STATE OF THE ART WINTER ROAD MANAGEMENT IN A HEAVY SNOWFALL AREA

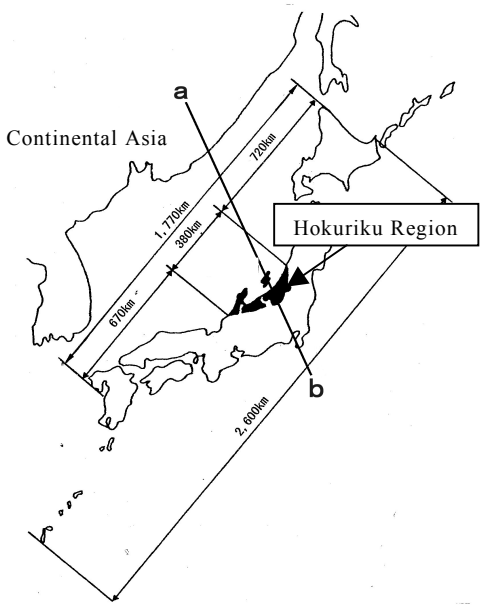
Kazunori Konno
konno-k84bj@hrr.mlit.go.jp
Road Department, Hokuriku Regional Development Bureau,
Ministry of Land, Infrastructure, and Transport
1-425-2 Hakusan-ura, Niigata-shi, 951-8505, JAPAN
Tel +81-25-266-1171 Fax +81-25-265-6148

Koetsu Takata
takata-k84bx@hrr.mlit.go.jp
Nagaoka National Highway Office, Hokuriku Regional Development Bureau,
Ministry of Land, Infrastructure, and Transport
4-430-1 Nakazawa, Nagaoka-shi, 940-8512, JAPAN
Tel +81-258-36-4551 Fax +81-258-36-4467

Teruhiko Maruyama
terum@vos.nagaokaut.ac.jp
Department of Civil and Environment Engineering,
Nagaoka University of Technology
1603-1 Tomioka-cho, Nagaoka-shi, 940-2188, JAPAN
Tel +81-258-47-9613 Fax +81-258-47-9600

1. Outline

The Hokuriku Region is one of the world's leading heavy snowfall regions where wet, heavy snow has accumulated to depths of more than 3 m on the Yuzawa Section of National Highway No.17. As the daily temperature in this region fluctuates rapidly between +10°C and –10°C, the accumulated snow freezes and thaws repeatedly, causing frequent changes in road surface conditions. Also, during the winter, large numbers of tourists use National Highway No.17 to travel from coastal cities, where snow rarely falls, to visit resorts in the region. Under these special conditions, snow is efficiently removed from the roads to keep traffic moving 24 hours a day to help maintain the smooth daily life and economic activities of this heavy snow region. At the Hokuriku Regional Bureau, advanced information technology and sensor technology have been used to develop a road surface information collection system and a snowfall prediction system and these have been established as practical working systems. These systems are efficiently used to carry out strategic road management in this heavy snow region.



