Construction of a road management support system using information forecast

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1. Introduction

In the Hokuriku Region of Japan, snow accumulates to depths rarely seen anywhere in the world. This occurs because of the meteorological and topographical features unique to this region. Specifically, under the effects of continental high pressure, north-west seasonal winds carrying large quantities of water vapor strike the range of mountains that extend from the north to the southern ends of the Island of Honshu, then the foothills of these ranges push this air back and transform it into ascending currents. As this moist air is forced upwards, it cools rapidly and its water vapor is crystallized, causing heavy snowfall. (Figure 1) In regions where this heavy wet snow falls, snow removal is the major task carried out by road managers during the winter. Winter road management work systems should now be introduced because this snow removal work [1] is work that is carried out in the face of weather conditions that fluctuate sharply both temporally and spatially so it is guided largely by each road manager's experience and cannot always be performed rationally and stably, [2] it is forecasting that the increase in the number of roads in service will result in a shortage of veteran workers with this necessary experience, and [3] the cost of road management must be lowered.

Thanks to recent advances in information technology, it is now possible to use the internet or portable telephones etc. to easily provide road users with road weather information such as the air temperature, wind speed, accumulated snow depth on roads that road managers accumulate for management use. Reports on the number
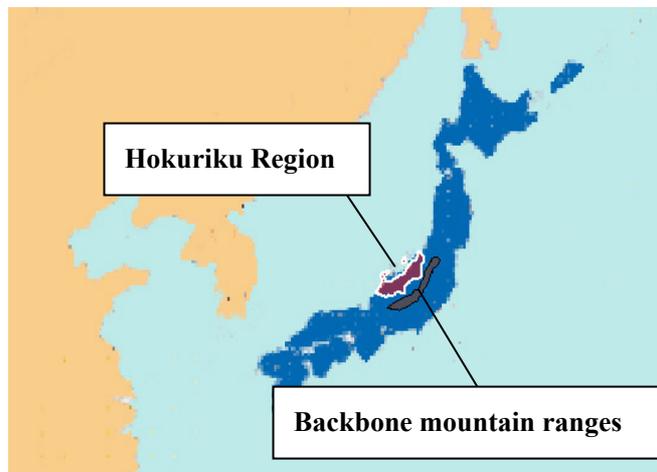

Figure 1. Location of the Hokuriku Region

of people with internet access show that information of these kinds will be accepted   by road users as information with high utilization value.

This report introduces the future direction of the development of road management systems that can establish indices to support decisions concerning when to mobilize snow removal organizations and perform snow removal work, and also to provide information seamlessly to road users.

2. Traveling speed forecasts for snow-covered road surfaces using roadway weather

2.1 Collecting and providing roadway weather

Offices of the Ministry of Land, Infrastructure, and Transport that manage national highways in snowy regions install information collection instruments and information provision systems along roadways and use meteorological data and traffic data to manage these roads in the winter. Table 1 shows an outline of the major information collection instruments and systems. Accumulated snow depth, total snowfall depth, road temperature and other elements of the road weather are collected on-line by the management offices where the office staff select road closure information and other information with high utilization value for road users from among this collected information and provide it on roadside display boards and through the internet.

Table 1. Names and Outlines of Information Equipment Used for Winter Road Management

Equipment name	Outline
Meteorological telemeters	Accumulated snow depth, total snowfall depth, air temperature, wind velocity, and wind direction are observed and collected ever hour on the hour.
Road surface freeze sensors	Non-contact sensors detect four properties of road surfaces that are dry, wet, ice-covered, and snow-covered. These data are collected online ever hour on the hour.
Snowfall and Freeze forecasting Systems	Aerological data from the Meteorological Agency, ground surface data from weather stations, AMEDAS and meteorological telemeter data are used to predict total snowfall and the time when freezing will begin.
Road surface information collection systems	Infrared rays are radiated from road center lines to observe the state of the road surface, packed snow depth, snow bank height, effective width, and so on.
ITV	TV cameras are installed on roads to observe the condition of the roads and traffic flow and to provide moving and still pictures to road users
Road information boards	As necessary, road closure information, road surface information, congestion information, etc. are displayed on LED type display boards. Air temperature display boards are also installed.

