Research on the Level of Winter Road Management

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1. Introduction

Snow removal is road service that is essential in heavy snow zones in Japan, not only to guarantee safe smooth road traffic, but also to stabilize social life and contribute to the growth of regional economies. And in today's mature society, the needs of these regions have grown and diversified and their people demand the improvement of this service. But road managers must meet these demands under severe budget restrictions.

The Nagaoka National Highway Office that is responsible for the Yuzawa District that is one of these heavy snow zones has, as one measure to achieve this goal, studied Road Performance Management intended to provide management that satisfies the needs of regions through a partnership between the public and private sectors. This approach is implemented by, based on the characteristics of the region and the views of road users, setting management goals for winter road surface management that is the most important challenge facing the region, performing management based on these goals, and evaluating its effectiveness. And, according to circumstances, working cooperatively with road users to improve this service.

This research that has been undertaken in response to the above circumstances is a study of the winter road management level suitable for a heavy snow region by focusing on the management goals and analyzing characteristics of the region, snow removal costs, and the degree of satisfaction of road users. The conclusions presented in this report do not directly reflect the views of the Nagaoka National Highway Office

2. Outline of the research

A variety of analyses were performed using meteorological and traffic data obtained from reference documents and from the findings of a fixed observation system installed beside National Highway No. 17 that passes through the Town of Yuzawa in Niigata Prefecture and is managed by the Nagaoka National Highway Office. Figure 1 shows the district studied and the snow removal sections on National Highway No. 17.

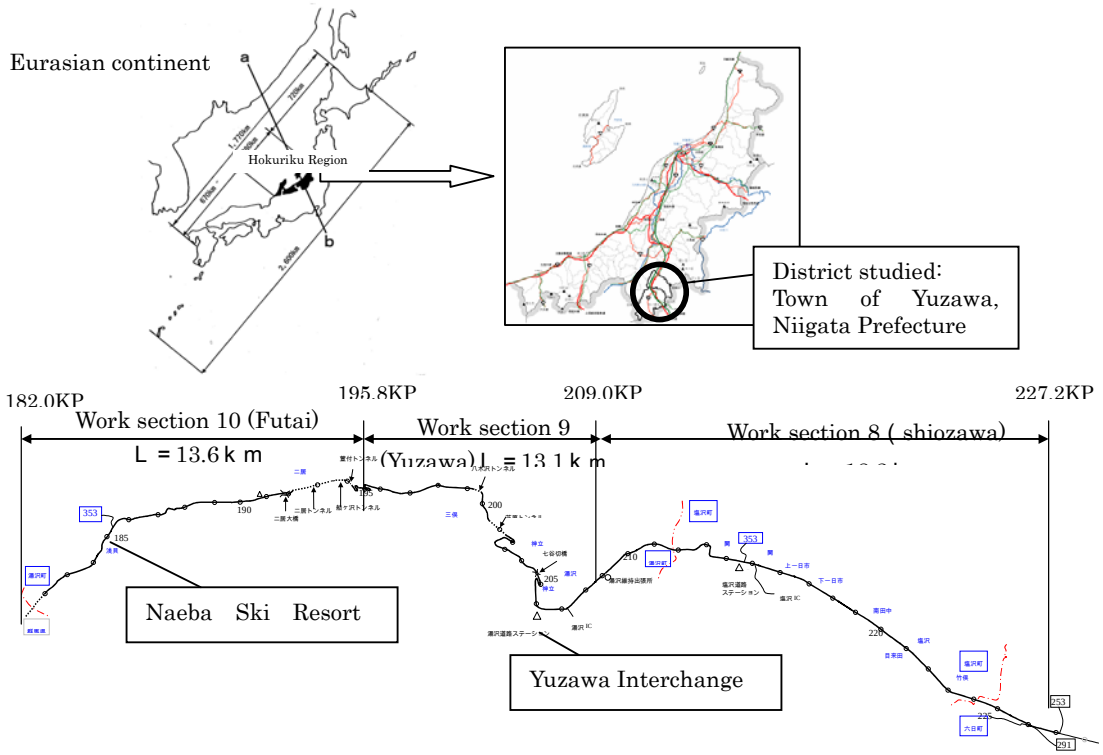

Figure1. District Studied and the Snow Removal Sections on National Highway No. 17 in the Yuzawa District

3. Winter Road Management Level Index

It is necessary to establish an index suitable for regional characteristics in order to set the level of winter road management. The authors studied an index for the level of winter road management by analyzing meteorological characteristics, traffic characteristics and the state of snow removal.

