A Study of Service Levels and Sensors Which Scan Cross-Sections of Snow on the Road and Provide Information of the Road Surface Characteristics

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1.Introduction

In snowy regions, it is extremely important to have road planning which takes snow into account and to organize road management methods in order to ensure safe and smooth traffic flows. To minimize snow's effect on the regional economy, various maintenance methods, focusing on road structure, snow prevention and snow clearing facilities, and snow clearing systems have all been promoted. However in recent years, with the developments in social economics, the requirements of road users have been growing more advanced and diversified and levels of schedule accuracy, comfort, reliability, and safety similar to those in summer are being demanded in winter too.

To achieve this, it is essential to have a firm understanding of road maintenance conditions in winter as far as snow clearing is concerned, as well as the traffic situation based on these. At present the meteorological data that is available for factor analysis of winter traffic flow features include depth of snowfall and the snowplow operation situation. A reduction in vehicle flow speed is a factor, which reduces traffic volume. Data relating to the road surface situation, such as reduction in effective road width due to compacted snow on the road surface and snow banks at the side of the road must be made available.

We set up a measuring device, which automatically observes the winter road surface situation in real time. Below is a report of the results of our on-site observations on its accuracy etc.

2. Outline of road surface information collection system

2.1 Overall research concept

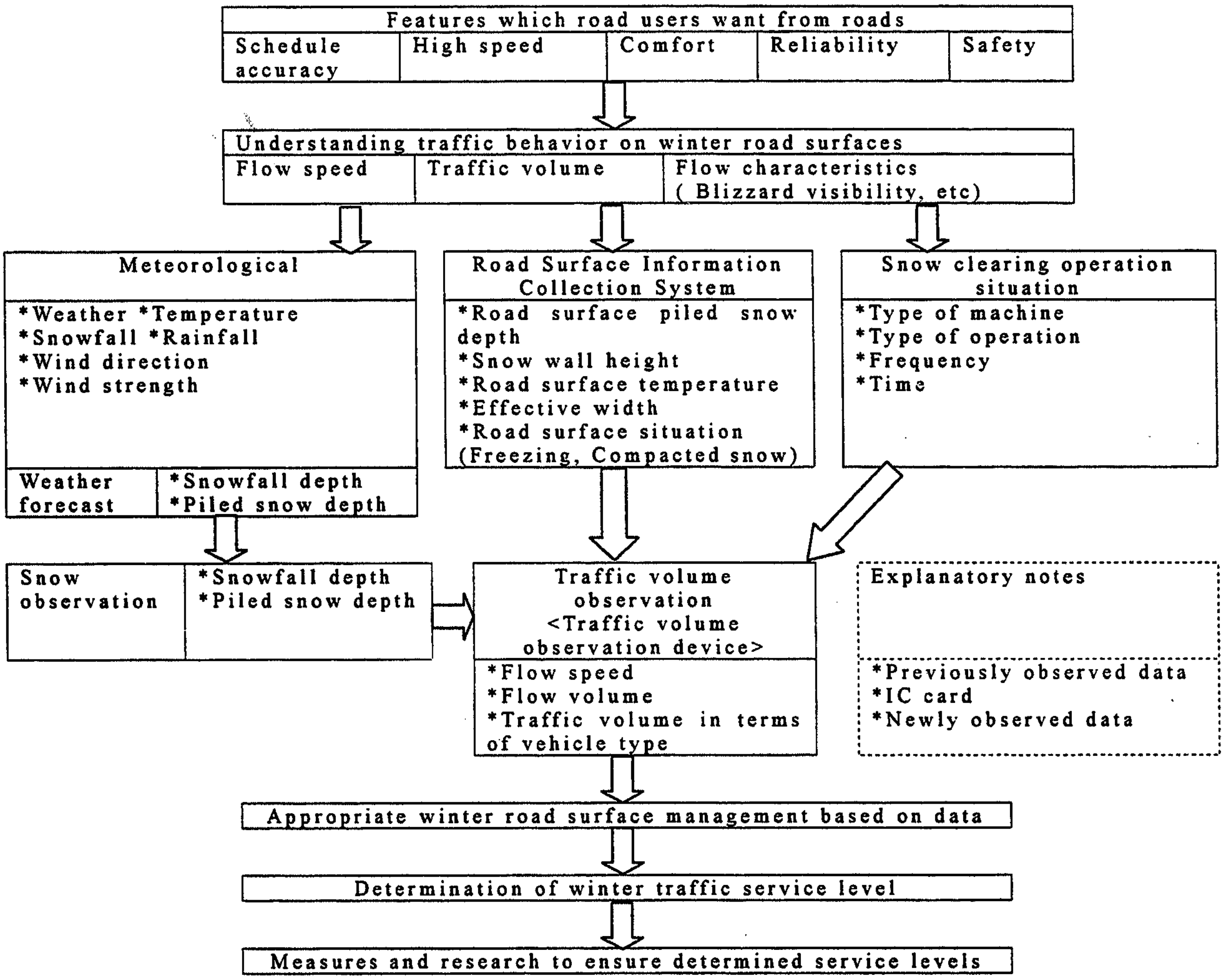


Fig.1 Overall research concept and road surface information collection system position

2. 2 Composition of road surface information collection system

As shown in Fig. 2, the road surface information collection system (hereafter called "system") consists of a "sensor section" which performs measuring, a "transformer section" which converts the measured value into a signal, and a "computer section" which makes illustrations and graphs.

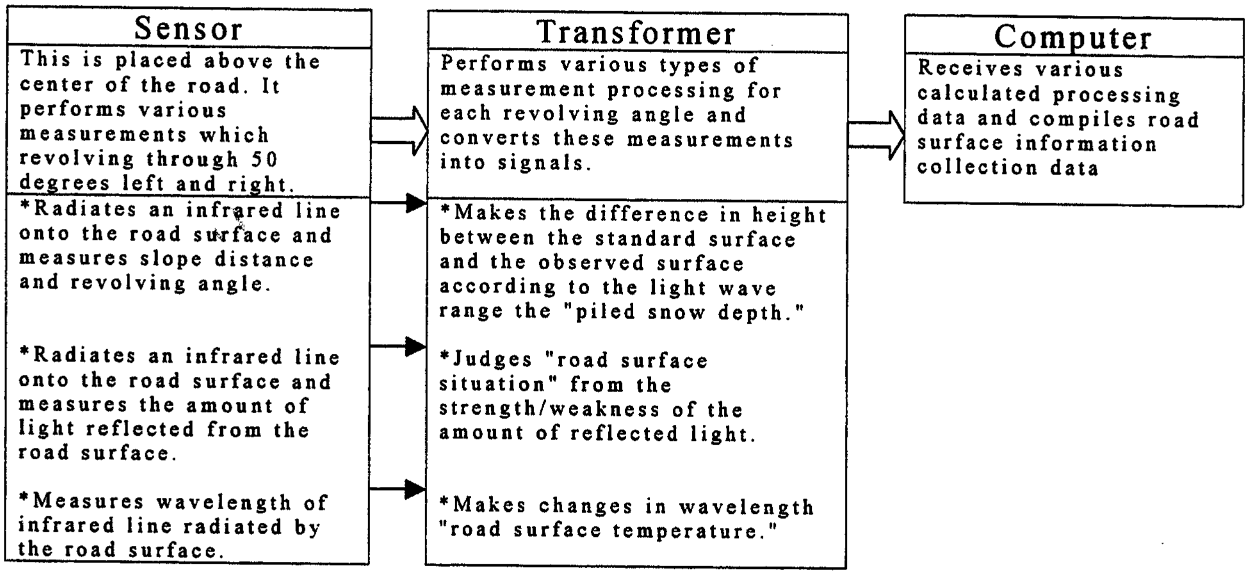
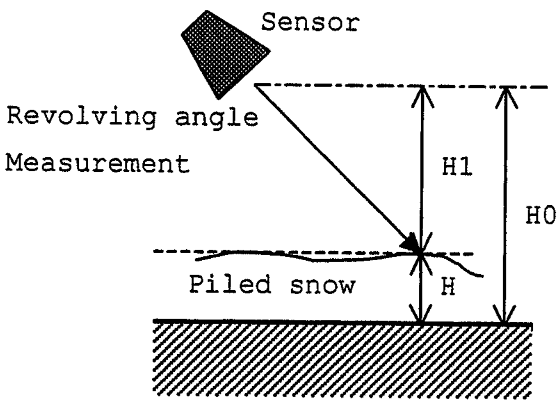


Fig. 2 Road surface information collection system structure and functions of each section

