PERFORMANCE MEASUREMENT OF WINTER ROAD MANAGEMENT

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ABSTRACT

For road administration organizations in cold, snowy regions, winter road management is an important part of their public works activities. Efficient, appropriate winter road management is called for because budgets are limited and society is becoming more concerned about the environmental loads from the spreading of anti-icing agents. To evaluate the appropriateness of winter road management operations, it is necessary to understand the relationship among what we define as the inputs (the budget for winter road management), activities (spreading of anti-icing agents), outputs (the amount of used anti-icing agents and so on), and outcomes (the results of road management operations). The authors constructed a logic model for winter road management by using the road surface friction as the intermediate outcome. Road surface friction is a determining factor in the movement of vehicles on snow- or ice-covered roads, and the improved road surface friction is the input's direct outcome that shows the results of road surface management operations including snow removal. For national highways in Sapporo, we monitored the slipperiness of the road surface and conducted experimental performance measurements and evaluations.

KEYWORDS

PERFORMANCE MEASUREMENT/ WINTER ROAD MANAGEMENT/ FRICTION / LOGIC MODEL

1. INTRODUCTION

The Japanese archipelago is between the latitudes of 20 and 45 degrees north, and Hokkaido, its northernmost major island, is particularly cold and snowy. In many municipalities of Hokkaido, the average temperature from December to March is below zero degrees centigrade and the average annual period of snow cover exceeds 100 days. In Japan, to improve the performance of tires on snowy, icy roads, the use of studded tires (tires with metal studs on the tread surface) started around 1960. Once studded tires became widely used, serious social problems arose: The tires damaged the roads by abrading and rutting them, and the dust from that abrasion caused air pollution in areas along roads. Local government ordinances restricting the use of studded tires were issued, and the use of such tires was restricted by law at the beginning of the 1990s. Restrictions on the use of studded tires considerably improved the living environment by preventing dust from being generated by tire abrasion.

When the use of studded tires stopped, a phenomenon called tsuru-tsuru romen (Japanese for “extremely slippery, icy roads”) began to occur (Fig. 1). New problems, such as increases in the number of “winter-type” road accidents and congestion caused by the lowered traveling speed of vehicles, have resulted (Fig. 2). To address the problems of worsening winter traffic conditions after the enforcement of studded tire use-restrictions, the amounts of anti-icing agents spread on roads, which were barely used when the restrictions were first enforced, markedly increased (Fig. 3). Because of the use-restrictions, road surface management, particularly measures against icy road surfaces, has become a very important part of winter road management.

Figure 1 - The phenomenon of extremely slippery, icy roads

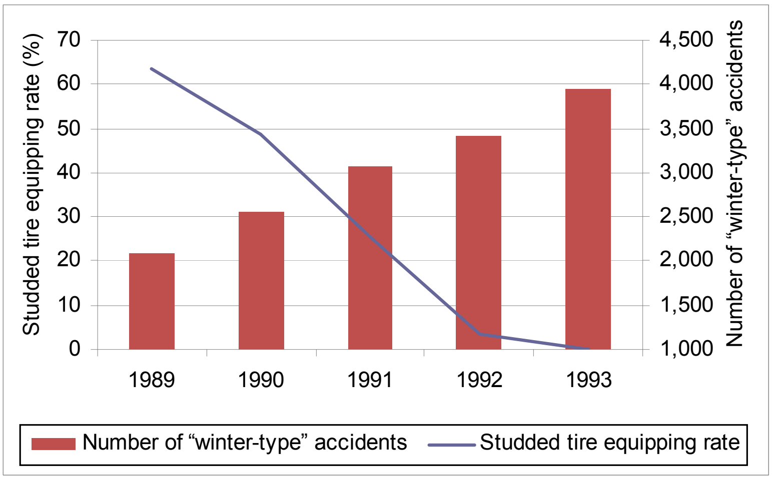


Figure 2 - Studded tire equipping rate and number of "winter-type" accidents in Hokkaido

