BENEFIT EVALUATION OF ROAD INFORMATION SERVICE ON WINTER MOUNTAIN PASSES

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1. Introduction

In order to prevent the obstruction of traffic by snow, various measures are taken by road management organizations on winter mountain passes. In addition to snow removal, snow melting, and snow protection measures, there is the provision of road traffic information using the latest information communication technologies. Primarily the Ministry of Land, Infrastructure, and Transport and other road management organizations in Japan provide this road traffic information, which is provided in order to guarantee a safe and smooth flow of traffic during the winter.

Like all public works, the road information provision should be done efficiently, and its cost-benefit should be quantitatively evaluated.

Most of past research has focused on the way of providing information effectively and its aim has mainly been to mitigate traffic congestion in urban regions, but there has been little analysis of the provision of road information service needed in mountainous regions, for example, roads crossing mountain passes.1)

One of the problems of the results of this research is that they are not necessarily based on an analysis backed up by economic theory. Research concerning weather information and road surface information that deals with this study includes the one by Rockvam et al. 2) , which presents a cost-benefit analysis of the provision of weather information taking the State of Minnesota as an example, but a theoretical approach to support the results is not clearly defined.

When road information service is provided, there are reductions in accidents of about 30 to 40% according to the European Commission DGVII/DGXIII 5), but we think we can obtain generalized travel cost reductions in addition to those safety benefits, because users can select a better route with accurate information.

Some countries report that there is a cost-benefit ratio of 2.66 for traveler information provision.6) In our research we obtained a value of 1.50 which represents the benefit of information given to travelers regarding different surface statuses of passes (dry, wet, pack snow and frozen), not all types of information that a traveler could expect related with other items (e.g. congestion, accidents, etc.).

The goal of this study is to present a method of quantitative measurement on the effects of provision of road traffic information, based on a micro-economic approach. For this purpose, this study applies the logit model method to formulate the route choice behaviors of road users when road traffic information about mountain passes is provided (or when it is not provided). It also measures quantitatively the benefits of provision of road information based on the generalized travel cost and the route choice behavior when road information is and is not provided.

2. Road users' behaviors when road information service is provided

2.1 Definition of information in this research

The content of the provided information that is dealt with in this research is limited to:

[1] Information about weather conditions in the pass based on meteorological predictions, and

[2] Information about the condition of the road surface in the pass provided by the road management institution.

Both are services that allow users to obtain information in a relatively easy way by radio, TV, internet, i-mode (which is a cell phone information service), or electronic information panels installed on roadsides.

For this study (which is an analysis of the provision of information about roads on passes in particular), the effects on users of information provision are assumed to be the effects produced only by the content of road information type [2], because localized information about passes is extremely important. The content of information [2] is the road surface condition in a pass that can be either dry/wet, pack snow, or frozen. Information [1] and [2] are combined, and assuming that this is the way that road information is provided, a situation where only [1] is provided is defined as a state where no road information is provided. Table 1 summarizes these hypotheses.

Consequently, the benefit for users can be measured based on the difference between two conditions: with road information provision (hereafter called "with") and without road information provision (hereafter called "without").

Table 1. Relationship Between Information Provision and the Content of the Information Provided in the Study

Content of the information provided		Weather information	Road surface information
Road Information Provision	With road information provision (with)	○	○
	Without road information provision (without)	○	×

2.2 Road users' behaviors with road information provision

This study considers the two-route choice problem shown in Fig. 1 in order to analyze road users' behaviors with road information provision. Route 1 in Fig. 1 goes through a pass and route 2 is a detour that avoids going through the pass. It is assumed that the users select one of these two routes based on weather information and road surface information when they begin a trip (pre-departure decisions). It is assumed that the weather information predicts exactly the actual weather in the pass.

First, in a case without road information provision, even though users obtain information about the weather in the pass, they cannot clarify the state of the road surface. In these circumstances, they do not know if the road surface in the pass is wet or dry, is pack snow, or is frozen. Therefore, users select their routes in a situation of uncertainty because they are forced to act by predicting the road surface condition based on their past experience. Because the users can accurately clarify the state of the road surface in a pass if road surface information is provided, they can select their routes with certainty in this case.

It is also assumed that road users have already traveled the routes in summer and in winter, and are aware of the time required to travel by both routes based on their past experience. It is also assumed that users will make the trip whether they are provided with information or not.

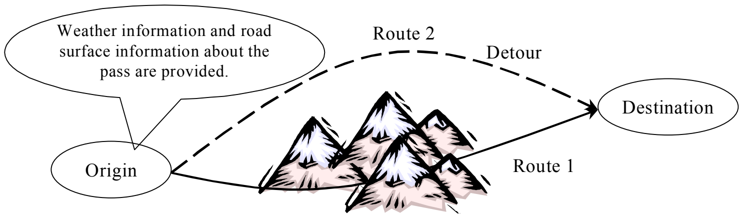

Figure 1. The Two-Route Choice problem

2.3 Road users' perception of the travel time

It is assumed that users perceive a certain range in the time required to reach their destination, and that this range varies according to whether or not information is provided. For example, consider a case where a user predicts, "Because it is winter and the weather forecast is clear, it will probably take between any value (y) and any value (z) minutes to get there." This study defines this prediction range of the travel time as the difference between the maximum travel time (T_H) and the minimum travel time (T_L) of the route as perceived by users, and represents the prediction range by the following equation.