(1) Sensor: The sensor, which is placed 6m above the center of the road, performs various measurements at intervals of 7 seconds while revolving at a speed of 7 degrees per minute. These measurements are shown in the sensor measurement principles below. (Fig. 3)

<Road surface piled snow depth>



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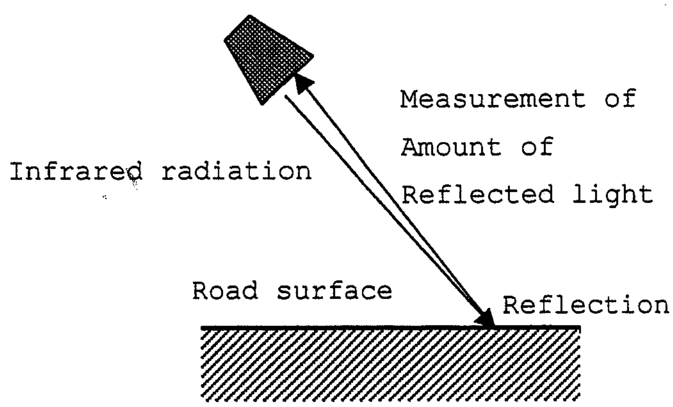


<Road surface temperature>

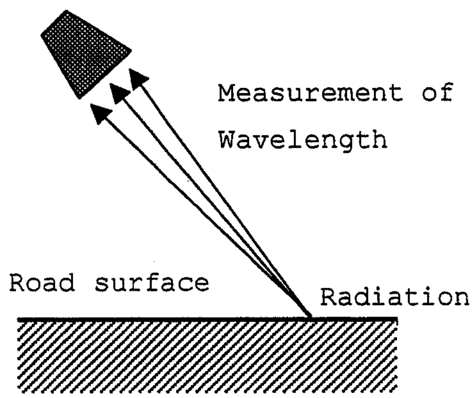


Fig. 3 Sensor measurement principles

(2) Transformer and computer; Data which have been measured with the sensor are calculated and processed with the transformer, transmitted to the computer, and displayed as road surface information collection data. (Fig. 4) The measurement range is a revolving angle of 50 degrees for both up and down lanes and approximately 16 minutes are required for one measurement cycle.

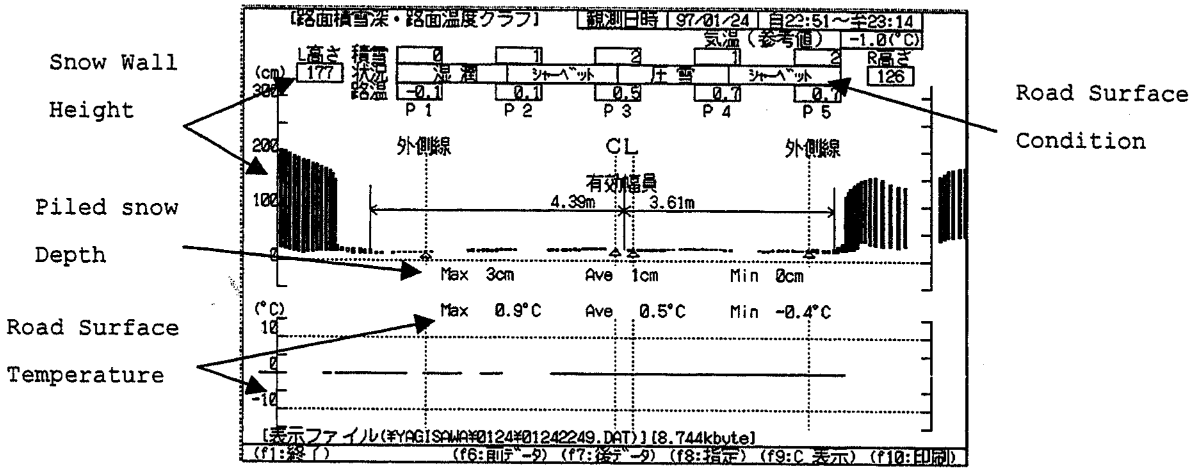


Fig. 4 Road surface information collection data (example)

2. 3 System measurement items and measurement method

As shown in Fig. 5, the system was set up on National Highway 17 beyond the Mitsumata area on Information Board type "A". We performed a function survey. Actual measurement methods are described below.