2.2 Traveling speed forecast equation based on multiple linear regression analysis

Up till now, it has been necessary to install many meteorological telemeters and other road information equipment on roads, and to use existing equipment to perform effective road management and to reduce its cost.

The road weather data that have been collected by these information instruments are now used to predict traveling speed, and this traveling speed is treated as reference information to support snow removal measures. The traveling speed is forecasting by multiple linear regression analysis with the depth of accumulated snow on the road, its effective width, and the snowfall per unit of time that have a big influence on traveling speed on winter roads used as variables for the analysis. Equation (1) is the speed forecast equation for a road surface without an accumulated snow cover and equation (2) is a speed forecast equation for a road with an accumulated snow cover.

$$V = (bx_1 + cx_2 + d) + eK \qquad (1) \qquad\qquad V = (ax_1 + bx_2 + cx_3 + d)EXP\left(-K/Kc\right) \qquad (2)$$

V: traveling speed (km/h)
x_i: road surface snow depth (cm)
x_2: weather (snowfall per unit of time: cm/h)
x_3: effective width (m)

a,b,c,e: regression coefficient of each element
d: constant term (km/h)
K: traffic density (vehicles/km)
Kc: critical density (vehicles/km)

Because there is a difference between the relationship of the traffic density with speed on roads with snow and on roads without snow, two equations have been prepared as higher precision regression equations.

2.3 Verification of the precision of the speed forecast equations

Figure 2 shows a comparison of actual traveling speeds with forecasting traveling speed obtained by the speed forecast equation performed to verify the precision of the speed forecast equation for a snow-covered road that is equation (1). The results show that the precision of the speed forecast equation is generally good.
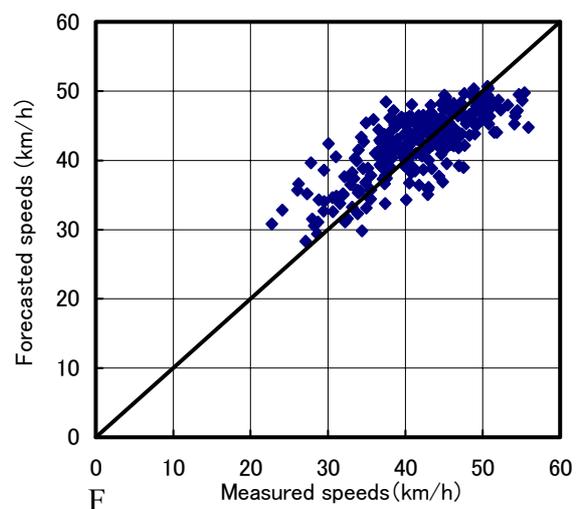

Figure 2. Comparison of Forecasting Speeds with Measured Speeds

3. Forecasts of travel time on winter roads

3.1 Forecasts of travel time by winter road traffic simulation

Travel time is forecasting by reproducing the road in a certain section during the winter to predict the section speed. The reproduction is done by using tracker theory to hypothesize a number of cars driving in the section in order to account for behavior between cars. The way the vehicles moved accounted for straight and for curved parts of the road alignment, and for curved parts, deceleration based on curve diameter and curve length were added.

3.2 Evaluation of the reliability of the winter road traffic simulation

The reliability of the winter road traffic simulation is evaluated by the comparison of changes in speed of actual traffic and changes in speed in the simulation shown in Fig. 3. Its reliability is also evaluated by Table 2 that compares the section average speed and travel time of an actual traffic flow and forecasting values obtained from the winter road traffic simulation.