Prediction range of travel time $T_H^K - T_L^K$ .... (1)
K: with (W) or without (WO) information provision

Assuming that users uniformly estimate the degree of uncertainty of achieving a certain travel time, it is hypothesized that there is a uniform distribution of the prediction range of travel time as perceived by users. Figure 2 shows that in a case where road information is not provided, the range of travel time predicted by users is broader because the condition of the road surface in the pass is unknown. This is uncertainty produced by the fact that the road surface condition is unknown. This is predicted because the weather and the road surface condition in the pass can be accurately obtained when road information is provided; the travel time prediction range is narrowed because users can compare present conditions with their past driving experiences.

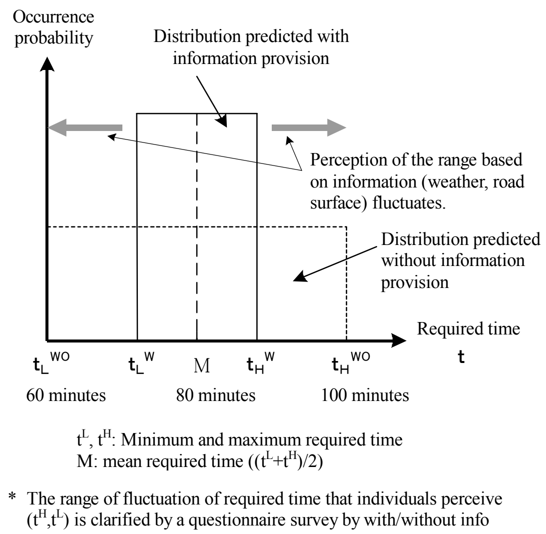

Figure 2. Travel Time and Prediction Range that Users Perceive

Next, this study considers the prediction range according to with/without road information provision focusing on the effects of weather. When the weather forecast indicates “clear weather” and road surface information is provided, users can more easily assume conditions in the pass than when information is not provided.

It is predicted that in the former case, the certainty of their perception of required travel time improves, the prediction range gets narrow, and the required travel time is shorter (Fig. 3). If the weather forecast indicates “snow”, it is predicted that users will assume the effects of falling snow including the problem of worse visibility, and as result the prediction range for travel time will be wider and the travel time longer than if the weather forecast had been for “clear” weather (Fig. 4). Because there are big differences in these perceptions among individual road users, it is necessary to carry out a questionnaire survey without making any sweeping generalizations.

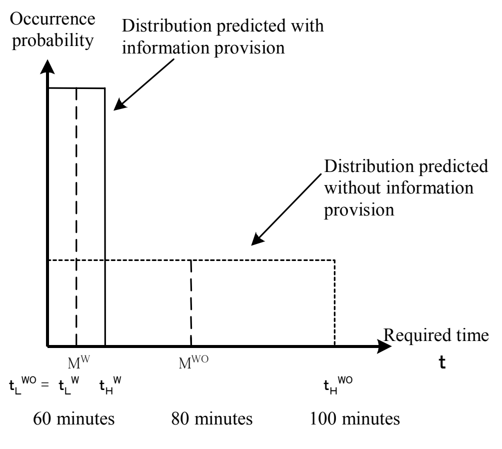

Figure 3. Clear Weather Case

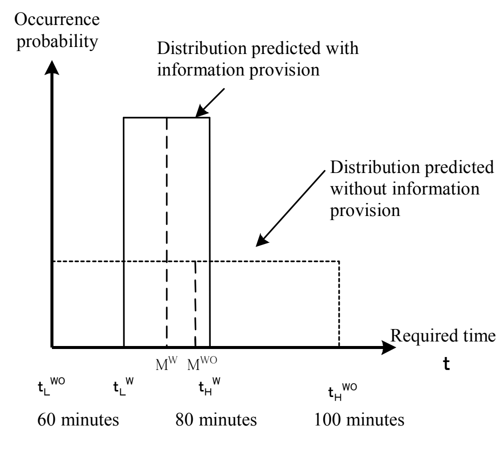

Figure 4. Snowy Weather Case

2.4 Benefits of providing road information

The benefits of providing road information are a product of changes in route choices caused by changes in the required travel time and range of travel time predicted by users as a result of the provision of road information. For example, consider the case shown in Fig. 1. Route 1 goes through the pass and route 2 detours from the pass. Assuming that the road information provided is only information for route 1 through the pass, if the predicted travel time and the range of the predicted travel time are both smaller than they would be in a case where no road information is provided, the probability of selecting route 1 would probably rise, as a result of the provision of "dry/wet" information.