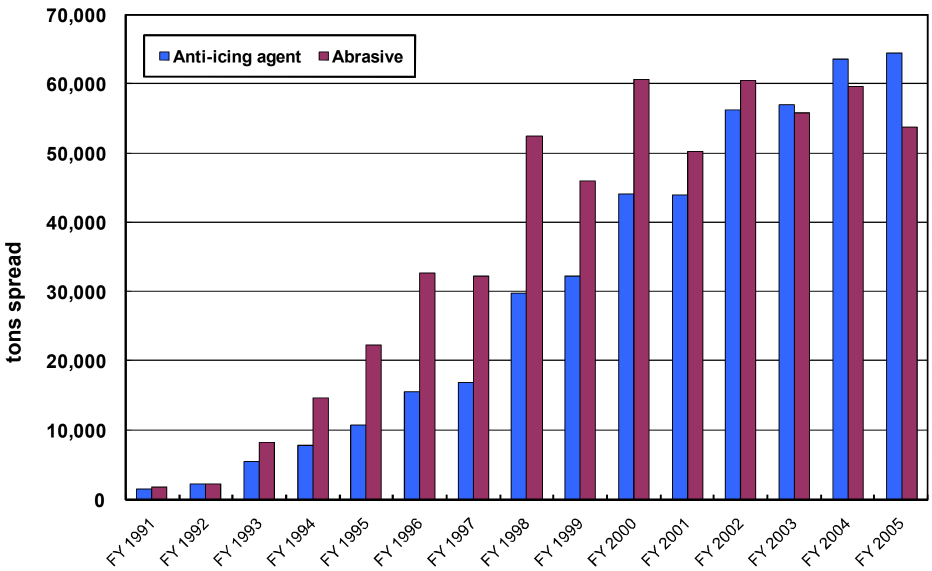


Figure 3 - Use of anti-icing agent and abrasives on Hokkaido's national highways

On national highways in Hokkaido, effective and efficient winter road management has been conducted based on clearly set road surface management targets for each road according to its traffic volume and the conditions along the route. Although winter road management in Hokkaido has been improved, traveling speeds in winter have remained extremely low and skidding accidents account for 90% of the prefecture's "winter-type" road accidents. Road traffic performance in winter has remained low. To improve the performance of winter road traffic under budget constraints and environmental concerns over the use of anti-icing agents, there is a need for accurate and efficient winter road management.

2. RESEARCH TRENDS IN PERFORMANCE MEASUREMENT OF WINTER ROAD MANAGEMENT

In Japan performance measurement has been used in measuring economic effects as a part of public project evaluation and in evaluating each program of a public project.

The Government Policy Evaluations Act was established in 2001. Road administration organizations of the government have been striving to improve their administrative activities by becoming more effective, efficient and transparent. They have been doing this by placing importance on the perspectives of citizens. To realize this goal, government organizations have been employing a road administration management system that has "Plan-Do-Check-Act" cycles. In the system, quantitative indicators are preset (Plan), policies and projects are implemented (Do), performance is evaluated (Check), and the evaluation is reflected in the future administrative management (Act) [1]. Although a few studies have addressed performance measurement and evaluation for winter road management, including a study by Yamamoto et al. [2] and one by Asano et al. [3], the introduction of such management cycles into winter road management has been slow.

There are some Western countries where performance evaluation of winter road management has been studied. One example is Sweden which has developed its Winter Model [4] (Fig. 4). In this model for optimizing winter road management, accident risk, accessibility (e.g., travel time), fuel consumption, corrosion (e.g., on the metal members of bridges from the use of anti-icing agents), road management costs, and environmental effects are monetized.

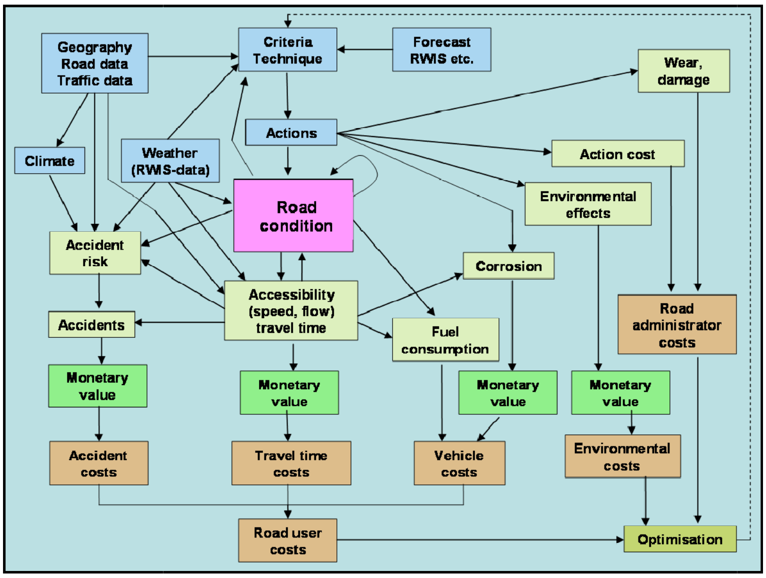


Figure 4 - Sweden's "Winter Model" [4]

In Canada the road administration has been collecting data on traffic volume, traffic speed and winter road surface conditions to implement performance evaluation of winter road management as a part of the nation's asset management [5]. The road administration of the United States has surveyed and reported performance evaluation for winter road management of other countries [6]. The American report shows that performance measurement for winter road management can be generally categorized in three areas: inputs, outputs, and outcomes.