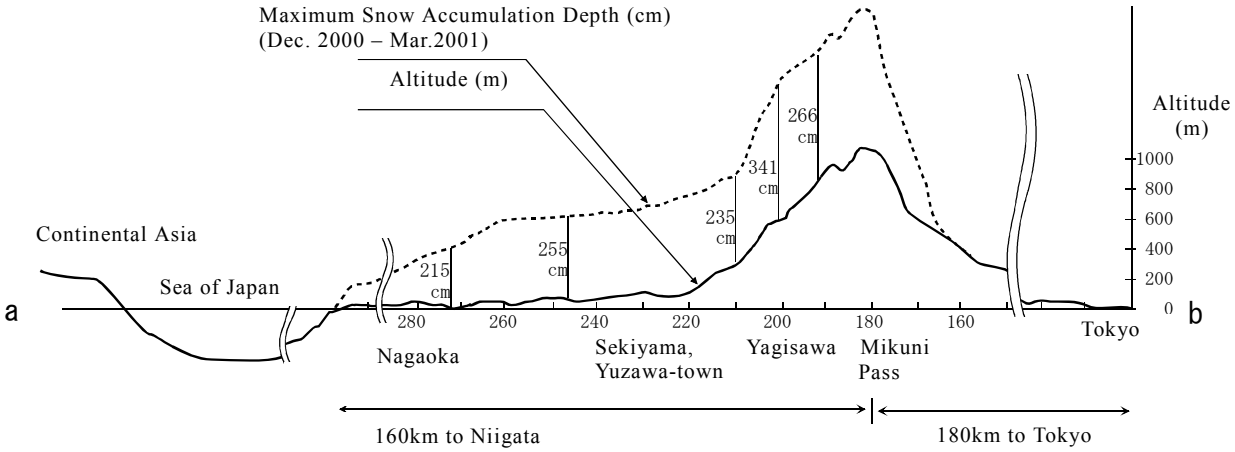


Fig.1 Topographical Cross Section of the Hokuriku Region (a-b section)

2. Collection of road surface information

On the Yuzawa Section of National Highway No.17, many ITV and meteorological observation devices are installed to collect information needed for road management. In addition, a system that quantitatively collects road surface information has been introduced (Fig.2, Photo.1). The sensors that are part of the road surface information collection system rotate at an angle of 50° to scan the road surface in order to measure the road surface temperature, road surface condition (dry, wet, sherbet, accumulated snow, packed