The benefits in this case must be measured based on the ex post facto actual travel time and travel time range that stipulate the actual benefits, without being measured according to costs obtained by multiplying the predicted travel time and travel time range respectively by each of their ratios. Therefore, the value representing the benefits of road information provision is the reduction of generalized travel costs of the traffic volume caused by route choice changes, resulting from changes in users' perception of travel time when making route choices based on information that has been provided.

Considering the above concepts, the benefits in this study are measured using actual quantities reflected by the results of user's behaviors. In other words, benefits are measured regardless of the traffic data, and route choice is determined according to each individual's travel time and travel time range.

3. Method of measuring benefits for users when road information service is provided

3.1 Definition of benefits and method of measuring benefits

"With and without analysis" is performed to measure the benefits of providing road information. Benefits are measured as the reduction in generalized travel costs caused by changes in traffic volume resulting from differences in users' perception of the travel time of routes with and without road information provision.

(1) Utility function for Logit Model Analysis

The utility function V_{ij}^{m} in a case of weather i (i = clear, snow) for route j, with provided road information m is specified as shown in equation (2).

$$V_{ij}^{m} = \alpha_{i1}^{\mathrm{m}} x_{j1} + \alpha_{i2}^{\mathrm{m}} x_{ij}^{m}{}_{2} + \alpha_{i3}^{\mathrm{m}} x_{ij}^{m}{}_{3} \quad (2)$$

Where:
- x_{j1} : toll charged on route j (unit: yen, does not vary according to weather)
- $x_{ij}^{m}{}_{2}$: mean travel time on route j with road information m and weather i (minutes)
- $x_{ij}^{m}{}_{3}$: range of the user's prediction of mean delay time on route j with road information m and weather i (minutes)
- i : weather information (clear = 1, snow = 2)
- j : route (1 or 2)
- m : content of information provided about the condition of the road surface (none = 0, dry/wet = 1, pack snow = 2, frozen = 3)
- $\alpha_{i1}^{\mathrm{m}} \sim \alpha_{i3}^{\mathrm{m}}$: parameters for $x_{j1}^{\mathrm{m}} \sim x_{ij3}^{\mathrm{m}}$

Regarding the pair-format questions in the questionnaire shown below, it is assumed that the respondents would have difficulty in responding to a question concerning the travel time prediction range, "Because the travel time will vary by ± minutes." For example, it would be difficult to answer the following question:

Which of the following routes would you select?

We have two possibilities:

No.1 A route when you have information, you know that the travel time is 80 minutes with a variation of ± 10 minutes, and you will pay a toll charge of 100 yen = 0.8 $US, or,

No. 2 A route when you don't have any information and you know that the travel time is 80 minutes with a possible variation of ± 20 minutes.

This study formulates the above question more clearly:

Which of the following routes would you choose and how much delay would you expect?

No.1 A route when you have information, you know that the travel time is 80 minutes, you will be a maximum of 10 minutes late, and you will pay a toll charge of 100 yen = 0.8 $US, or,

No.2 A route when you don't have any information, you know that the travel time is 80 minutes and that you may be 20 minutes late.

In this study, the parameters were estimated based on data obtained from this questionnaire survey.

The variable x3 is the difference between the maximum travel time and the mean travel time (TH-M in Figure 2), and it is defined as the predicted delay range.

The predicted delay range of the travel time (x_3) = $(T_H^m - T_L^m)/2 = T_H^m - M$ ....(3)

Here, the road users' route choice probability is represented by the logit model shown by equation (4).

$$P_{ij}^m = \frac{\exp V_{ij}^m}{\sum_j \exp V_{ij}^m} = \frac{\exp V_{ij}^m}{\exp V_{i1}^m + \exp V_{i2}^m} \quad \text{......(4)}$$

P_{ij}^m: probability of a user selecting route j with road information m for weather condition i

The generalized travel cost of the users in yen units is calculated by dividing equation (2) by the weight of the toll charge.

$$C_{ij}^m = \frac{V_{ij}^m}{\alpha_{ij1}^m} = \sum_k \beta_{ijk}^m x_{ijk}^m \quad \left(\beta_{ijk}^m = \frac{\alpha_{ijk}^m}{\alpha_{ij1}^m} \right) \text{........ } (k=2,\ 3) \text{ ......(5)}$$

And because the benefits by the state of road information provision are defined as the saving in the generalized travel cost, the following equation is obtained by a comparison of the states with and without information provision.

$$B^m = \sum_i \sum_j (C_{ij}^0 \times OD_{ij}^0 \times D_m) - \sum_i \sum_j (C_{ij}^m \times OD_{ij}^m \times D_m) \quad \text{......(6)}$$

$$OD_{ij}^m = OD \times P_{ij}^m \quad \text{......(7)}$$

$$Total \quad Benefit = \sum_m B^m \quad \text{......(8)}$$

D_m: number of days the road surface condition m is manifest (or the number of days when information about the road surface condition is provided)

OD: Total OD volume passing route 1 or route 2

3.2. Questionnaire survey and its results

(1) Outline of the questionnaire survey

This study proposed a survey using the pair-format questionnaire form (shown in Fig. 5) in order to estimate the parameters for the model. The question considers the trade-off between road information provision and toll charge by asking the respondents whether they would select “a route with road information provided and including a toll charge” or “a route without road information and without toll charge.”