3.1 Meteorological characteristics

Figure 2 shows changes of the cumulative snowfall in the Yuzawa District, and Figure 3 shows winter meteorological conditions in Yuzawa District. The cumulative snowfall exceeded 10m every year except 1996 and 1997, showing how heavy snowfall is in this district. The temperature begins to fall in early

November, reaches its minimum from January to mid February and begins to rise in late February. Another characteristic of the district are climatic conditions that cause extreme variability of road surface conditions. Specifically, a daily temperature differential reaching as high as about 10°C with the daily maximum and minimum above and below 0°C that is the road surface freeze-thaw boundary from late December to mid February: a period snowfall is extremely heavy.
Another feature of this heavy snowfall district is its high population concentration: 20,000 in Shiozawa and 9,000 in Yuzawa.

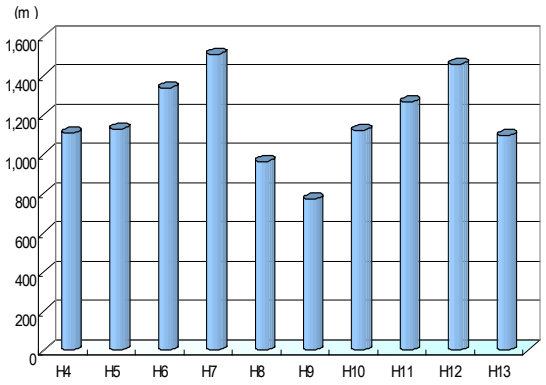

Figure2. Changing Cumulative Snowfall in the Yuzawa

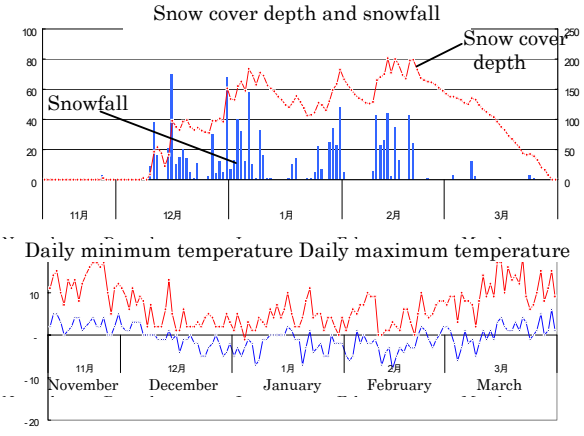

Figure3. Winter Meteorological District in Yuzawa District Conditions

3.2 Traffic characteristics

Figure 4 shows the monthly average traffic volume by snow removal work section and Figure 5.shows the average monthly driving speed by snow removal work section in the winter. In the Shiozawa work section, the traffic volume exceeds 10,000 vehicles in both the autumn and winter, that is far heavier than in the Yuzawa and Futai work sections. By day of the week, the autumn traffic is heavier on weekdays than on holidays, but in the Futai and Yuzawa work sections, winter traffic is heavier on holidays than on weekdays. (Fig. 4) In the Shiozawa section, the driving speed on weekdays is slowest at 30km/h, and the degree of congestion is highest at approximately 2, but the degree of congestion on holidays is highest in the Futai work section. (Fig. 5)
It can be hypothesized that because there are ski resorts, hot springs, and numerous other tourist facilities that attract many winter visitors to this district, the traffic volumes rises and falls complexly according the number of visitors. It is, therefore, necessary to carry out prompter and more reliable winter road management in this district.

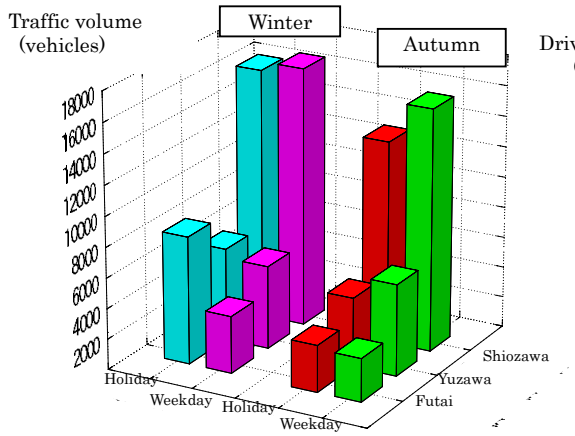

Figure4. Average Monthly Traffic Volume by Snow Removal Work Section (2003)