snow), depth of accumulated snow, road width, and height of the snow embankment. The results of the analysis of the measured data are displayed on screens at the maintenance branch offices in real time, thus it is possible to constantly and quantitatively monitor the state of the road surface and to make accurate judgments as to the correct time to perform snow removal work, including wide-area snow removal and processing of packed snow (Fig.3). It is possible to use this system and traffic counter data to clarify winter vehicle travelling speed and improve the level of services and road management.

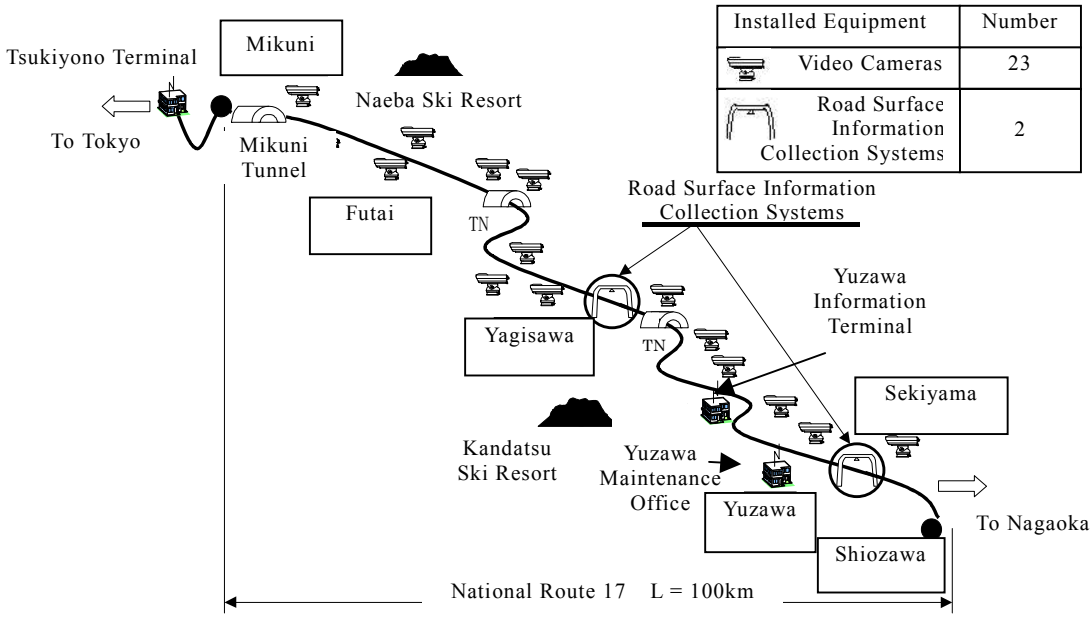
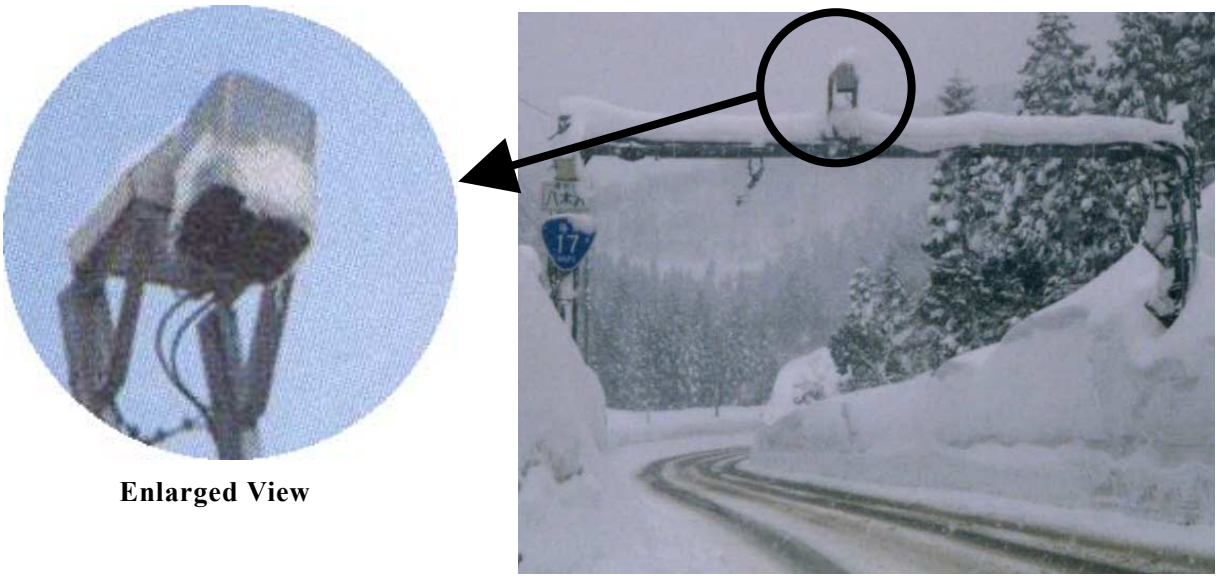