To allow the study to deal with the route choice problem after setting the parameters, a question was proposed to clarify how the respondents perceive the travel time and predicted range of routes according to the content of the information. For example, one question is: “What are the maximum and minimum travel times that you predict when the weather report states that the sky in the pass region is clear and the road information reports pack snow?” When the content of the road information provision is improved and travel time information is provided, the provided travel time and delay time may be substituted for x_2 and x_3.

Route A: Road traffic information is provided, the required time is 80 minutes, the delay time ranges are from 0 to 10 min, and the toll charge is ¥100
Route B: Road traffic information is not provided, the required time is 100 minutes and the delay time ranges are from 0 to 20 minutes,and no toll charge

Which route would you choose in this case?

1. Route A. 2. Don’t know. 3. Route B

Figure 5. Example of the Pair-Format Questionnaire

(2) Questionnaire for survey region

This study evaluated the content and scale of information about a road on a pass in winter for a region between Yamagata and Shonai on the National Highway No. 112. Two major routes were analyzed, the route No. 112 – No. 7 (on a pass) and the route No. 13 – No. 47 (detour). These are routes that primarily have traffic between Yamagata and Shonai (Tsuruoka and Sakata), but the National Highway No. 112 is sometimes regulated by snowfalls during the winter. Assuming that road condition information about passes (wet/dry, pack snow, frozen) is provided only for the National Highway No. 112, the benefits of providing information about this road were calculated.

(3) Results of the questionnaire survey

This study estimated the parameters for the utility function based on the data obtained from the questionnaire. Table 2 shows the results of this estimation. Judging from this table, *t* values indicate 5% level or above, and the adjusted likelihood ratio index and hit ratio are statistically satisfactory. Table 3 shows the generalized travel cost C_{ij}^{m} defined in (5). The interpretation of this table is as follows: the value is larger when it is snowy than when it is clear and this accurate information is more needed on a snowy day. The ratio of the generalized travel time x_2 and the delay in the travel time are almost identical by the weather, and it is concluded that the respondents evaluate these equally.

Table 2. Parameter Estimation Results

Weather	Clear	Snow
Toll charge x_1	-0.010(-11.46)	-0.003(-9.12)
Required mean time x_2	-0.212(-9.90)	-0.123(-9.03)
Predicted delay time x_3	-0.198(-64.57)	-0.130(-40.11)
The adjusted likelihood ratio index	0.658	0.437
Hit ratio	90.4%	85.5%

numbers in ( ) show *t* value.

Table 3. β_{ij}^{m} (From eq.5)

	Weather	x_2	x_3
β_{ij}^{m}	Clear	20.92	19.53
	Snow	40.76	43.06

Tables 4 and 5 and Figs. 6 and 7 show the results of calculations of the travel time and predicted delay range of routes. First, in Fig. 6, the shape of the graph of the predicted travel time according to the content of the information provision is identical when the weather prediction is snow and when it is clear. It also shows that the worse the content of the provided information (dry/wet→pack snow→frozen) the longer the predicted mean travel time. But when no road information is provided, the road users predict the travel time optimistically as if they assume that the travel time is almost the same when the road surface is wet and when it is dry. Considering Tables 7 to 9 shown below, we assume the number of days the information is provided. Figure 7 shows that whether the forecast is snow or clear, when road information is provided, the average predicted delay range tends to be smaller, and the better the road condition, the smaller the predicted delay range. But there were also questionnaire respondents who predicted that the delay time would be longer when information was provided.

Table 4. With Road Information on R112

Weather information		Time when weather information is "clear" and with information provision						Time when weather information is "snow" and with information provision					
Road information		Dry/wet		Pack snow		Frozen		Dry/wet		Pack snow		Frozen	
Predicted required time (minutes)		Min. time	Max. time	Min. time	Max. time	Min. time	Max. time	Min. time	Max. time	Min. time	Max. time	Min. time	Max. time
Samples	19	131.1	154.7	155.8	184.2	171.3	203.2	151.6	177.4	168.2	203.2	182.6	221.6
Mean required time (minutes)		142.9		170.0		187.2		164.5		185.7		202.1	
Predicted delay time range (minutes)		11.8		14.2		15.9		12.9		17.5		19.5	

Table 5. Without Road Information

Route		[1] National highway routeNo. 112 to No. 7				[2] National highway routeNo. 13 to No. 47			
Weather information		Forecast: clear		Forecast: snow		Forecast: clear		Forecast: snow	
Predicted delay time range (minutes)		Min. time	Max. time	Min. time	Max. time	Min. time	Max. time	Min. time	Max. time
Samples	19	138.4	174.2	159.5	200.0	143.7	176.3	162.6	199.5
Mean required time (minutes)		156.3		179.7		160.0		181.1	
Predicted delay time range (minutes)		17.9		20.3		16.3		18.4	