During the winter, the road environment changes continually along with changing weather conditions. Therefore, assuming that travel time fluctuates accompanying these changes, it can be said that overall travel time fluctuations are reproduced, but it is impossible to respond to abrupt changes in speed, and it will be necessary to improve the ability of the simulation to follow these changes. But a comparison of the section average speed, travel time etc. shows that good results with the errors within the allowed range were obtained. And considering the fact that these physical values, the section average speed and travel time, both depend upon the road section, the snow removal is performed separately for each section, and the two indices can be maintained at a forecast level that allow their use, even during actual snow removal.
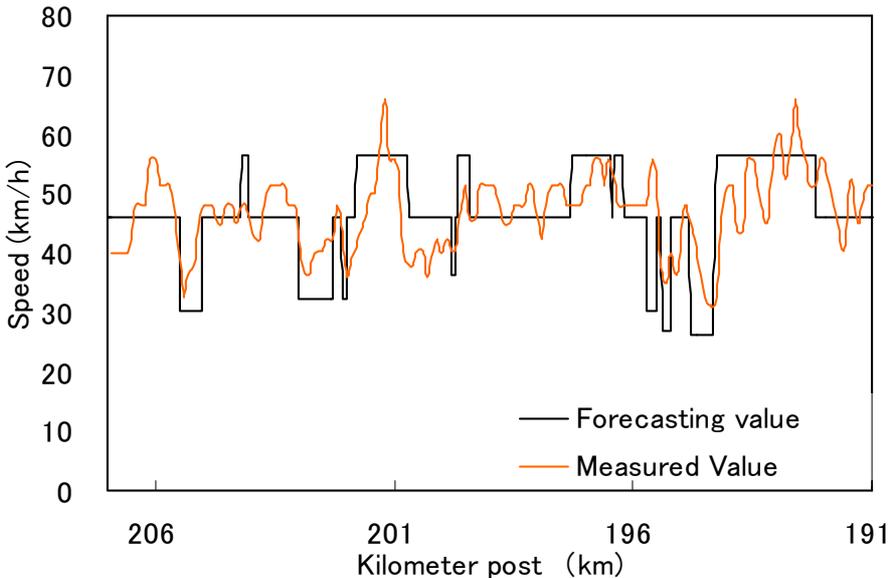

Figure 3. Changes in Measured and Forecasting Speed

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Table 2. Section Average Speed and Travel Time

	Section Average Speed (km/h)	Travel time (min.)
Measured values	46. 6	20
Forecasting values	45. 2	21