Fig.2 Road Surface Information Collection System Installation Locations



Enlarged View

Photo.1 Road Surface Information Collection Sensor

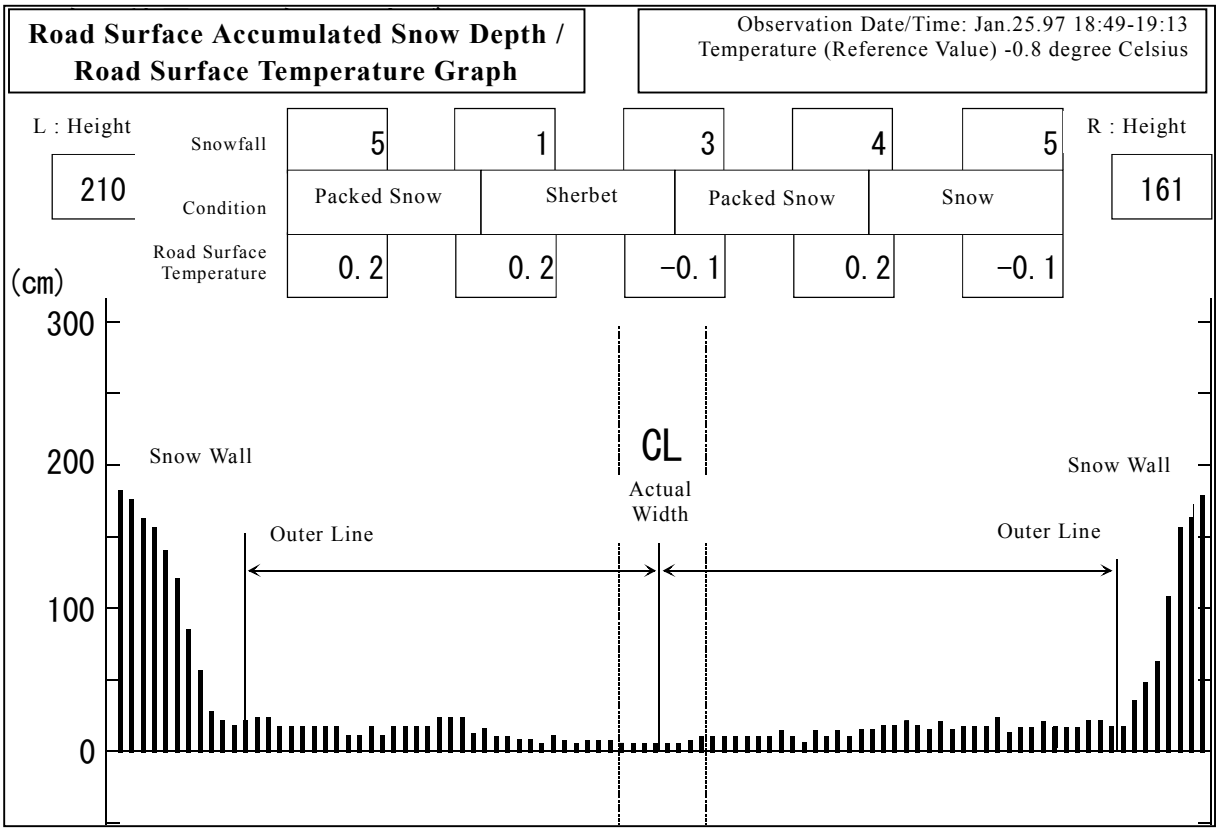


Fig.3 Display Image of Measured Data

3. Prediction of snowfall and freezing

At the Nagaoka National Highway Office, road managers predict snowfall and freezing by their own methods, which in turn id used to execute road management more efficiently. The predictions include long-term predictions (about 16 hours), applied to establish the snow removal system and short-term predictions (about 3 hours) applied to decide when to dispatch

the snow removal vehicles. The former predict the quantity of snowfall and freezing throughout the region in grids of 2.5 km, by analyzing telemeter observation values within the jurisdiction of the office and numerical forecast GPV distributed by the Meteorological Agency. The latter predict snowfall and freezing based on the results of telemeter observations within the jurisdiction of the office and weather radar results. At the Nagaoka National Highway Office, these predictions are distributed to the prefectural government and to municipal governments within its jurisdiction over the internet (Fig.4).

The results of the long term predictions for snowfall have been compared with measured values to check the percentage of times the prediction was accurate to within a depth of 10 cm. The results show that an accuracy rate of more than 80% has been obtained throughout the Yuzawa Region. These snowfall and freezing prediction results can be used to predict driving speed and travel times to destinations by entering them into a winter traffic flow simulation program.