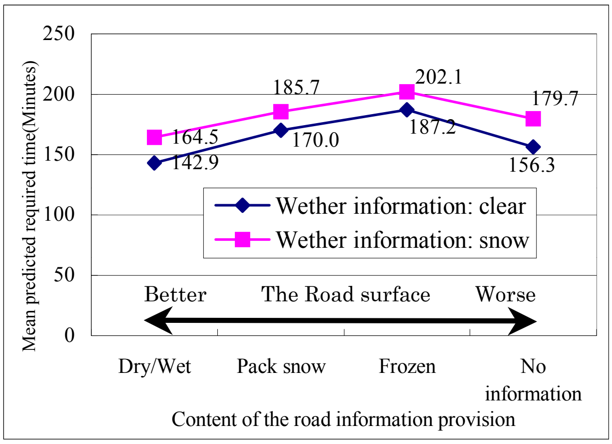

Figure 6. Mean Predicted Travel Time of the R112 – R7 Route

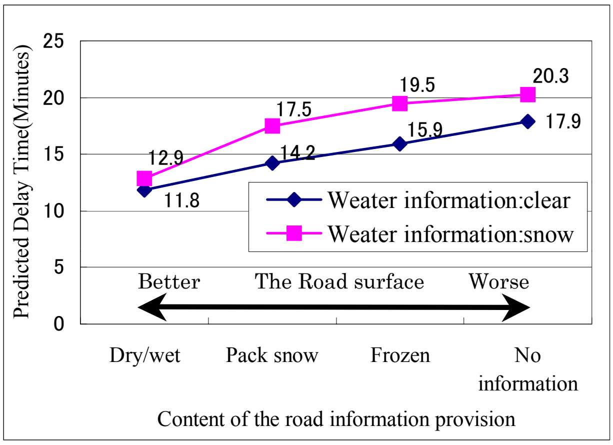

Figure 7. Predicted Delay Range of the R112 – R7 Route

4. Calculation of benefits

The parameters α in Table 2 and the coefficients β in Table 3 are used to calculate the benefits of road information service. It is assumed that road information is provided only for the National Highway No. 112, that the content of the information is the condition of the road surface in the pass, and that it is either dry/wet, pack snow, or frozen.

Because there is no toll charged on both the National Highway route No. 112 – No. 7 and the National Highway route No. 13 - No. 47, xji is 0 (yen), and the OD traffic volume between Yamagata and Shonai is 6,057 vehicles/day (obtained from multiplying the 1997 census data by a winter factor of 5% as a reduction rate); this is distributed into 5,655 vehicles/day on the National Highway route No. 112 – No. 7 and into 402 vehicles/day on the National Highway route No. 13 and No. 47.

The delay times in Table 4 and Table 5, which are predicted by users, were substituted into equation (4) to calculate the road users' route choice probability. But the objective measured data in Table 6 is used for the benefits calculation because that reality turns out different from the prediction. The travel time used in this case was clarified from road timetables. Because the National Highway route No. 13 – No. 47 is a flat road, the travel time by road conditions was calculated assuming a uniform speed decrease of 10% as the road condition got worse from "wet/dry to pack snow to frozen." This uniform decrease of 10% is based on the results of surveys in flat regions [3)], but because it is assumed that the speed reduces more in a pass, the calculation was performed assuming that the speed decline is 80% for pack snow and is 70% for a frozen road surface.

Table 6. Travel Time by Road Surface Condition

Route name	Length	Required time	Dry/wet			Pack snow			Frozen		
			Reduction rate	Speed	Required time	Reduction rate	Speed	Required time	Reduction rate	Speed	Required time
	(km)	(min.)	(%)	(km/h)	(min.)	(%)	(km/h)	(min.)	(%)	(km/h)	(min.)
Nat. Highway No. 112 - 7	113.4	130	100%	52	130	80%	42	163	70%	37	186
Nat. Highway No. 13 - 47	105.1	130	100%	49	130	90%	44	144	80%	39	163

Documents: based on the Road Timetable Book of Japan Highway Public Corporation

The time cost was obtained by multiplying the coefficients β in Table 3 by the required times in Table 6. And the delay time cost was obtained by multiplying the delay time range of the travel time obtained from the questionnaires by the β values in Table 3. Because there were no measured data for delay range, the delay range obtained from the questionnaire survey was used. Because this value can be obtained from questionnaire surveys under present road information provision, it is assumed that it approximates the actual value. Tables 7 to 9 show the results of calculating the above data used for benefit measurements by the content of road information.