(1) Road surface piled snow depth

We measure the difference in height between the road surface without any piled snow and the height of the sensor and enter this information into the transformer as a standard transverse diagram. We measure the compacted snow surface under piled snow conditions, compile a transverse diagram, and display the difference between the two on a bar graph as piled snow depth. The five points P1- P5, shown in Fig. 6, which are required for road management, display piled snow depth in 1cm units.

(2) Road surface temperature

The surface temperature of compacted snow etc. is measured with an infrared detection-type radiation thermometer which measures the wavelength of the infrared ray radiated by the road surface itself, and displayed on a line graph. The five points P1-P5, which are required for road controls such as chemical sprinkling, display the surface temperature in 0.1 degrees Celsius units.

(3) Road surface situation

The strength/weakness of the amount of infrared light reflected from the road surface, the compacted snow surface, etc., is measured and the situation is judged to be either "dry", "damp", "sherbet", "piled snow" or "compacted snow." This situation is then displayed separately for both up and down lanes.

(4) Effective width

The distance from the bottom of the snow bank to the center of the road is measured artificially according to the road surface piled snow depth bar graph displayed on the road surface information collection data and this is taken as the effective width of up and down lanes separately.

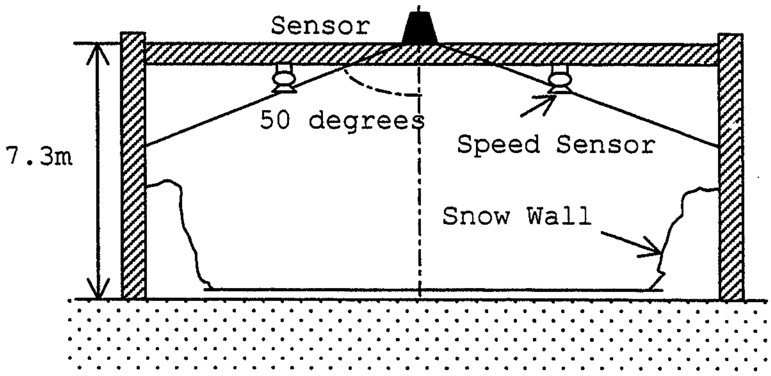
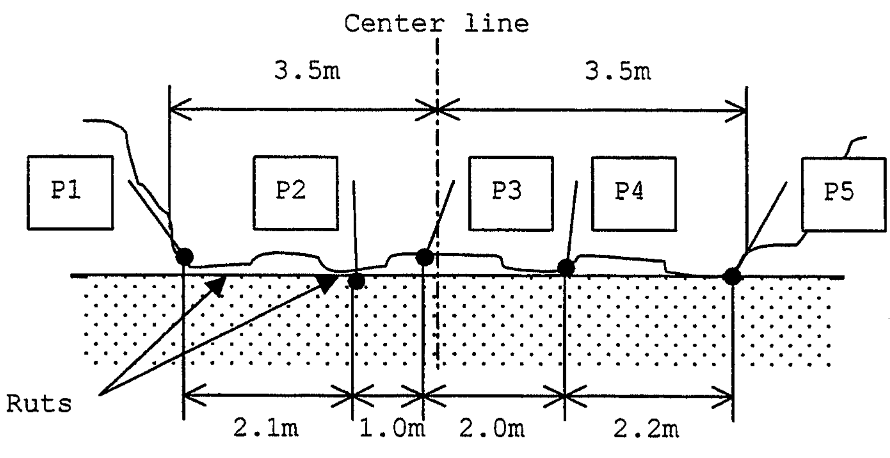


Fig. 5 System setup diagram and measurement items



P1/P5	Points 10cm beyond the outside line on both sides where the area around the outside line is measured.
P2	Point where ruts are easily formed.
P3	Point where ruts are hard to be formed.
P4	Point at border between P2 and P3

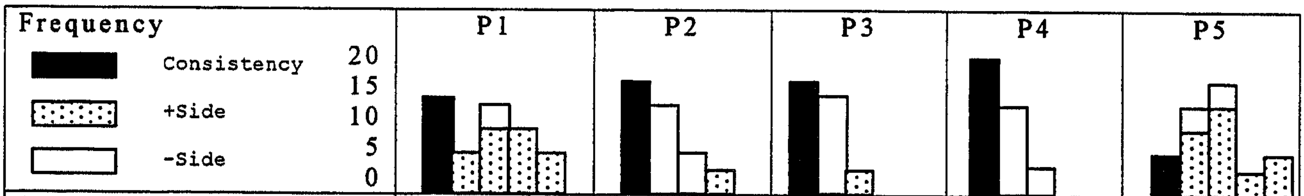
Fig. 6 Display positions of road surface piled snow depth and road surface temperature