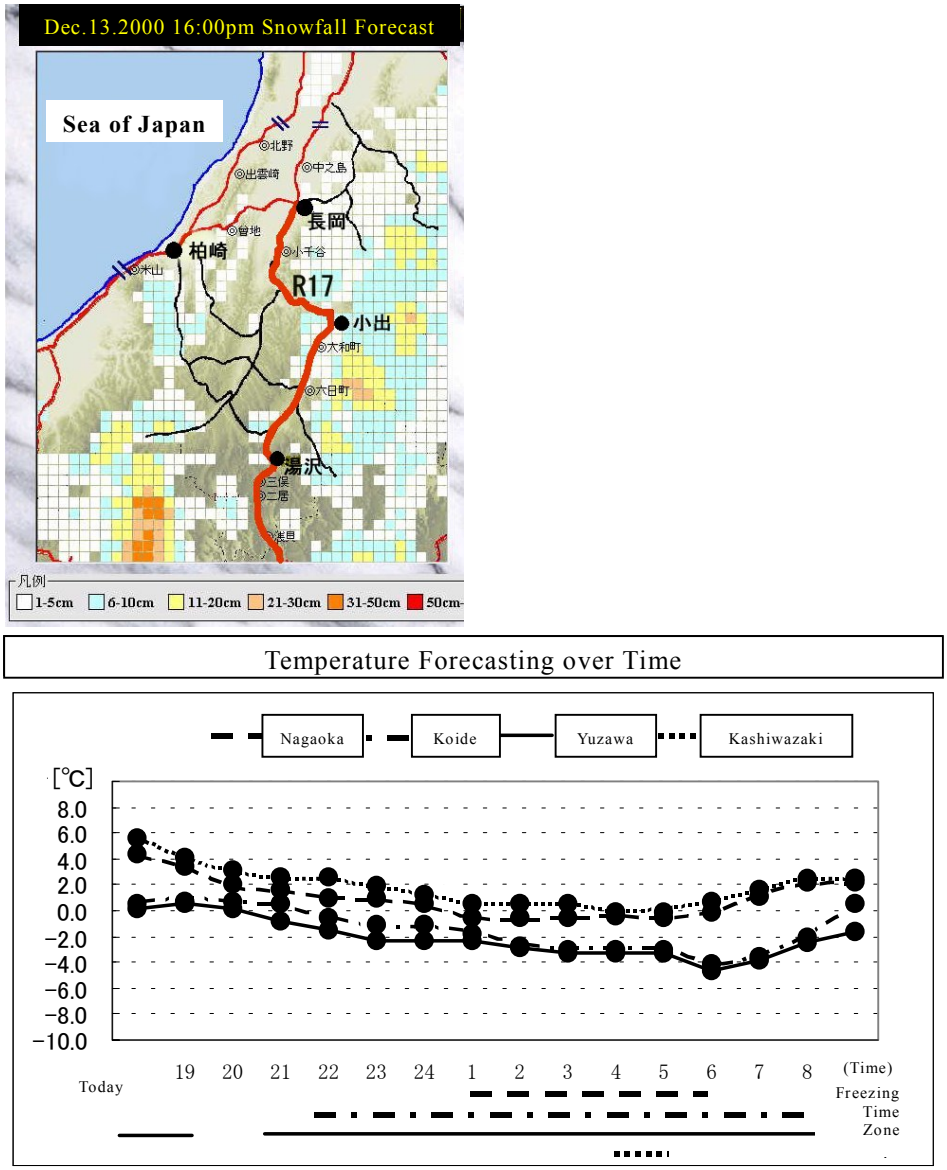


Fig.4 Long-Term Forecasting Result

4. Winter traffic flow simulation

The data obtained from the information collection systems and from vehicle test results have been used to prepare a driving speed prediction equation based on the method of least squares and is used to construct a winter traffic flow simulation based on a neural network. (Fig.5, Fig.6)

The method of least squares was performed by entering the quantity of snowfall, road surface snow accumulation depth, road surface temperature, air temperature, effective width, and traffic density to obtain the driving speed. The data obtained from January to March 2000 was entered into the neural network based model. The results were applied to data for 2001, confirming their accuracy. The estimated driving speed and travel time accurately reproduced measured values (Fig.7).

$$V = (ax_1 + bx_2 + cx_3 + d)EXP\left(-K/Kc\right)$$

V : Driving Speed (km/h)

x_1 : Road Surface Snow Depth (cm)

x_2 : Weather (Snowfall per hour:cm/h)

x_3 : Actual Road Width (m)

a,b,c,e : Regression Coefficient

d : Constant Term (km/h)

K : Traffic Density (vehicles/km)

K_c : Critical Density (vehicles/km)

