SECURING THE WINTERTIME TRAFFIC FLOW BY MEANS OF MULTI-VEHICLE SNOW REMOVAL

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ABSTRACT

The speeding-up of snow-removal operations on expressways and the implementation of efficient snow-hauling operations has made it possible to ensure a steady flow of wintertime traffic.

KEYWORDS

EXPRESSWAY / MULTI-VEHICLE SNOW REMOVAL / SNOW HAULING

1. INTRODUCTION

As shown in Fig. 1 and 2, the city of Sapporo in Hokkaido is located at lat. 42 degrees N; it has an annual snowfall of as much as 5m. In spite of being subject to these harsh natural conditions, it is the leading city in Hokkaido, with a population of some 1.9 million. As a major city prone to very heavy snowfall, Sapporo is unparalleled in the world.

East Nippon Expressway Company Limited (hereafter NEXCO East) is responsible for the building and management of approximately 4,000 kilometers of expressway. There are approximately 580 kilometers of expressway in Hokkaido, of which some 30 kilometers run through Sapporo.

The expressway in Sapporo is important not only for the city; it also plays an important role as the principle trunk road serving the whole of Hokkaido. It follows that the closing of the expressway to traffic has a huge impact on local communities; and in Hokkaido where climatic conditions are especially harsh, securing the wintertime traffic flow is a task of the utmost importance.

The Sapporo Operation Office of the Hokkaido Branch of NEXCO East (which will be called E-NEXCO) has up until now attempted in many ways to secure the wintertime flow of traffic on its expressway, where, it being a toll road, a high level of management is demanded.

This paper describes efforts to ensure a steady flow of traffic through the city in wintertime, in particular attempts to speed up snow-removal operations.

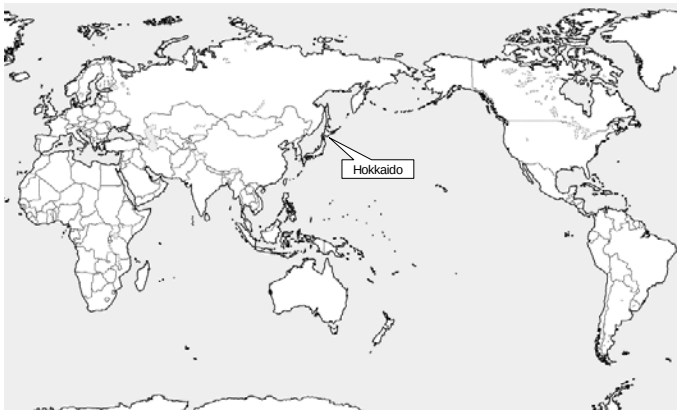
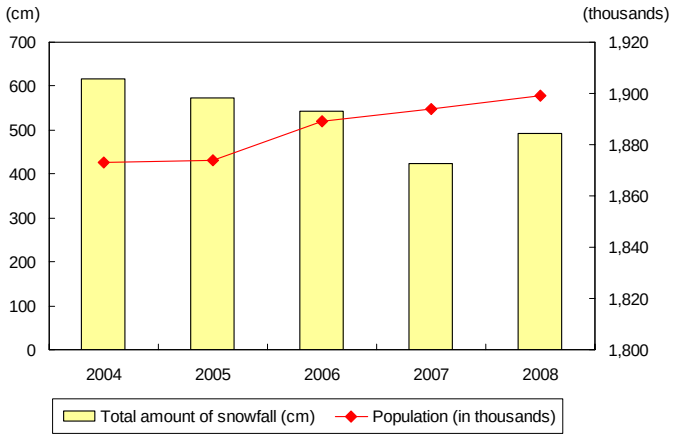


Fig.1-Map showing position of Sapporo



Sources Total amount of snow fall : Japan Meteorological Agency HP
Population：Sapporo City HP

Fig.2-Changes in the population of Sapporo and total amount of snowfall

2. OVERVIEW OF THE EXPRESSWAY WITHIN SAPPORO, AND PROBLEMS ARISING IN WINTER

(1) Characteristics of the expressway within Sapporo
The following five points can be said to characterise the expressway within Sapporo:

1) A continuous elevated bridge approximately 20 km long (Sapporo Nishi Interchange to Sapporo Minami Interchange) (see Fig.3)

2) Double-deck construction, the expressway running parallel to the national highway (see Photograph 1)

3) Short distances between interchanges (approximately 2.3 km on average)
There are 9 interchanges (of which 8 are half interchanges) and one junction in the 20 km stretch.