3. PERFORMANCE MEASUREMENT FOR WINTER ROAD MANAGEMENT

3.1. Method of performance measurement

In this study, a logic model was employed to conduct performance measurement for winter road management. The logic model diagrammatically displays the process of winter road surface management from the initial resource inputs to the effects of improvements (=products). The diagram clearly shows the link relationship between causes and results. The logic model has been widely used for program evaluations. The model describes the logical flow of elements necessary for performance measurement as a diagram with inputs, activities, outputs and outcomes flows, and it makes it possible to visually understand the causal relationships between the elements. Logical tracking from the initial inputs to the end products makes it possible to accurately formulate a systematic policy and determine each outcome toward achieving the final goal.

3.2. Logic model for winter road management

Figure 5 shows the flow of winter road management described in a logic model. The inputs are the budgets, equipment including vehicles for spreading anti-icing agents, and personnel; the outputs are the number of deployments of snow removal/anti-icing agent spreading fleets and the amount of anti-icing agent spread. For this model we set intermediate and end outcomes. As an intermediate outcome that could be used as a quantitative indicator in evaluating the road surface conditions, we set road surface friction. As the end outcomes, we set the winter traffic conditions (travel speed, traffic volume, traffic capacity), data on winter-type accidents (number of accidents, categories of accidents, occurrence rate), data on reliability in travel time (decrease and variance in travel time), and data on satisfaction (number of complaints, ease of driving).

As the intermediate and end outcomes, road surface friction and winter traffic conditions were used, for the following reasons. Intermediate outcome is "an outcome that is expected to lead to a desired end, but is not an 'end' in itself." The end outcomes are the results of programs that are implemented, or an event, occurrence, or condition outside the activity or program itself and of direct importance to clients and the public [7].

The purpose of winter road surface management (a program) is to improve the road surface conditions, and the final goal of that program is to provide a safe, convenient road traffic environment to the road users (= customers). Based on these, the road surface friction, which is a direct result of winter road surface management, was employed as the intermediate outcome, and the traffic conditions, which are measurable in the form of satisfaction and road traffic data, were employed as the end outcomes.

