using stated preference data (SP data) to apply a logit model with a linear utility function. In particular, it focussed on the psychological effects of current level dependency on the road snow level on drivers: a factor rarely considered in the past. The time value was a little smaller than that used by the present manual, but the results have revealed that its evaluation of punctuality is high and when snow has accumulated, there is a stronger consciousness of guaranteeing punctuality than of the time reduction effects. It has also shown that the harsher the driving environment, when it is snowing rather than clear for example, the higher the benefits ratio for comfort.

The questionnaire survey was performed on the assumption that the trips would definitely be made, but it is necessary to account for benefit measurements of a case where the traffic volume is elastic on the road conditions.

Another remaining challenge is to measure benefits more precisely by accurately measuring driving speed by road surface condition (using a probe car).

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