Table 7. Road Information Provision Content (Wet/Dry)

			Traffic volume		Input(ex post time)			Generalized travel cost (yen/vehicles • min.)			Benefits calculation			
Information provision	Weather	Route	Subjective selection probability	Traffic volume (vehicles/day)	Toll charge (yen)	Required time (min.)	Delay time range (min.)	Time cost	Delay time cost	Total	Days manifest	Total by weather (¥100 million)	Total generalized travel cost (¥100 million)	Benefits (¥100 million)
without	Clear	R112,R7	0.62	3726.0	0	130	11.8	2719.9	231.2	2951.2	52	9.4	23.2	0.40
		R13,47	0.38	2331.0	0	130	16.3	2719.9	318.6	3038.5				
	Snow	R112,R7	0.48	2911.2	0	130	12.9	5299.2	555.2	5854.4	38	13.8		
		R13,47	0.52	3145.8	0	130	18.4	5299.2	793.2	6092.4				
with	Clear	R112,R7	0.99	5991.4	0	130	11.8	2719.9	231.2	2951.2	52	9.3	22.8	
		R13,47	0.01	65.6	0	130	16.3	2719.9	318.6	3038.5				
	Snow	R112,R7	0.94	5695.3	0	130	12.9	5299.2	555.2	5854.4	38	13.5		
		R13,47	0.06	361.7	0	130	18.4	5299.2	793.2	6092.4				

Table 8. Information Provision Content (Pack Snow)

			Traffic volume		Input(ex post time)			Generalized taravel cost (yen/vehicles • min.)			Benefits calculation			
Information provision	Weather	Route	Subjective selection probability	Traffic volume (vehicles/day)	Toll charge (yen)	Required time (min.)	Delay time range (min.)	Time cost	Delay time cost	Total	Days manifest	Total by weather (¥100 million)	Total generalized travel cost (¥100 million)	Benefits (¥100 million)
without	Clear	R112,R7	0.62	3726.0	0	163	14.2	3410.4	277.3	3687.7	9	1.9	21.9	0.3
		R13,47	0.38	2331.0	0	144	16.3	3012.9	318.6	3331.4				
	Snow	R112,R7	0.48	2911.2	0	163	17.5	6644.4	753.5	7397.9	47	20.0		
		R13,47	0.52	3145.8	0	144	18.4	5869.9	793.2	6663.0				
with	Clear	R112,R7	0.15	933.5	0	163	14.2	3410.4	277.3	3687.7	9	1.8	21.6	
		R13,47	0.85	5123.5	0	144	16.3	3012.9	318.6	3331.4				
	Snow	R112,R7	0.39	2363.1	0	163	17.5	6644.4	753.5	7397.9	47	19.8		
		R13,47	0.61	3693.9	0	144	18.4	5869.9	793.2	6663.0				

Table 9. Information Provision Content (Frozen)

			Traffic volume		Input (ex post time)			Generalized travel cost (yen/vehicles • min.)			Benefits calculation			
Information provision	Weather	Route	Subjective selection probability	Traffic volume (vehicles/day)	Toll charge (yen)	Required time (min.)	Delay time range (min.)	Time cost	Delay time cost	Total	Days manifest	Total by weather (¥100 million)	Total generalized travel cost (¥100 million)	Benefits (¥100 million)
without	Clear	R112,R7	0.62	3726.0	0	186	15.9	3891.6	310.9	4202.5	3	0.7	2.2	0.1
		R13,47	0.38	2331.0	0	163	16.3	3410.4	318.6	3729.0				
	Snow	R112,R7	0.48	2911.2	0	186	19.5	7581.9	838.5	8420.4	3	1.5		
		R13,47	0.52	3145.8	0	163	18.4	6644.4	793.2	7437.5				
with	Clear	R112,R7	0.003	20.2	0	186	15.9	3891.6	310.9	4202.5	3	0.7	2.1	
		R13,47	0.997	6036.8	0	163	16.3	3410.4	318.6	3729.0				
	Snow	R112,R7	0.06	372.3	0	186	19.5	7581.9	838.5	8420.4	3	1.4		
		R13,47	0.94	5684.7	0	163	18.4	6644.4	793.2	7437.5				

The next step is to estimate the route choice from content of information provision in Tables 7 to 9. When the content of information provided in Table 7 is “dry/wet”, as shown in Figure 6 and in Figure 7, because the provision of the information “dry/wet” for the National Highway No. 112 reduces the predicted travel time and predicted delay range below their levels without information provision, it can be concluded that route No. 112 – No. 7 will be selected more frequently when road information for this route is provided.

When the content of the road information is “pack snow” or “frozen” (Table 8 and Table 9), as shown by Fig. 6 and Fig. 7, although the predicted delay time is shortened by providing information, the predicted travel time is higher than it is without information provision, revealing that providing road information increases the frequency that users select the National Highway route No. 13 – 47.