4) The volume of traffic at its maximum is roughly 45,000 vehicles per day between interchanges. Traffic is close to 40,000 even in winter.

5) Traffic volume is concentrated in the daytime hours.

Roughly 80% of the traffic volume is concentrated into the 12 hours of daytime (7:00 to 19:00).

Fig.3-Road network within Sapporo

Photo 1-The expressway running through Sapporo

(2) Problems in management of the roads in winter
The structure of the roads and traffic characteristics described previously have posed the following obstacles to snow removal operations.

1) Restrictions on operating time
Because the large number of interchanges require more time for snow removal so that daytime operations when traffic is heavy causes congestion, and because of the high risk of collisions between ordinary vehicles and snow removers working in formation, in effect it has been impossible to conduct snow-removal operations during daytime hours (Snow-removal operations have been conducted only at night.)

2) Road structure making disposal of snow impossible
Because of the structure of the continuous elevated bridge with the national highway running in parallel below, it is not possible to dispose of the snow by throwing it off the bridge: the snow moved by the snow removers has had to be piled along the shoulder of the bridge. Since the bridge shoulder has a width of only 1.75m, when this does not provide enough space in which to pile the snow, snow piled onto the shoulder from repeated snow removal operations would often overflow into the traffic lane.

3) Longer road closures due to removal of snow from the shoulder
In order to keep the traffic lanes open and reopen the road, it would be necessary to haul away the snow overflowing off the shoulder, and this work would lead to the road being closed for a longer period of time.

4) This resulted in 2005 in road closure kilometer hours (hours of road closure x distance

closed) over the stretch of road in question of 8,600 km hrs; the loss in income from this has been estimated at roughly 100 million yen.

From the need to improve this situation, work has gone ahead to bring about the introduction of ‘high speed snow removal operations’ and ‘effective snow hauling operations’.

3. INTRODUCTION OF THE MULTI-VEHICLE SNOW-REMOVAL METHOD IN AN EFFORT TO SPEED UP SNOW REMOVAL

In snow removal operations so far, work had been carried out by a formation of vehicles comprising 3 snow removers and 2 traffic sign vehicles; on reaching an interchange section one of the snow removers would move repeatedly backwards and forwards on the interchange ramp clearing the snow, while the other snow removers in the formation came to a halt. This severely reduced the speed at which work progressed, so that the average operating speed was 10 km/h: even with the Sapporo Nishi Interchange to Sapporo Minami Interchange stretch (approximately 22 km) split into two sections and worked by two formations, snow clearing would take roughly 120 minutes to complete.

Thus in order to speed up the removal of snow from the interchange ramps and make operations more efficient, the two formations were combined to make a single formation comprising 7 snow removers and 2 traffic sign vehicles, and the system was changed so that this single formation carried out snow removal over the two sections. Under this new system when the snow removers reach an interchange ramp one snow remover goes to work on the ramp while the remaining snow removers do not stop but are able to work on the main road without any reduction in speed. As a result the speed of operations is 2 to 3 times faster than the old method, and it is possible to cut working time to roughly one-third. From its use of multiple vehicles to carry out a variety of operations non-stop and at high speed, E-NEXCO has named this snow removal system ‘multi-vehicle snow removal;’ and from 2004 to 2005, repeated test operations during the daytime hours have been carried out.

Under test operating conditions, the number of vehicles following the formation reached a maximum of 150, but there was no congestion; and so it was decided to introduce the system full-scale from 2006. This made possible daytime snow removal operations, something that had long been a problem. (see Figs 4, 5: Photo 2)

‘Multi-vehicle snow removal’ was implemented 14 times in 2006, 29 times in 2007 and 35 times in 2008, and while the line of vehicles following the formation has reached up to about one kilometer, so far there have been no major problems in particular.