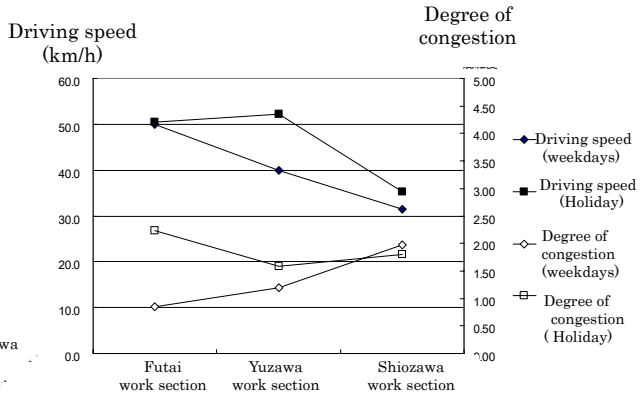

Figure5. Monthly Average Driving Speed by Snow Removal Work Section (Winter 2003)

3.3 State of snow removal

Figure 6 shows the operating hours by type of snow removal machine and Figure 7.shows the rate of occurrence of each road surface condition in the Yuzawa work section. The total operating hours of the snow-plow equipped graders, snow removal trucks, snow-plow equipped tractors, rotary snow plows, small snow removal vehicles, and small snow removers account for about 70% of all operating hours, showing that snow removal and disposal is a very time-consuming and costly part of snow and ice measures.

The state of the road surface shows that 51% of the time the road surface is snow-free (it is either dry or wet), while 43% of the time it is snow covered (either slush or compacted snow). It is frozen 6% of the time.

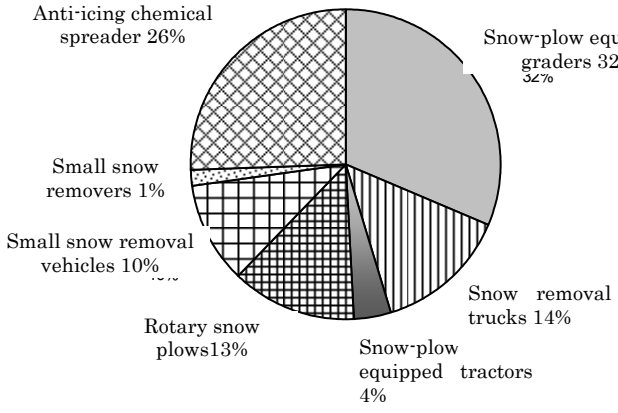

Figure6. Operating Hours by Type of Snow Removal Machine

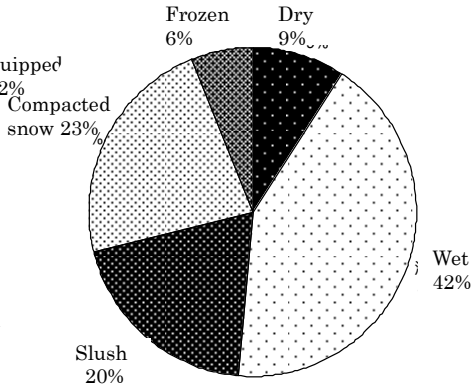

Figure7. Road Surface Condition Occurrence Rate

3.4 Impact of road surface snow cover on road traffic

Because the removal and disposal of snow accounts for most of the time and cost of road management in the Yuzawa District, the impact of road surface snow cover on road traffic was analyzed.

Figure 8 presents the distribution ratio of the time headway by road surface snow cover depth. An increase of road surface snow cover depth shifts the distribution ratio to the right, increasing the time headway. The time headway on dry roads is generally assumed to between 2 to 3 seconds, but snow cover increases this by about 1 second. The relationship between the time headway and the traffic volume is represented by equation (1), revealing that a rise in the road surface snow cover lowers the traffic volume. Where t: time headway (second), Q: traffic volume (vehicles/h)

$$t=l/Q \qquad (1)$$

Figure 9 shows the road surface snow cover depth – time headway relationship and the 95% reliability zone. The range of the 95% reliability zone is large, and scattering of the time headway to the road surface snow cover depth is large. Considering the fact that at a road surface snow cover depth of 6cm or more, the data are extremely few in number and include many abnormal values, and if the road surface snow cover depth rises, the time headway tends to fall. The relationship of the time headway with the traffic volume, traffic density, and driving speed are represented by equation (2), but the small time headway signifies large traffic density.