Fig.5 Driving Speed Prediction Equation

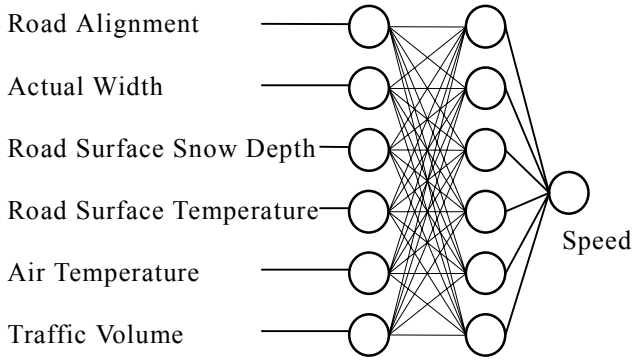


Fig.6 Neural Network Model

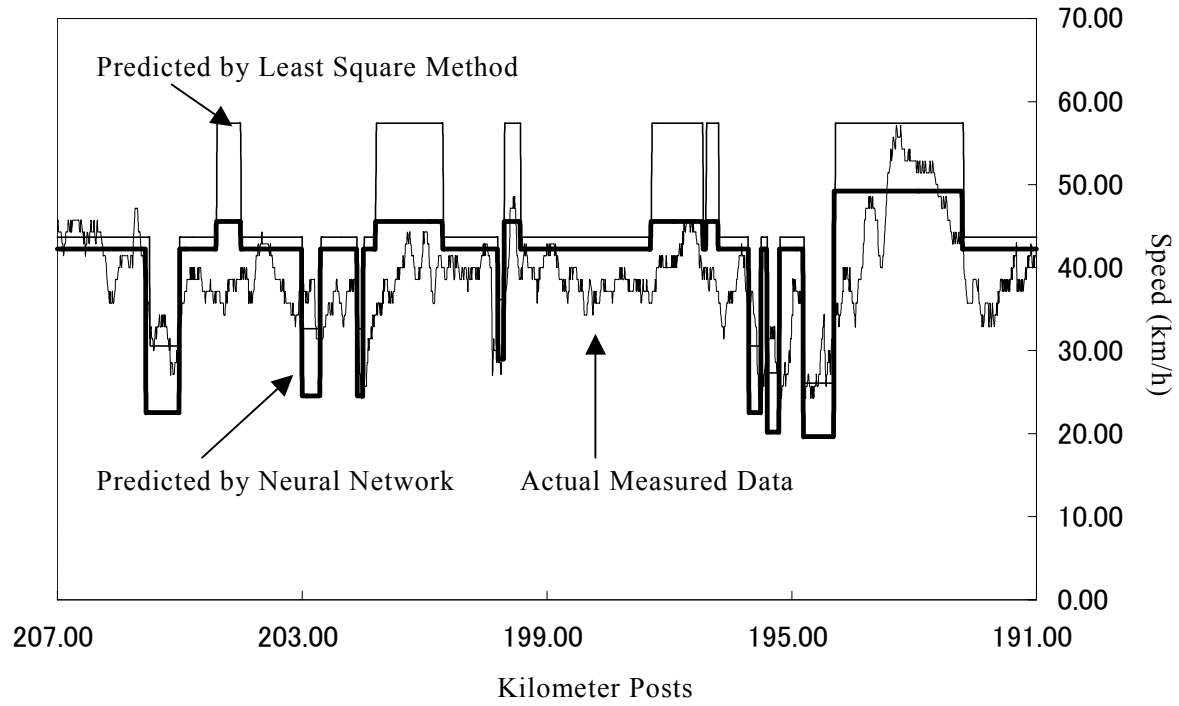
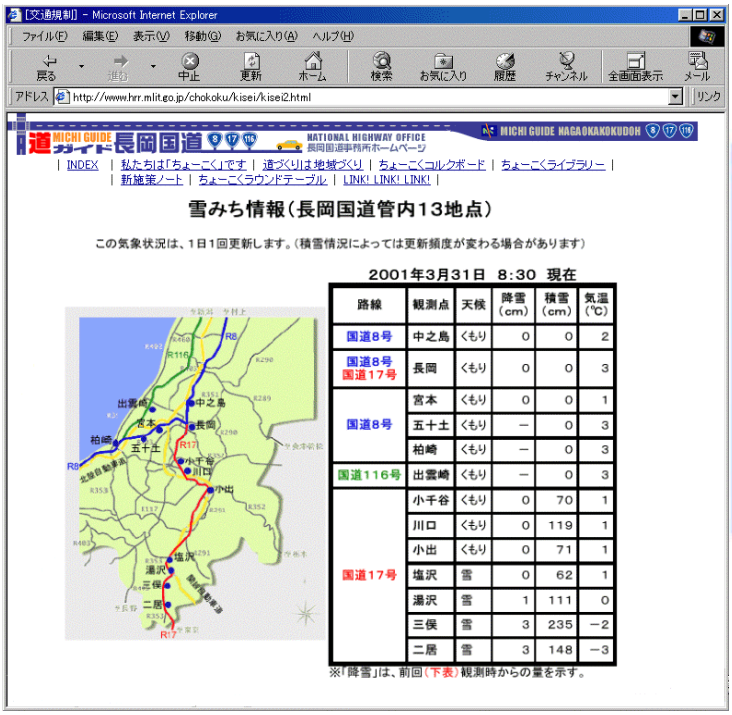