Old method of snow removal

- A formation of 3 snow removers and 2 traffic sign vehicles
- On reaching an interchange section, one snow remover moves repeatedly backwards and forwards on the interchange ramp clearing the snow.
  (During this time operations on the main route come to a halt.)
- Speed is roughly 5 to 30 km/h (Time needed to complete operations, approximately 120 minutes.)

Multi-vehicle snow removal

- A formation of 7 snow removers and 2 traffic sign vehicles
- On reaching an interchange section one snow remover operates on the ramp (Operations on the main route do not come to a halt)
- Speed is roughly 30 to 40 km/h
  (Time needed to complete operations, approximately 40 minutes.)

Fig.4-Diagrams outlining the old method of snow removal and multi-vehicle snow removal

a. Start of operations: Sapporo Minami Interchange　b. Front part of the formation　c. Tail end of the formation

Photo 2-Multi-vehicle snow removal operations

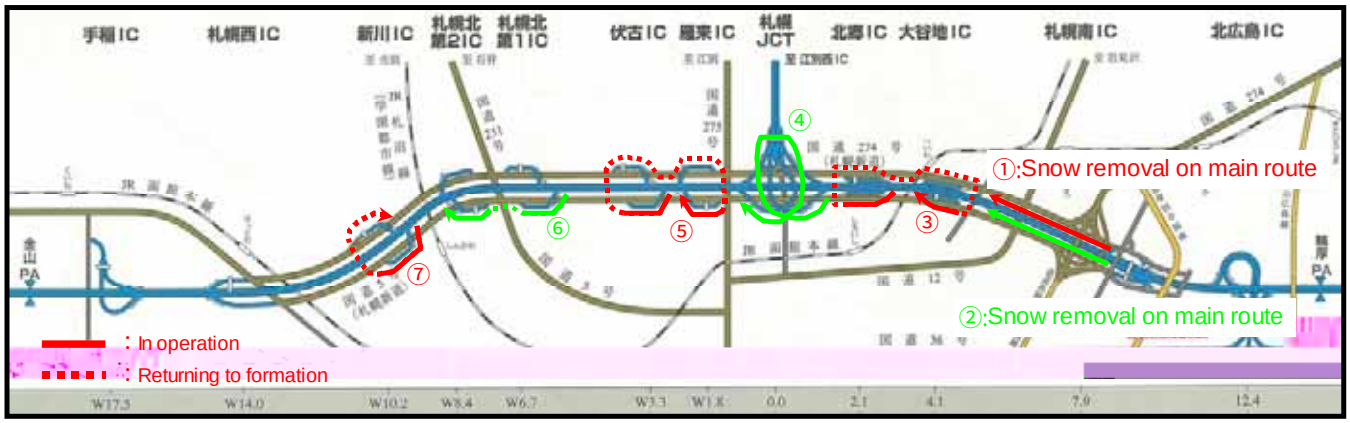


Fig.5-Movement of vehicles in multi-vehicle snow removal
（working from Sapporo Minami Interchange to Sapporo Nishi Interchange）

4. INTRODUCTION OF SCHEDULED SNOW HAULING OPERATIONS

With regard to the snow piled up on the shoulder of the bridge, as was previously mentioned the national highway runs parallel to the expressway, so that it is not possible to dispose of the snow by pushing it off the bridge. For this reason hauling operations are carried out to haul the piled snow away to a snow dump, using rotary vehicles and dump trucks. Up until now the method by which the snow was hauled away was a 'centralised snow hauling system' whereby dump trucks are summoned when the snow pile completely fills the width (1.75m) of the shoulder (see Photograph 3). However, when this method is used, the fact that there is little room to pile snow on the shoulder means that when snow-removal operations are carried out on a closed road, the snow on the shoulder protrudes onto the driving lane and the road closure cannot be lifted. In addition, the presence of snow on the shoulder reduces the number of places a vehicle can pull into in an emergency and makes the driving environment seem closed-in, and is thus thought to be an underlying factor in traffic accidents. This situation led to the road being closed for longer periods of time, and raised the incidence of road closures.