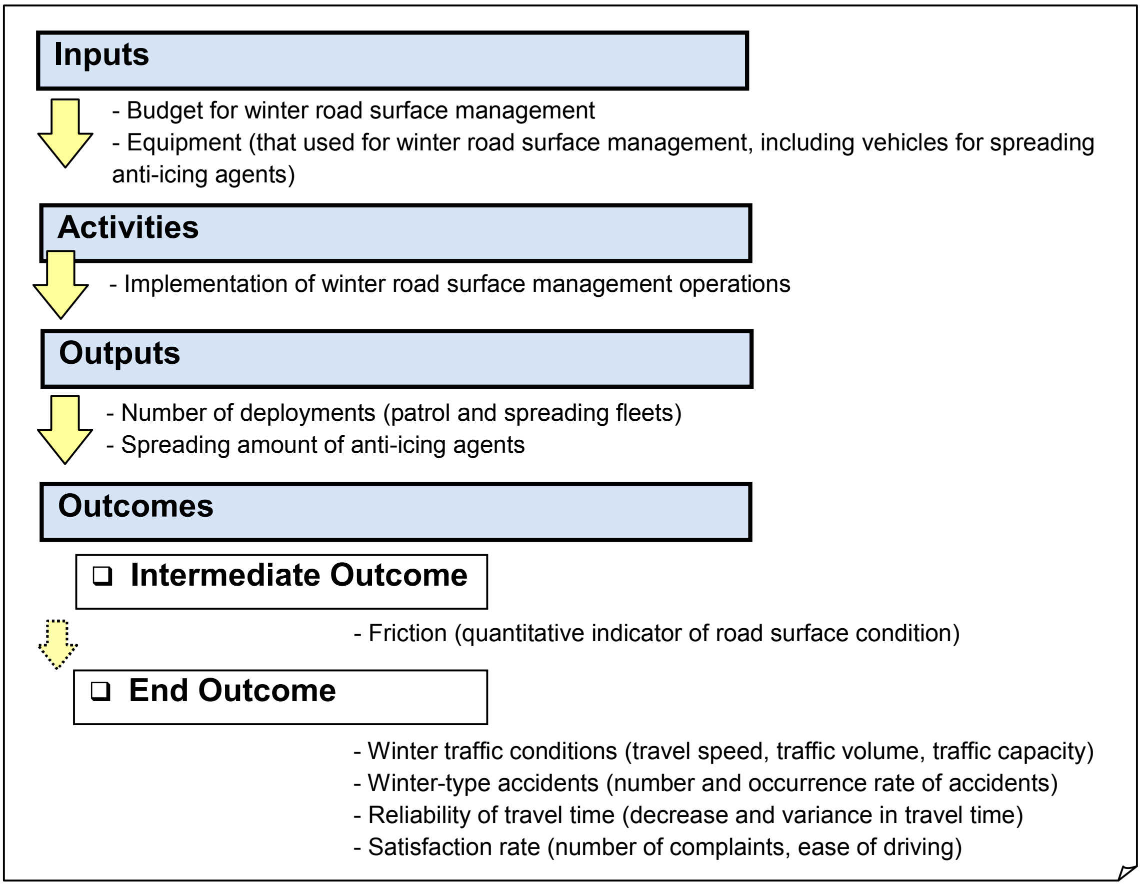


Figure 5 - Logic model for winter road management

3.3. Measuring the surface friction

In Japan we had no useful equipment for measuring the slipperiness of the road surface, which varies continuously along the road. We have conducted winter road surface management by assessing the slipperiness of the road surface based on visually categorized road surface conditions, including ice and compacted snow. Backwardness in the development of technologies for quantitatively evaluating the road surface conditions can be counted as a reason for our slow progress in performance measurement in winter road surface management. In our study we used a continuous friction tester (CFT) to monitor the road surface conditions of the routes under investigation (Fig. 6, left). This device determines the Halliday Friction Number (HFN) for the road surface by using the measuring wheel attached to the rear of the vehicle while driving, which makes it possible to continuously measure the friction of the road surface (Fig. 6, right).

Figure 6 - Left: Continuous Friction Tester; Right: Display of monitored friction

4. TRIAL PERFORMANCE MEASUREMENT FOR WINTER ROAD MANAGEMENT

4.1. Trial for performance measurement

Our monitoring of the road surface friction using the CFT for national highways in Sapporo started in the winter of 2007. National Highway 230 was selected as a case study route. This route has a roughly 44-km section within the boundaries of Sapporo, and that section has three different roadside conditions: urban, suburban and mountainous. We used the CFT to measure the road surface friction of the section for the 40 day period that started in December 2007 and ended in February 2008. Round trip measurement runs were done twice per day.

Figure 7 shows the result of the measurements described in the logic model explained in Figure 5. The horizontal axes of the graphs in the outcomes part of Figure 7 are road distances, which makes it possible to examine the data for any given section within the monitored 44 km. The horizontal axes of the bottom three graphs show observation points.

The starting point of the monitored route in each graph is kilopost (KP) 1.0. The section from KP1.0 to KP17.0 is in the densely inhabited district (DID) of central Sapporo, the section from KP17.0 to KP29.0 is in the suburbs and the section from KP29.0 to the endpoint at KP45.0 is in a mountainous area. The endpoint is at a mountain pass. Thanks to the road administrator’s cooperation we were able to collect all available data.

For inputs we used the budget and personnel for winter road surface management. For outputs we used the number of deployments for spreading anti-icing agents and the amount of anti-icing agent spread. The road surface friction expressed by HFN was used for the intermediate outcome, and travel speed and winter-type accidents were used as the end outcomes.