Therefore, an increase of the road surface snow cover depth lowers driving speed, increases traffic density, reduces traffic volume, and causes the traffic flow to fall in congested flow zones. Where s: average time headway (m), Q: traffic volume (vehicles/h), K: traffic density (vehicles/km), v: driving speed (km/h)

$$s=l/K=v/Q \qquad (2)$$

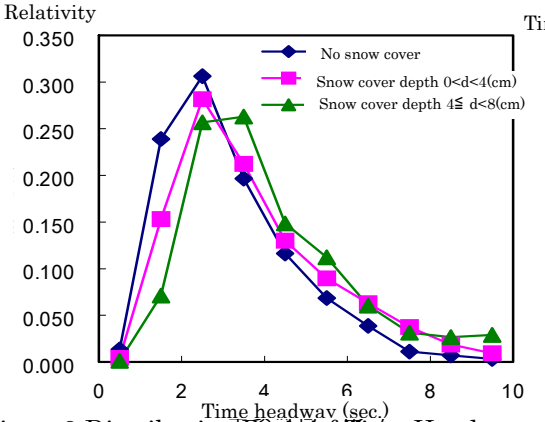

Figure9.Distribution Ratio of Time Headway

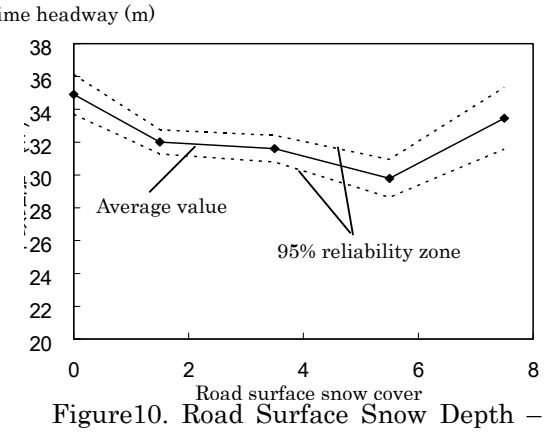

Figure10. Road Surface Snow Depth – Time Headway Relationship

For the above reasons, roads are managed in the winter by setting management goals with driving speed as one of the indices for the level of the service in a district where snowfall is heavy, snow removal and disposal account for more than half of road management, and road surface snow cover remarkably reduces the driving speed. And because the characteristics of traffic in different snow removal work sections differ, it is necessary to set the driving speed separately for each snow removal work section.

4. Level of present winter road management

In a case where driving speed has been hypothesized to be an index of service level, road management is performed considering the level of service to be guaranteed. Figure 10 shows the rate of decline of the driving speed from the Yuzawa Interchange to the Naeba Ski Resort. The average driving speed falls by about 10% on the outbound lanes when the road is dry and by about 15% on the inbound lanes when the road is dry. He present level of winter road management guarantees a service level between 85% and 90% of the level when the road is dry. * Driving speed reduction rate = dry road speed/compacted snow speed X100%

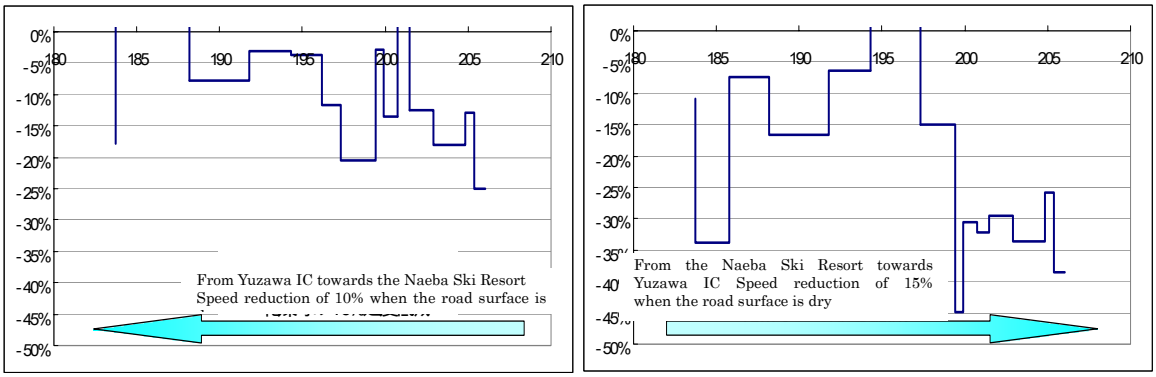

Figure10. Driving Speed Reduction Rate

5. Snow removal cost analysis

5.1 Winter road management level and snow removal cost

Winter road management must provide appropriate road services under strict budget restrictions. So the relationship of snow removal cost and snowfall with the road management level (driving speed) is analyzed.

Figure 11 shows the relationship of daily snowfall with snow removal cost in the Yuzawa district in 2001. The snow removal cost is calculated by multiplying the operating time of snow removal machines by the snow removal cost per unit of

time based on past performance. As the snowfall rises, the snow removal costs rises, with a high coefficient of determination of 0.94. This shows that by predicting the snowfall, it is possible to use it to set the snow removal cost and use this cost to plan the target budget.