From 2006, from the need to resolve these problems, in parallel with the 'multi-vehicle snow removal' described above 'scheduled snow hauling' was implemented as set forth below.

1) The system adopted so far, of summoning dump trucks to haul the snow at the time of snow removal operations, was put on hold; a set number of trucks were put on permanent call, and additionally organised into squads.
2) Operations were carried out as and when the total snowfall was roughly 30 cm.

As a result the work was levelled out, making it possible to implement efficient snow hauling and ensure room on the shoulder for piling snow. (see Photo 3b).

a. The shoulder of the road in 2005 and before: centralised snow hauling. Snow is piled to the limit and there is nowhere for vehicles to pull over. When the road is closed due to snowfall snow hauling has to be carried out.

b. The shoulder of the road from 2006 onwards: Scheduled snow hauling There is room for vehicles to pull over. More room to pile snow avoids the need for lengthy road closures

c. Snow hauling operations on the elevated section

Photo 3-Scenes of snow piled on the shoulder and snow being hauled away

5. RESULTS OF THE INTRODUCTION OF THESE STRATEGIES

Let us look at the changes in road closure kilometer hours etc., before and after the introduction of 'multi-vehicle snow removal' and 'scheduled snow hauling'. Fig.6 compares the years 2004 to 2005 (before their introduction) with the years 2006 to 2008 (after their introduction). While there was a drop in total annual snowfall of roughly 20% on average, the fall in road closure kilometer hours was much greater than this, at some 80%.

Fig.7 further compares the daily snowfall and road closure kilometer hours during two periods of intense winter cold before and after the introduction of the strategies, namely, January to February 2006 and January to February 2009. From this the following can be said.

1) Before introduction of the strategies a snowfall of around 10 cm would cause a road closure: there were days when a snowfall in excess of 20 cm produced over 1000 road closure kilometer hours. 2) After introduction of the strategies a snowfall of around 10 cm produced no road closures, and in some cases even a snowfall of 20 to 30 cm did not produce a road closure. 3) Even when a road closure did occur, it did not continue long but was soon lifted, leading to a large-scale reduction in road closure kilometer hours. 4) After scheduled snow hauling there is always space on the shoulder to pile snow; because the amount of snow piled on the shoulder never exceeds the limit, work does not take a long time, so that there are no incidences of the period of road closure being extended due to snow hauling operations.