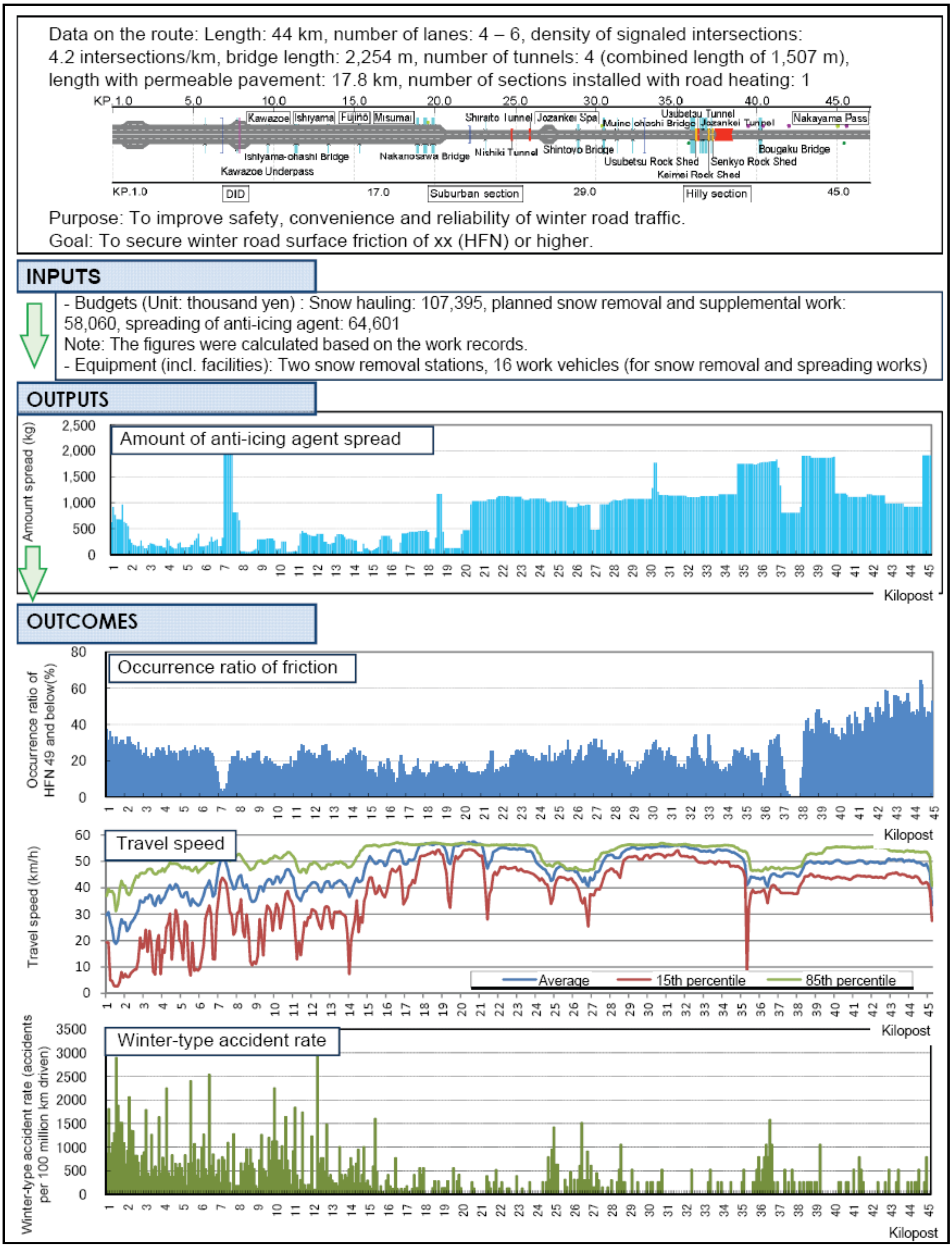


Figure 7 - Trial performance measurement using a logic model for winter road management on National Highway 230

4.2. The relationship between road surface friction and traffic conditions

Measurement of road surface friction made it possible for us to describe the flow of winter road maintenance. Measurement of friction alone, however, is not enough for performance evaluation of winter road management. To measure and evaluate the performance of winter road management, it is necessary to clarify the causal relationships between inputs, outputs and outcomes. In the following we show the result of analysis in order to clarify the relationship between the friction as the intermediate outcome and the traffic characteristics as the end outcome, both of which are obtained from the collected data.

<u>Friction and travel speed</u>

The left-hand graph in Fig. 8 shows the change in travel speed at an intersection in the urban area of Sapporo. The blue lines represent the travel speed when the road surface condition is good, and the red lines represent the travel speed when the road surface condition is bad. When the road surface condition is bad, the travel speed is low and movement before stopping and after restarting are slow, which suggests that the driver might need to be very careful. Slow travel speed and slow stopping and starting speed affect the traffic flow on that route.