3. System function check survey

A survey was carried out for a total of 6 days, two days each in January, February, and March 1995, to check the functions of the system in comparison to human measurement. On each day of the survey, measurements were made six times every one and a half-hours or six times every hour during heavy snowfall. The road surface piled snow depth was measured at points P1- P5 in 1mm units and the road surface situation and effective width were measured in 1cm units for the up and down lanes. To check the road surface temperature, bearing in mind the influence of the outside temperature, we used a Thermistor thermometer, which can measure fairly instantly with little exposure of the sensitive part, and measured 5 points in 0.1 degrees Celsius units. There are 36 items of data for each point P1 -P5 in terms of the road surface piled snow depth and road surface temperature and 72 items of data relating to the road surface situation and effective width for the up and down lanes. The function check and inspection results for each item are as follows.

3. 1 Road surface piled snow depth

There was little variation among P2, P3 and P4 in terms of the five measurement points previously mentioned. The consistency rate was 50% and nearly 90% were precise to within a range of +1cm. P1 and P5 showed considerable variance and the consistency rate was low.



		P1	P2	P3	P4	P5
System input(cm)		0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Maximum difference	+side	+40mm	+32mm	+22mm	0mm	+42mm
	-side	-20mm	-18mm	-12mm	-20mm	-48mm
Average difference value		+11mm	-2mm	-1mm	-5mm	+10mm
Difference rate	Consistency	34%	50%	50%	50%	13%
	+/-1cm	50%	88%	94%	88%	44%

Fig. 7 Road surface piled snow depth inspection results

3. 2. Road surface temperature

There was no noticeable difference for the 5 points. There was little variance for P2, P3, and P4, with differences of between 2-3 degrees Celsius. The system tended to make lower measurement.

3. 3 Road surface situation

When the road surface situation was similar on up and down lanes as far as the effective width was concerned, the consistency rate was high. However, when the situation was complex and confused, the system made a judgment about and displayed one or the other. There were also five cases of mistaken judgments where the system judged a damp road surface to be dry.

3. 4 Effective width

Although the system has a tendency to make wide measurement, 80% of measurements were precise to within a range of +10cm.

4. Evaluation and points for improvement

Survey: The various items in the survey and inspection results are evaluated below. Points for improvement are also noted.

4.1 Road surface piled snow depth

The system was able to make highly accurate measurements where the road was relatively flat as at points P2, P3, and P4 and also where the surface was hard (average difference 3mm). However, where there were slopes or bumps and hollows, as at points P1 and P5 near snow walls, precision was lower. Since accurate measurements at these points will be important from now on in determining the effective width too, improvements in precision are needed.

4.2 Road surface temperature

The system has a tendency to make measurements which are approximately 2-3 degrees Celsius lower than inspections made by human measurement on anything other than dry road surfaces. In future, to achieve increased precision, we should improve the software side of the system, such as the standard values for judging and processing measured values. We should also discuss the selection and measurement method of the Thermistor thermometer used in human measurement.

4.3 Road surface situation

The consistency rate was high when the road surface situation was similar for effective width. However, there were cases where the system mistakenly judged damp road surfaces to be dry. In future, we should include an order of priority for judgment criteria for the road surface as well as a display which shows a complex road surface situation.

4.4 Effective width

The average value of the difference between the values measured by the system and values measured by humans were about 2cm, i.e. acceptable. Improvements for the future would be to display the effective width and the snow wall height numerically on the monitor screen.

5. Future policies

5.1 System function check survey

On the basis of the results of the system function check survey, we will improve the system by carrying out repeated inspections, checking functions, and inspecting precision with the aim mainly of increasing precision and improving the monitor screen. In the winter of 1995 we will set up the system on National Highway 17 beyond Yagisawa, Yuzawa-machi, and carry out a function survey on five items, road surface piled snow depth, road surface temperature, road surface situation, effective width, and snow wall height. In particular, we will inspect improvements in results for (1) and (2).
(1) Displaying snow wall height and effective width on a piled snow depth graph.
(2) Displaying numerically the road surface situation for effective width.