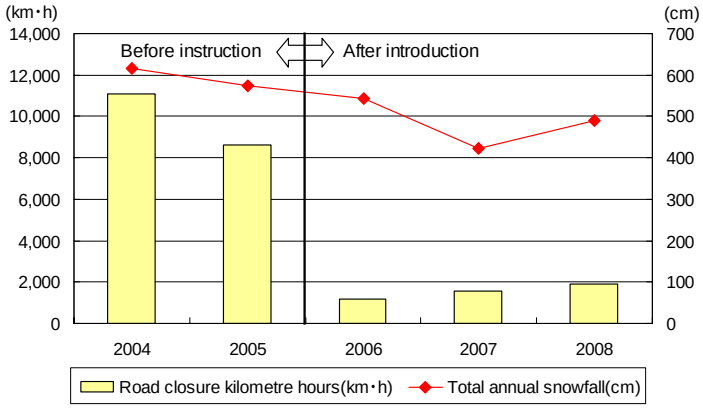


Fig.6-Changes in road closure kilometer hours and total annual snowfall

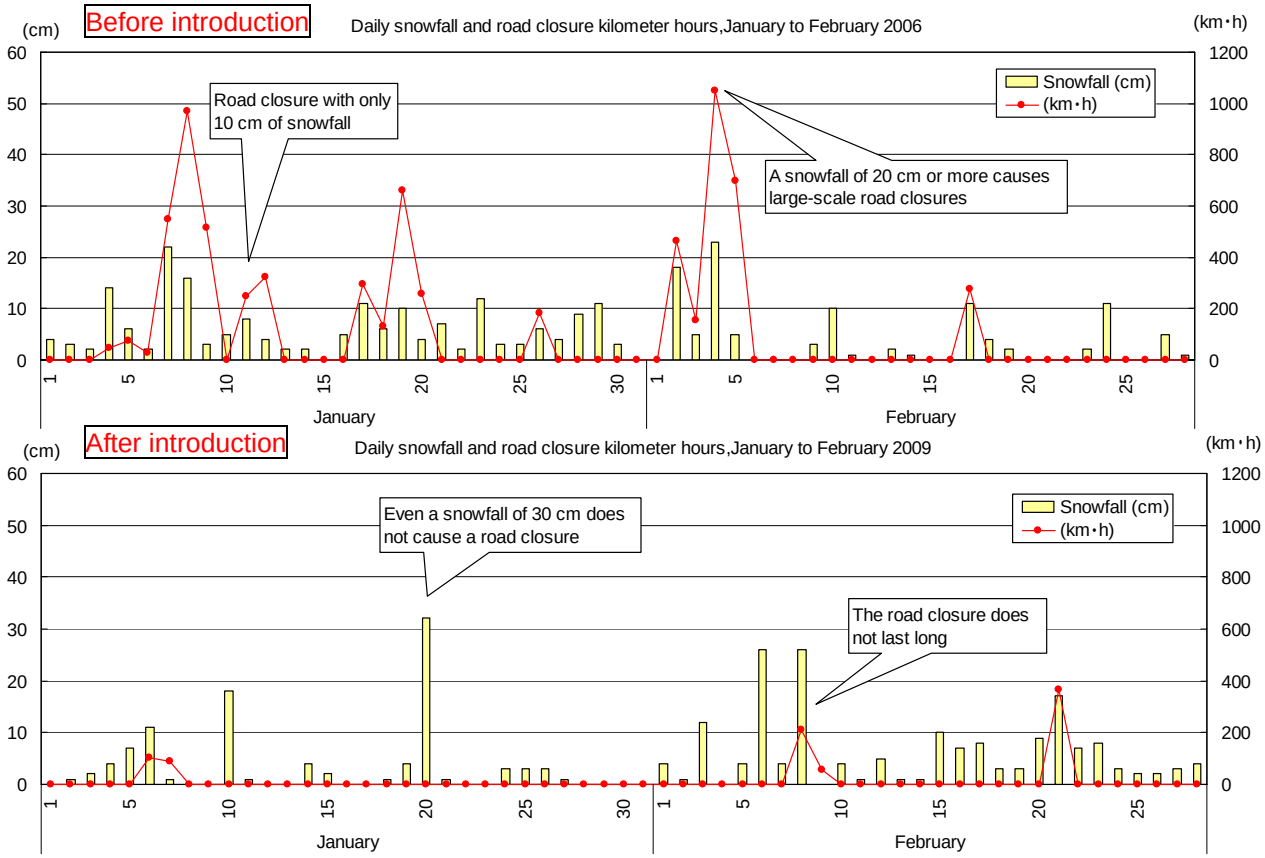


Fig.7-Daily snowfall and road closure kilometer hours in January and February, before and after introduction of the strategies

Next, Fig.8 shows the incidence of accidents in wintertime. Shown are the changes in the number of accidents occurring during the winter (November to March) on the roads controlled by the Sapporo Operation Office, including the Sapporo Nishi Interchange – Sapporo Minami Interchange stretch. It can be seen that after introduction of the new strategies the number of accidents fell 20% on average, from roughly 300 to roughly 240. One of the major reasons for this may be considered to be that the new snow removal/snow hauling operations have secured more space on the shoulder and helped improve the driving environment, leading to fewer accidents. It is further conjectured that in the event of an accident, being able to use the shoulder, where previously snow would be piled up, to get the vehicles involved in the accident off the road has contributed to keeping down the number of times the road must be closed due to an accident.