4, Road management support system

4.1 Road management support system flow

Fig. 4 shows the road management support system flow: the procedure followed to convert road weather data to forecasting traveling speed and forecasting travel time, plus the procedures road managers will follow to utilize these forecasts and procedures for the use of this information by road users.
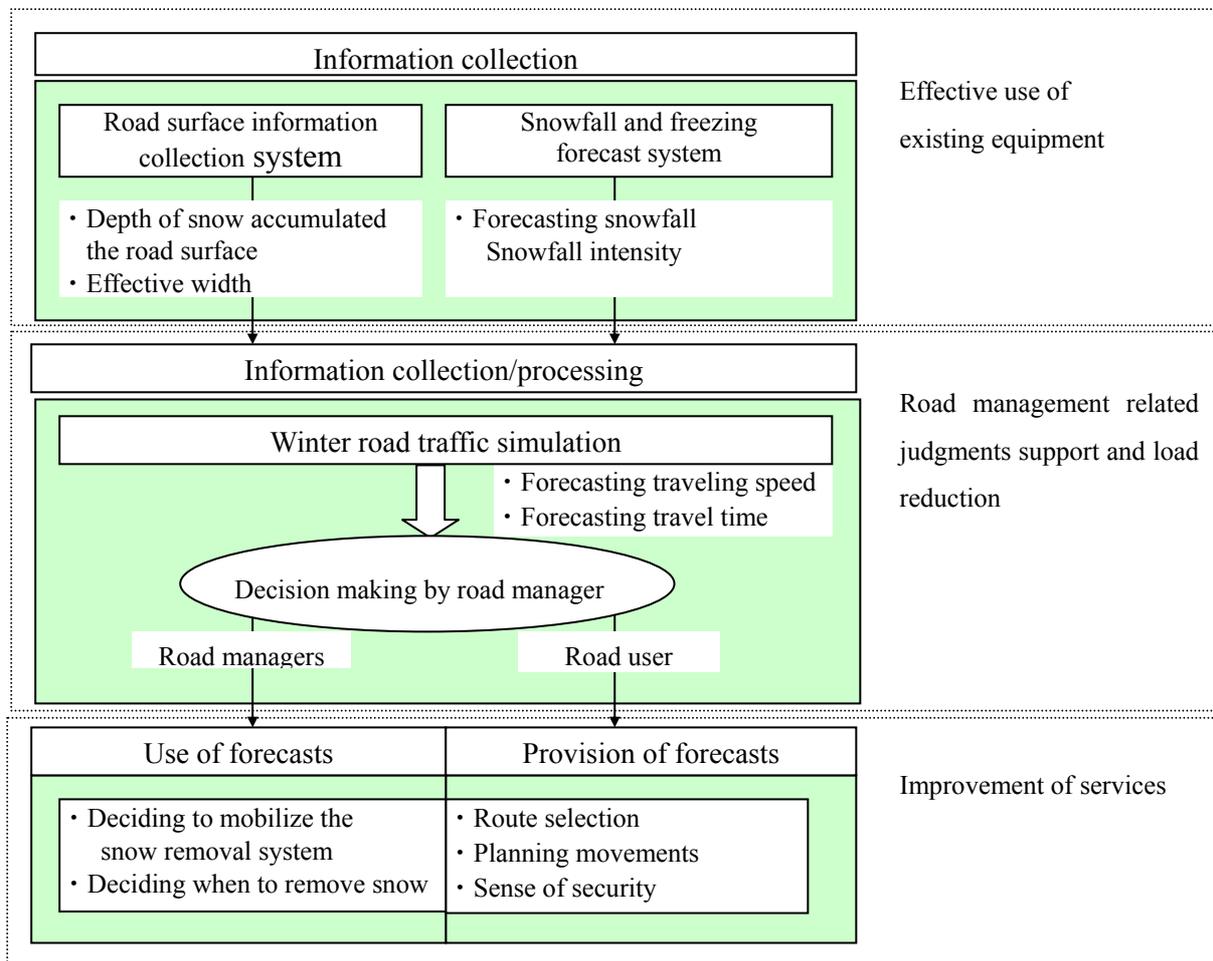
Figure 4. Road management Support System Procedure

4.2 Use of information by visualizing road information

To reach judgements necessary to make decisions regarding snow removal shown in Fig. 4, indices visualized by plotting them on graphs supports decision making more effectively from the perspective of human engineering than by applying the numerical values as in the past.

Fig. 5 shows a graph that plots traveling speed, road surface temperature, and air temperature forecasting as a time series. Simultaneously plotting the three indices on a single graph is done to allow the user to see the three indices at the same time to reach a comprehensive judgment.

Presenting numerical values in visual format so the air temperature above the road and other aspects of the road environment can be intuitively and visually understood supports judgments that are both immediate and accurate. It is assumed that this approach will narrow the range dependent upon experience.