5.2 As well as system data we will also collect data relating to snow

observation, traffic volume observation, and the snowplow operation situation for the area beyond Yagisawa and determine how such data relate to winter road surfaces.

(1) Grasping the effect of snow (snowfall depth, piled snow depth) on the road surface situation.
(2) Grasping the effect of the road surface situation on winter traffic (flow speed, volume).
(3) Grasping changes in the road surface situation due to snow clearing operations (operation type, machine type, time, and frequency).

5. 3 Prospects

In future, we hope to establish an appropriate winter road management method by including road surface observations among existing data relating to snow and traffic volume observations and the snowplow operation situation, analyzing and gaining a comprehensive view of traffic behavior on winter roads on the basis of the various data available, and examining simulations of traffic behavior with a constant observation system.

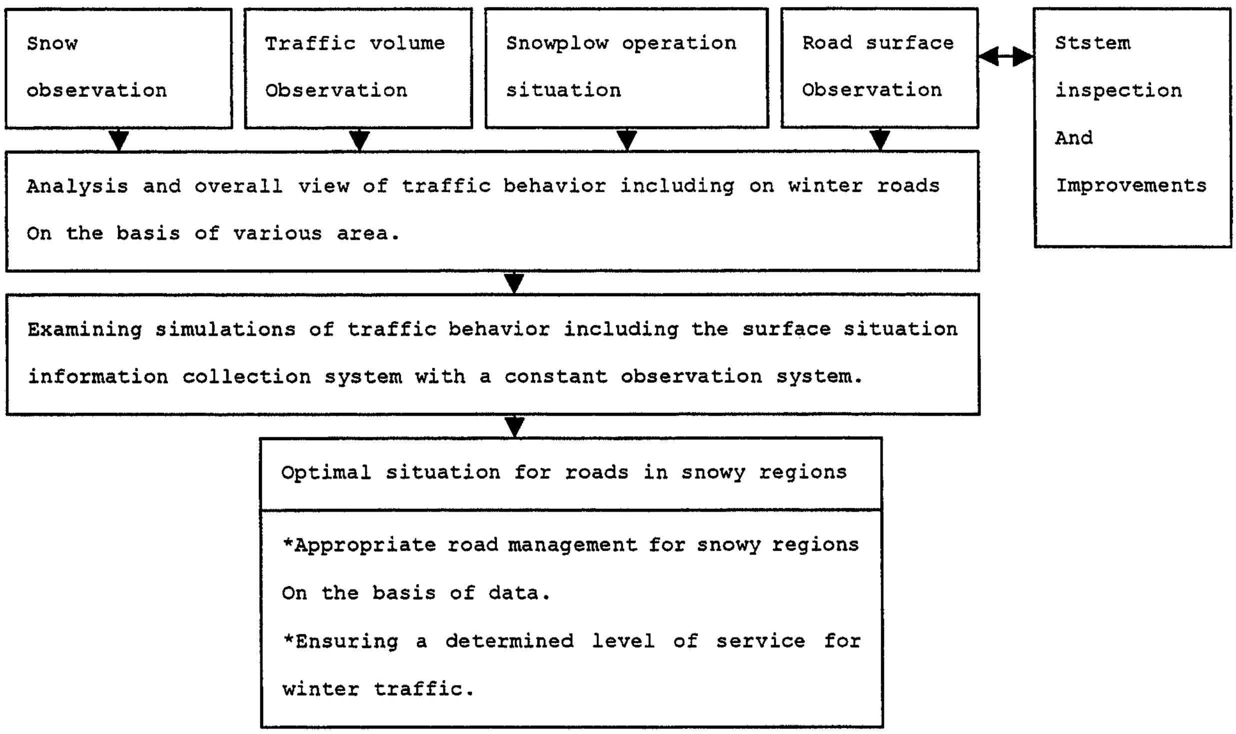


Fig. 8 Future image

6. Conclusion

It was clear that the sensor used on this occasion, which performed automatic measurement in real time of the winter road surface situation, had sufficient precision to determine road service levels. In 1995, on the basis of an overall research concept, we decided to carry out a survey of traffic features under winter road surface conditions, clarify the relationship between service levels and snow clearing levels, and set up a winter road management method. We would like to thank Takuwa Ltd. for their cooperation in developing this system.