Regardless of the fact that the travel times for the two routes are almost identical in Table 7, the benefits are positive because the provision of road information reduces the delay time cost on the National Highway route No. 112 – No. 7 where traffic volume is heavy. The benefits are also positive in Table 8 and Table 9, because the provision of road information reduces the travel time on the level part of the National Highway route No. 13 – No. 47 that carries heavy traffic volume. If the above benefits by road information provision are added, the total annual benefits are:

40 million yen + 30 million yen + 10 million yen = 80 million yen

Table 10 shows the annual costs including the addition of CCTV costs, meteorological observation systems costs, communication systems costs, and inspection costs. These costs were obtained from the Yamagata Construction Office. However, these estimates do not include labor costs. Our research focuses on road users, though road users and road management organizations use these information systems. So, we assume annual costs of 52.5 million yen as half of the annual total cost, as shown by the equations below:

Annual cost (52.5)={(343+720+440.4)/15+4.7}/2

Table 10. Costs Information

<table>
<tr><th rowspan="2">Route</th><th rowspan="2">Administrative office</th><th colspan="3">CCTV system cost (¥ million, 15 years)</th><th colspan="3">Meteorological observation system cost (¥ million, 15 years)</th><th colspan="3">Communication system costs (optical fiber cable) (¥ million, 15 years)</th><th>Inspection cost</th><th>Annual cost</th></tr>
<tr><th>Number of installed systems</th><th>Unit cost</th><th>Total Cost</th><th>Number of installed systems</th><th>Unit cost</th><th>Total Cost</th><th>Length (km)</th><th>Unit cost (yen/m)</th><th>Cost</th><th>(¥ million/ year)</th><th>(¥ million/ year)</th></tr>
<tr><td rowspan="3">National Highway No. 112 Gattusan</td><td>Yamagata Construction Office</td><td>13</td><td>13(11),20(2)</td><td>183</td><td>9</td><td>45</td><td>405</td><td rowspan="3">99.2</td><td rowspan="3">4,438</td><td rowspan="3">440.4</td><td rowspan="3">4.7</td><td rowspan="3">52.5</td></tr>
<tr><td>Sakata Construction Office</td><td>8</td><td>20</td><td>160</td><td>7</td><td>45</td><td>315</td></tr>
<tr><td>Total</td><td>21</td><td>20</td><td>343</td><td>16</td><td>90</td><td>720</td></tr>
</table>

Because the total benefits are 80 million yen and winter information provision cost is approximately 53 million yen, the cost-benefit ratio (B/C) is B/C = 80 million yen/53 million yen= 1.5. And the net benefit (B-C) is B-C = 80 million yen– 53 million yen = 27 million yen. It can be concluded that the present winter information provision is an effective project.

5. Sensitivity analysis

Because the calculation of benefits described in the previous section does not account for delay range data, it is calculated based on the travel time range as perceived by individuals and used as actual values. Because the values based on the road timetables were used as the travel times, the measurement results were based on objective data. Therefore sensitivity analysis is required. The travel times perceived by individuals were used as the travel times to perform the calculations, and the results were compared with the measurements based on the above objective data.

Table 11. Road Information Provision Content (Wet/Dry)

			Traffic volume		Input(ex post time)			Generalized travel cost (yen/vehicles • min.)			Benefits calculation			
Information provision	Weather	Route	Subjective selection probability	Traffic volume (vehicles/day)	Toll charge (yen)	Required time (min.)	Delay time range (min.)	Time cost	Delay time cost	Total	Days manifest	Total by weather (¥100 million)	Total generalized travel cost (¥100 million)	Benefits (¥100 million)
without	Clear	R112,R7	0.62	3726.0	0	142.9	11.8	2989.7	231.2	3221.0	52	10.7	28.5	1.5
		R13,47	0.38	2331.0	0	160.0	16.3	3347.6	318.6	3666.2				
	Snow	R112,R7	0.48	2911.2	0	164.5	12.9	6704.4	555.2	7259.7	38	17.8		
		R13,47	0.52	3145.8	0	181.1	18.4	7380.3	793.2	8173.4				
with	Clear	R112,R7	0.99	5991.4	0	142.9	11.8	2989.7	231.2	3221.0	52	10.2	27.0	
		R13,47	0.01	65.6	0	160.0	16.3	3347.6	318.6	3666.2				
	Snow	R112,R7	0.94	5695.3	0	164.5	12.9	6704.4	555.2	7259.7	38	16.8		
		R13,47	0.06	361.7	0	181.1	18.4	7380.3	793.2	8173.4				

Table 12. Road Information Provision Content (Pack Snow)

			Traffic volume		Input(ex post time)			Generalized travel cost (yen/vehicles • min.)			Benefits calculation			
Information provision	Weather	Route	Subjective selection probability	Traffic volume (vehicles/day)	Toll charge (yen)	Required time (min.)	Delay time range (min.)	Time cost	Delay time cost	Total	Days manifest	Total by weather (¥100 million)	Total generalized travel cost (¥100 million)	Benefits (¥100 million)
without	Clear	R112,R7	0.62	3726.0	0	170.0	14.2	3556.8	277.3	3834.1	9	2.1	25.6	0.2
		R13,47	0.38	2331.0	0	160.0	16.3	3347.6	318.6	3666.2				
	Snow	R112,R7	0.48	2911.2	0	185.7	17.5	7568.0	753.5	8321.5	47	23.5		
		R13,47	0.52	3145.8	0	181.1	18.4	7380.3	793.2	8173.4				
with	Clear	R112,R7	0.15	933.5	0	170.0	14.2	3556.8	277.3	3834.1	9	2.0	25.4	
		R13,47	0.85	5123.5	0	160.0	16.3	3347.6	318.6	3666.2				
	Snow	R112,R7	0.39	2363.1	0	185.7	17.5	7568.0	753.5	8321.5	47	23.4		
		R13,47	0.61	3693.9	0	181.1	18.4	7380.3	793.2	8173.4				