The right-hand graph in Fig. 8 shows the relationship between the friction value and travel speed. The friction is low when the snow depth on the road is deep, and when the friction is low, the travel speed decreases and the dispersion in travel speed becomes great. The worse are the road surface conditions in winter, the more the reliability of travel time is impaired.

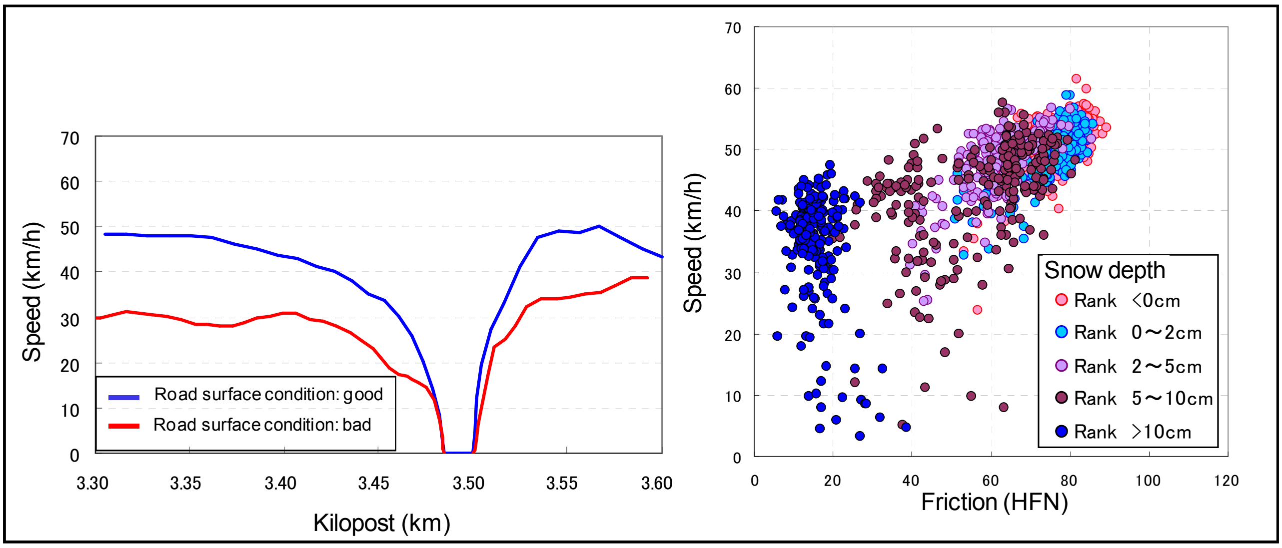
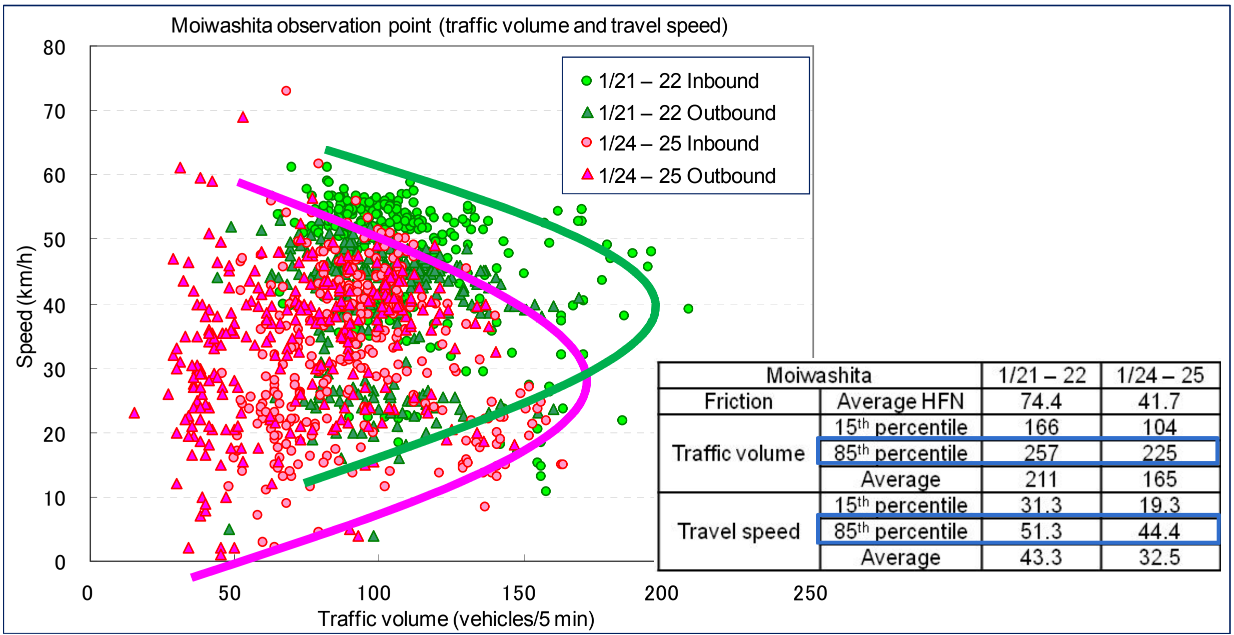