4.3 Example of the utilization value of traveling speed and its method

Many road managers now use forecasting road surface temperature (forecast of freezing of the road surface) to plan when to spread anti-freezing chemicals as a snow and ice measure, but the forecast of traveling speed shown in Fig. 5 is used to decide when to remove snow. As stated earlier, in heavy snowfall regions, along with spreading anti-freezing chemicals, snow removal also plays an extremely important part in maintaining road traffic, so efficiently implementing both measures can sharply reduce costs and contribute to the earlier realization of more effective and more efficient winter road management.
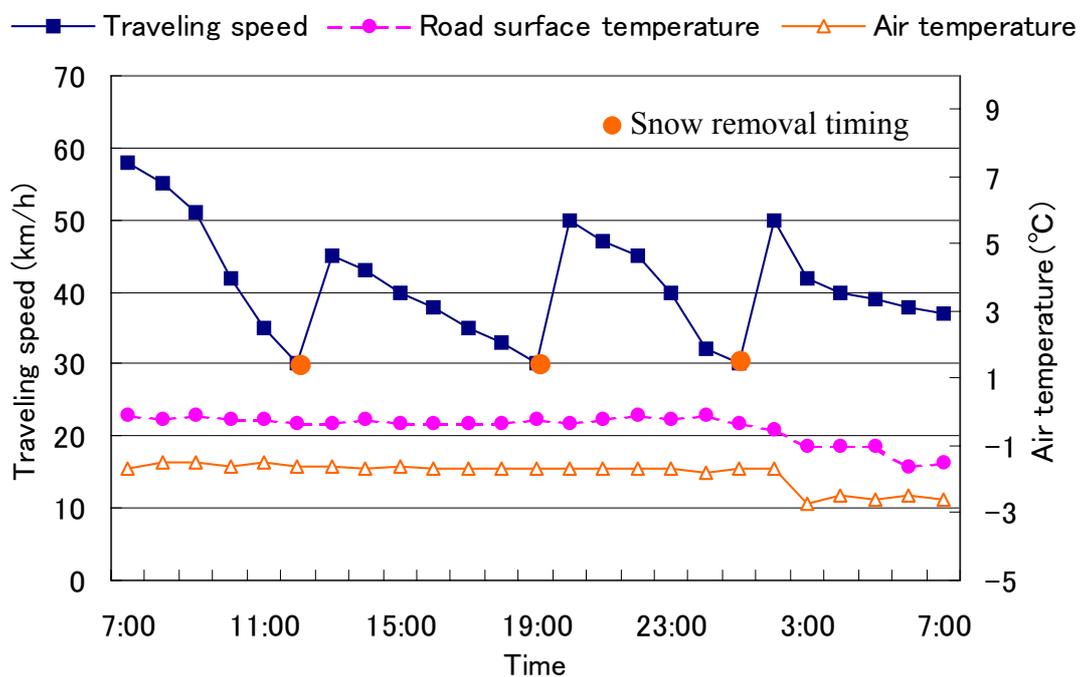

Figure 5. Support for Decisions Regarding the Timing of Snow Removal (Image diagram)

4.4 Road management support system screen

Considering the fact that a road management support system will be used for day-to-day operations, such a system must be designed to be easy to use and include functions that permit

anyone to use it intuitively and skillfully. Regarding this point, the design of a screen for road management use must not be limited to functions that display information; top priority must be on the provision of a human interface that links the human operators with the machine. The configuration of the screen of this human interface must be designed as a human centered system to conform to the versatility and flexibility that are human characteristics. And by providing a hierarchically structured interface that permits pleasant interactions and designing it so that the overall structure and partial structures are analogous, it is possible to allow users to quickly understand the information it presents.

Fig. 6 shows an image of the screen of a road management support systems that meets these requirements. In the example shown in Fig. 6, a map of the jurisdiction is provided in the background of the screen to let the user visually observe the geographical conditions, and on the left and right sides respectively, passive judgments that provide an awareness of present conditions (weather observation data, road environment, etc.) and active judgments made to provide protection (forecasting snowfall, forecasting travel time, forecasting traveling speed, etc.) are displayed.