Table 13. Road Information Provision Content (Frozen)

			Traffic volume		Input(ex post time)			Generalized travel cost (yen/vehicles • min.)			Benefits calculation			
Information provision	Weather	Route	Subjective selection probability	Traffic volume (vehicles/day)	Toll charge (yen)	Required time (min.)	Delay time range (min.)	Time cost	Delay time cost	Total	Days manifest	Total by weather (¥100 million)	Total generalized travel cost (¥100 million)	Benefits (¥100 million)
without	Clear	R112,R7	0.62	3726.0	0	187	15.9	3917.5	310.9	4228.4	3	0.7	2.3	0.1
		R13,47	0.38	2331.0	0	160	16.3	3347.6	318.6	3666.2				
	Snow	R112,R7	0.48	2911.2	0	202	19.5	8238.4	838.5	9076.9	3	1.6		
		R13,47	0.52	3145.8	0	181	18.4	7380.3	793.2	8173.4				
with	Clear	R112,R7	0.003	20.2	0	187	15.9	3917.5	310.9	4228.4	3	0.7	2.2	
		R13,47	0.997	6036.8	0	160	16.3	3347.6	318.6	3666.2				
	Snow	R112,R7	0.06	372.3	0	202	19.5	8238.4	838.5	9076.9	3	1.5		
		R13,47	0.94	5684.7	0	181	18.4	7380.3	793.2	8173.4				

The results shown in Tables 11 to 13 reveal that the total benefits are 150 million yen + 20 million yen + 10 million yen = 180 million yen, which is about 2.3 times the benefits obtained based on the objective travel time described in the previous section.

The benefits for all road information provision contents are positive because the travel times predicted by the users are achieved. In other words, users choose the routes with the smaller predicted travel times and the travel times of the routes are actually shorter, and traffic costs are reduced. Also when road information "dry/wet" was provided, the predicted travel time for the National Highway route No. 112 – No. 7 was much shorter than that for the National Highway route No. 13 – No. 47, so the benefits are higher than the benefits based on the objective data in Table 7.

Furthermore, the predicted travel time was almost identical to the objective travel time obtained from the road timetable when the road information provided was “frozen,” so the benefits were almost identical. Calculating the cost-benefit ratio and net benefit in the same way as in the previous section we obtain the following results:

B/C = 180 million /53 million yen = 3.4, and B-C = 180 million - 53 million yen = 127 million yen.

In this sensitivity analysis, the calculation assumed that individuals perceive the required time as the travel time. In other words, the travel time as perceived by individuals was calculated by carrying out a questionnaire survey of users who regularly drive on the route, and it is assumed to be more reliable than the objective data based on the road timetables.

6. Concluding remarks

This study presented a method for evaluating the effects of different statuses of roads (dry, wet, pack snow and frozen) in monetary amounts when winter information is provided about roads on passes in mountains. The benefits of information provision to users regarding other kinds of roads in other seasons can also be calculated by this method. Because it is a relatively simple calculation method, it can be used for practical road management.

From the results of the evaluation of road information on the National Highway route No. 112 performed on this method, the calculation demonstrated that the project was effective.

This study provided the following four conclusions

1) When “wet/dry” information about a pass is provided, the certainty of the required driving time increases, and the travel time and the range of the travel time predicted (difference between the maximum travel time and the minimum travel time) for road users are both shorter than if information is not provided. This conforms with a revealed tendency by cognitive psychology [4), namely the tendency for an individual’s judgements of probability (objective probability) to estimate a higher probability of desirable outcomes.
2) When it is certain that the road surface condition is poor, namely “pack snow” or “frozen,” the provision of information results in a tendency for the travel time to be longer but for the predicted range to be smaller than when no information is provided.
3) From Table 3, the generalized travel cost of the travel time and the range of the travel time are almost identical by the weather, and it is concluded that the respondents evaluate them in a similar way. Comparing both the generalized travel cost, we can also conclude that the “clear” case is approximately 2 times the “snow” case, demonstrating that information related with snowing times is very important.
4) In this study, we calculated the benefits using the actual travel time by the road timetable and using the travel time that individuals responded in the questionnaire survey. The former is objective data because it is actually realized values, while the latter is subjective data because it is based on individual perception. If we compare both cases, it is better to use the subjective data than the actual data, because the phenomenon expected by individuals was actually realized. In other words, traffic costs are reduced because users choose the routes with the smaller predicted travel times and the travel times of the routes are actually shorter.

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