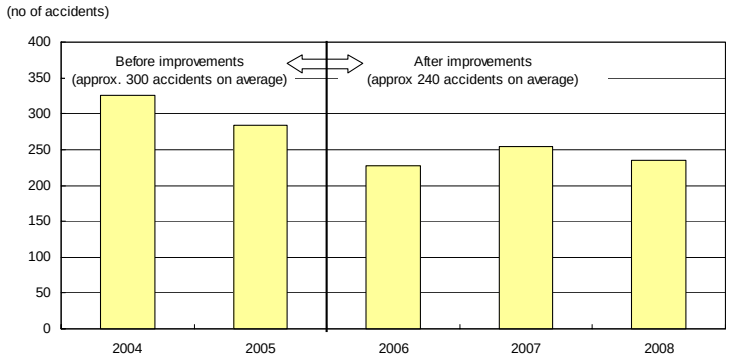


Fig.8-Changes in the incidence of accidents in wintertime (totals for November to March)

Finally, let us look at the cost aspect. Due to the introduction of ‘multi-vehicle snow removal’ and ‘scheduled snow hauling’ in this instance, the costs of snow and ice control operations on the relevant stretch of road managed by the Sapporo Operation Office are showing an upward trend. Fig.9 shows the changes in costs for each year, and compared to before the introduction of the new strategies there is an increase in costs of about 7%. However, as can be seen in Fig.6, one effect of the strategies has been a huge reduction in road closures, and the estimated cost of reduced income due to road closures should be taken into consideration. The result is shown in Fig.10: the reduction in income is in excess of the increase in costs, and it is clear that taken overall, there has been a reduction in costs of roughly 10% compared to before the introduction of the new strategies. In this way, fortifying the snow and ice control strategies has produced a result that also has a positive effect on company profits.

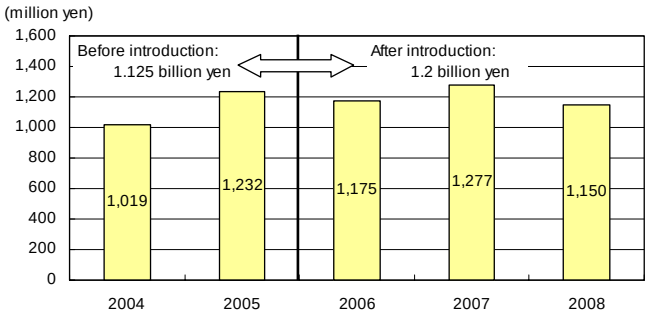


Fig.9-Cost of snow and ice control operations

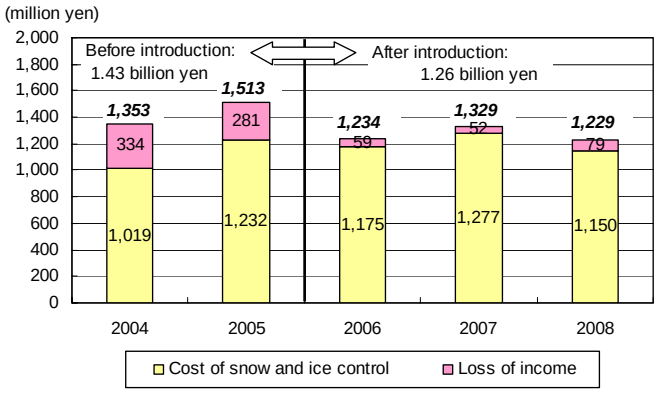


Fig.10-Cost and loss of income

6. CONCLUSION

E-NEXCO has thus far introduced various strategies in its efforts to ensure the flow of traffic on the expressway, which is a major trunk line running through the city. The two examples described in this paper have been implemented through repeated trial and error, the result of which was a huge impact in the reduction of road closures and of traffic accidents. In order to make operations still more efficient and effective, E-NEXCO intends to continue studying ways to make improvements. These strategies are the result of concerted efforts over many years by the maintenance, support and engineering groups of NEXCO East in charge of expressway management in Hokkaido. We would like to express our gratitude for the endeavours of all those involved.