Fig.7 Comparison of Measured Data with Simulation Predicted Data
(Experiment Day : Feb.16.2001)

5. Information provision methods

The Nagaoka National Highway Office provides the public with road closure and other traffic information, weather information, snow conditions, and ITV images, in real time using its internet home page, which can be accessed through cell phones, and by means of VICS (Fig.8, Fig.9). Studies will be carried out in the future to plan ways to provide travel times to destinations. Road users can use this kind of information to check on weather conditions and road conditions to their destinations in real time, allowing them to use the results to prepare and or revise travel plans. Road managers can clarify and share the information in real time and use it to carry out efficient snow removal work.

Fig.8 Providing Information for Mobile Phones



路線	観測点	天候	降雪(cm)	積雪(cm)	気温(℃)
国道8号	中之島	くもり	0	0	2
国道8号 国道17号	長岡	くもり	0	0	3
国道8号	宮本	くもり	0	0	1
	五十土	くもり	−	0	3
	柏崎	くもり	−	0	3
国道116号	出雲崎	くもり	−	0	3
国道17号	小千谷	くもり	0	70	1
	川口	くもり	0	119	1
	小出	くもり	0	71	1
	塩沢	雪	0	62	1
	湯沢	雪	1	111	0
	三俣	雪	3	235	−2
	二居	雪	3	148	−3

Fig.9 Provision of Information on web site

6. Trial calculation of the effects of the project

The Nagaoka National Highway Office uses the snowfall and freezing prediction system and road surface information collection system to aid the smooth flow of traffic, establish appropriate snow removal systems, and perform rapid snow removal work. To evaluate effectiveness, the Office performed two kinds of trial calculations: one to measure driving support effects and another to assess snow removal support effects.

A) Driving support effects: Performing well-timed snow removal work lowers travel costs and reduces lost travel time caused by road users travelling more slowly.

B) Snow removal support effects: Road managers reduce costs by shortening stand-by time

and work time for snow removal work.

The trial calculation has shown that the snowfall and freezing prediction system saves ¥18 million throughout the region under the jurisdiction of the Nagaoka National Highway Office and the road surface information collection system saves ¥13 million on the Yuzawa section (Fig.10). Based on these results, it has been determined that the introduction of these systems provides adequate cost-benefits considering their cost and service life.

Project	Value of Effects	Support Effects
Snowfall and freezing forecasting system (In the region under the jurisdiction of the Nagaoka National Highway Office)	¥18 million	Driving support effect
Road surface information collection system (Yuzawa section of National Highway 17)	¥4 million	Driving support effect
	¥9 million	Snow removal support effect
	Total: ¥13 million	

Fig.10 Results of a Trial Calculation of Effects of Project Investment
(Dec.2000 – Mar.2001)

7. Conclusions

On the Yuzawa Section of National Highway 17, qualitative monitoring by ITV is supplemented by the use of a road surface information system to qualitatively clarify the state of road surfaces in real time. In addition, snowfall and freezing predictions are used for winter road surface management including the establishment of snow removal systems and planning the dispatch of snow removal equipment. The predictions are also publicly released to road users using the Internet and other media. Advanced winter road management of this kind guarantees safer and smoother winter road traffic and its introduction is counted on to reduce effects on the environment of regions along road routes. Future plans call for work to improve the precision of these systems and provide more useful information in order to execute superior winter road management.