The screen display can be extensively modified by software development, and it allows the addition of data needed by other road managers.
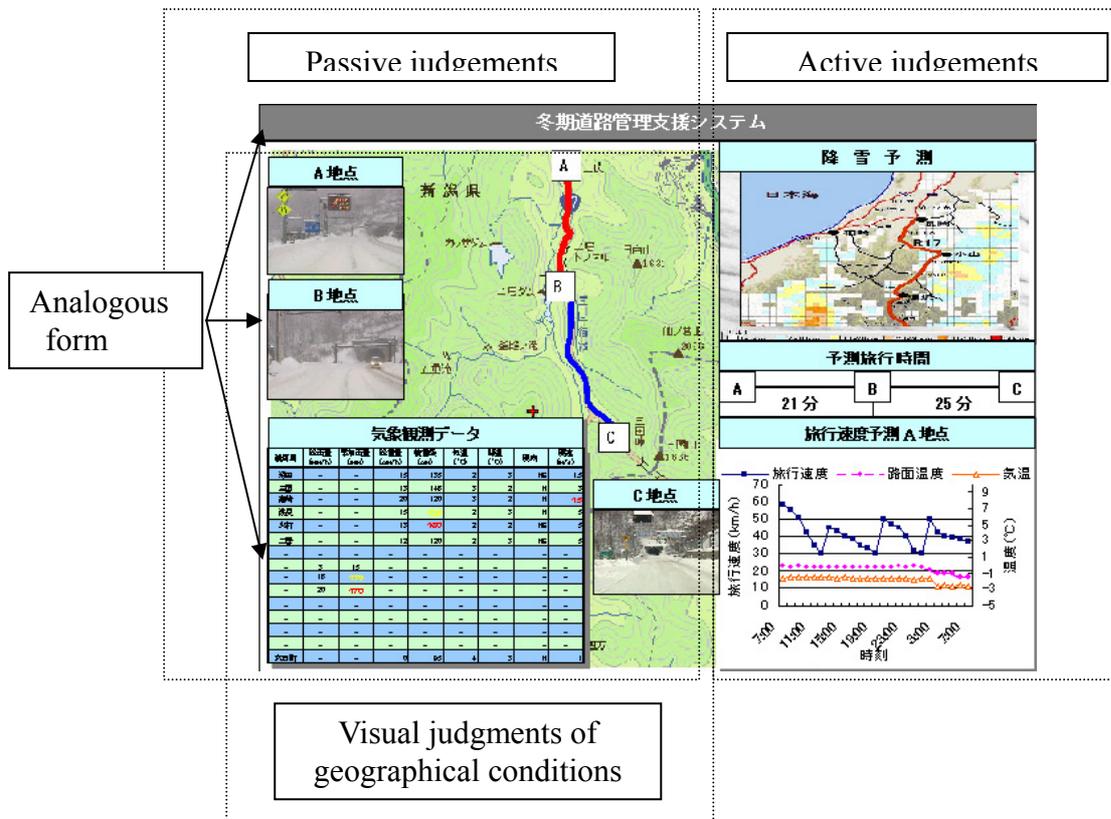

Figure 6. Example of a Road Management Support System Screen

4.5 Provision of information to road users

Forecasts such as forecasting traveling speed or forecasting travel time are gradually becoming information with utilization value not only to support decision making by road managers, but for road users as well. The results of providing forecasting travel times in particular vary according to the provision range and method, but in many cases, this data allows users to avoid congested routes to reduce their travel time.

The road management support system flow shown in Fig. 4 indicates how information is provided based on judgments by road managers. Although past information provision by roadside display panels and roadside stations is now being supplemented by the provision of information by portable telephones and by the internet, two systems that have achieved remarkable progress in recent years, it will be necessary to study the content of information and the ways that it is supplied in order to more effectively use the information.

5. Conclusion

This report has shown how road weather based forecasts support road management and benefit road users. But challenges that remain include the improvement of the reproducibility and the accuracy of simulations of winter roads that is the foundation for these forecasts. Road traffic during the winter is difficult to reproduce, because it depends not only on the road alignment, but also on road surface freezing and visibility problems caused by low air temperatures, snowfall, and other weather conditions, and because of the complex mutual effects of many other factors including the occurrence of sudden congestion and motor vehicle accidents resulting from the appearance of road environments characteristics of the winter season. One important way to resolve such complex science is the use of simulation technology on today's large computers, and this is another research challenge that must be overcome.

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