Figure 8 - Friction and travel speed
(Left: Travel speed at an intersection; Right: Friction vs. travel speed)

Decrease in the friction value results not only in decreases in the travel speed but in decreases in the traffic capacity. Figure 9 shows friction, traffic volume and travel speed measured at a fixed observation point. The average friction decreased from 74.4 HFN on January 21 and 22, 2008, to 41.7 on January 24 and 25. The traffic volume showed a 22% decrease and the travel speed showed a 25% decrease for the same observation periods as those for friction.



Moiwashita		1/21 – 22	1/24 – 25
Friction	Average HFN	74.4	41.7
Traffic volume	15th percentile	166	104
	85th percentile	257	225
	Average	211	165
Travel speed	15th percentile	31.3	19.3
	85th percentile	51.3	44.4
	Average	43.3	32.5

Figure 9 - Relationship between average friction, traffic volume and travel speed

Friction and traffic accidents

As shown in Figure 7, the occurrence rate of accidents in winter is high on the DID section, densely populated areas in the suburbs (KP25 - KP27), and at Muine Bridge (KP37). Figure 10 shows the average HFN and travel speed for the road sections without intersections or railway crossings in the DID, suburbs, and mountainous areas. The period for observation was 14:00 – 15:00, which is in the off-peak hours. In the DID section, even though the variation in the friction is great the average travel speed is low, which results in a high rate of light injury accidents. In contrast, the rates of serious and fatal accidents are high in the mountainous area, which can be attributed to the high travel speeds in that area despite its low HFN.

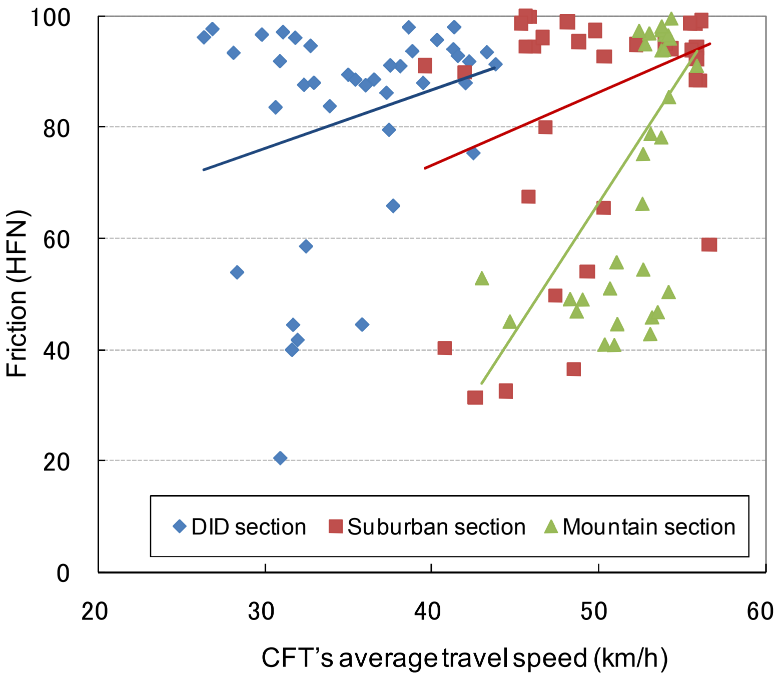


Figure 10 - Average HFN vs. average travel speed

Friction improvement by winter road management

Figure 11 shows the friction before and after the spreading of anti-icing agent. The top graph in Figure 11 describes the distribution of friction values (HFN), and the bottom graph shows the distribution of friction values on the route maps.
The red circles in the map represent HFN of 49 or lower, the yellow circles represent HFN of 50 – 69, and the green circles represent HFN of 70 or higher.
Observation was done on February 6, 2008, when sub-zero temperature continued all day long. The lowest temperature was -10 degrees centigrade. The friction of HFN 50, which was measured at 06:00, before the spreading of anti-icing agent, rose to HFN 80 at 09:00. These data support the need for the spreading of anti-icing agents and the effectiveness of anti-icing agents in improving the road surface condition.