Figure 12 shows the relationships of driving speed and daily snowfall with snow removal cost. As the snowfall rises, the snow removal cost also rises, but the driving speed inevitably falls. The driving speed when snowfall is heavy (35cm/day) is about 20% less than it is during a light snowfall (0cm/day), and is about the same level as the road management stated above. Considering that present snow removal is performed by full operation of snow removal machines for road management, it is difficult to seek significant improvement of the service level using only snow removal machinery.

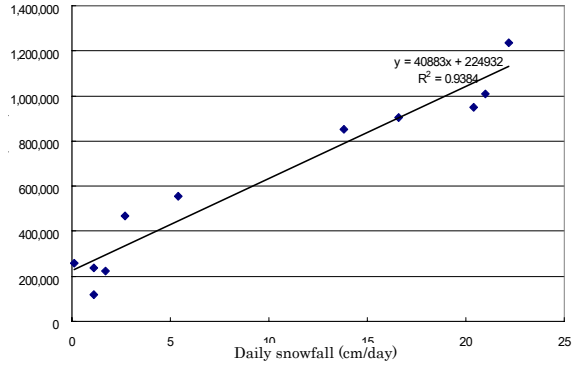

Figure11. Daily Snowfall – Snow Removal Cost Relationship

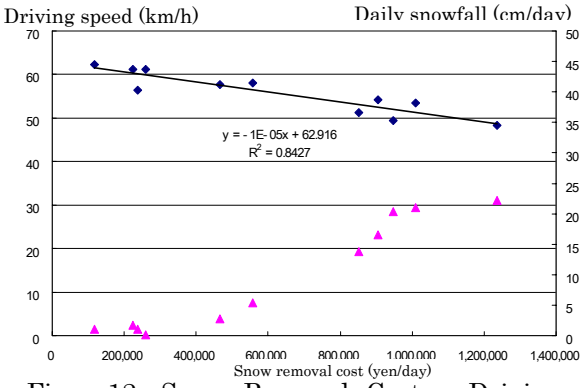

Figure12. Snow Removal Cost – Driving Speed – Daily Snowfall Relationship

5.2 Cost – benefits

A cost benefits analysis of present snow removal was performed based on the prerequisite conditions in Table 1. It obtained the driving time reduction benefits to measure this as the snow removal effects based on the difference between the driving speed with and without snow cover on the road surface.

Table1. Prerequisite Conditions

Work section	Traffic volume	Large vehicle percentage	Travelling speed	Time value
Kandatsu – Mikuni (23.8km)	6,400 vehicles/day	27.3%	With snow : 49.19km/h Without snow: 53.88km/h	Normal vehicles: 67.27 yen/min. Trucks: 101.39 yen/min.

As a result, the cost-benefits ratio is 1.4, and a measurement based only on the driving time reduction benefits satisfies the efficiency standard. Because the total benefit presumably includes driving expense benefits and traffic accident reduction benefits etc., the benefits of actual snow removal are probably several times larger than shown here.

6. Degree of satisfaction of road users

The setting of the winter road management level must reflect not only the views of the road manager, but also those of road users. The degree of satisfaction of road users with present road management was analyzed based on the content of requests and comments received by the Road Consultation Office. The complaints concerning snow and cold include many complaints of problems closely related to daily life, requests for snow blowing, post-processing of snow banks, but few complaints about winter road surfaces.

7. Summary

It is also appropriate to set the winter road management level premised on the fact that the present service level will be maintained in order to guarantee economic suitability and the degree of satisfaction of road users. It is assumed that it is possible to achieve effective and efficient winter road management by setting this driving speed as the target for management of winter roads and by removing snow in order to provide specified benefits to road users. Driving speed can be used beneficially by both road managers and road users, by for example, allowing a road manager to provide an index or pass through time in order to help road users more easily understand the benefits of snow removal.

8. Future challenges

Managing roads with the driving speed as a road service index guarantees road users speed and on-time arrival at their destinations, but there have not been adequate surveys of the psychological state of road users, their concern with safety and comfort. It is also necessary to set detailed management goals such as the range of permissible driving speeds.

In the future, many-sided analyses such as detailed traffic analysis including traffic accident analyses and interview surveys of road users must be performed to complete the data.

References

1) Jun Wada, Yoshitaro Masuda, Masahiko Okuzumi: Study of Winter Road Management Level, Traffic Engineering, Vol. 21, No. 1, Japan Society of Traffic Engineers, 1986

2) Arakawa, Hayakawa, Ichinose: Research on the Enactment of Winter Road Surface Management Level, Report on the Fifteenth Symposium on Cold Region Technologies, pp. 622-627, 1999