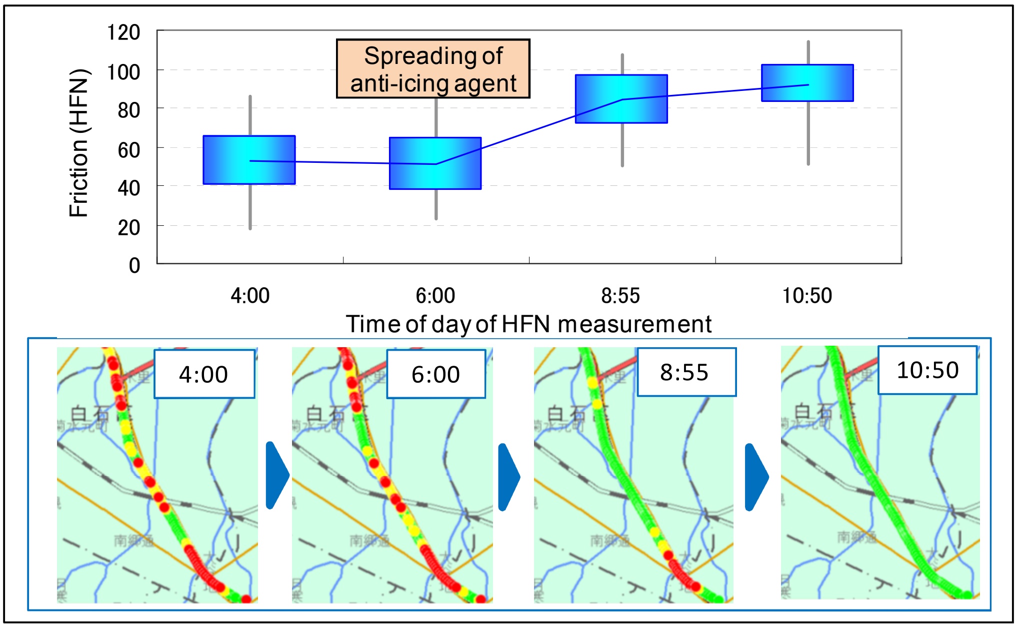


Figure 11 - Friction (HFN) before and after the spreading of anti-icing agent

5. CONCLUSIONS AND SUGGESTED RESEARCH

In this study we constructed a logic model for winter road management, and by using the CFT, we measured the road surface friction, which is used as an intermediate outcome in our logic model. We then analyzed the relationship between 1) friction and travel speed, 2) friction and traffic accident occurrence, and 3) friction and spreading of anti-icing agent.
Only one route was used for this study, and the periods for data aggregation were not uniform. It is necessary to further clarify the causal relationship between inputs, outputs, and outcomes in winter road management by conducting performance measurement for more than one route and by collecting additional data on winter road surface friction and related road management data.
Our future research objectives are described below.

Study on setting standards and indicators

To conduct performance evaluation, it is necessary to set appropriate standards and to determine the priorities of the set standard items; however, this study has not achieved

those yet. The standards for performance evaluation can be set as a certain level of friction or as the number of hours in which the friction is below a certain level.
At the ends of a tunnel or an underpass, the changes in friction values were great and the occurrence rates of winter accidents were high. As it is hard for drivers to respond to sudden changes in road surface conditions, it might be possible to use the variability in friction as an indicator for road surface management.
Depending on routes, it is also possible to use the degree of visibility hindrance, number of traffic closures, and/or number of avalanches as indicators.
By collecting further data on routes in wider areas, we will examine and determine what shall be the indicators, how to measure the indicator elements, what shall be the standard values for such indicators and which indicator shall be prioritized.

Clarifying the relationships between winter weather, road conditions and friction

This study clarified the changes in friction resulting from the spreading of anti-icing agent, but it found no relationship between the amount of anti-icing agent spread (output) and the road surface friction (intermediate outcome). To clarify the relationship between these, it will be necessary to clarify the relationship between the weather and road conditions and the road surface friction.
Our future research will be on estimating friction by utilizing a method to estimate the road surface temperature from the weather and road conditions [8], taking the influence of moisture on the road surface into consideration.

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