Effects of Studded Tire Regulation on Road Environments and Traffic Conditions in Hokkaido

Hideki Takagi, Hidetsugu Onuma, and Akihiro Shimojo,
Hokkaido Development Bureau, Civil Engineering Research Institute, Japan

To prevent dust pollution generated by studded tires in Japan, the use of such tires was first regulated in the winter of fiscal year 1991 in accordance with the law on the prevention of road dust caused by studded tires, which took effect in June 1990. For the last several years, the rate of vehicles equipped with studded tires has decreased from 0.9 to almost zero in Hokkaido. The ban on the use of studded tires helped considerably to decrease the environmental pollution caused by airborne particles. On the other hand, several new road traffic problems have arisen, including an increase in traffic accidents and congestion caused by changing conditions on roads covered with snow and ice. The past problem of studded tires causing wear of paved surfaces was replaced with a new problem of studless tires polishing surfaces covered with snow and ice. In recognition of this, road environmental effects, snow- and ice-covered road surfaces in the age of studless tires, road maintenance using antifreezing or antislipping agents, and traffic accidents are examined, and present and future problems are discussed.

The use of studded tires rapidly spread beginning around 1970 in Hokkaido. Five years later, almost 100 percent of passenger cars were equipped with such tires in the winter. The tires began to generate controversy in 1977 or 1978, however, because road abrasion and falling dust generated by studded tires were feared to be polluting roadsides and the air, to the detriment of public health. Subsequently, a grassroots anti-studded-tire movement gained momentum. As a consequence, studded tire regulations went into effect in 1990, followed by the enactment of penal provisions in the winter of 1992.

The process of applying the studded tires regulation in Hokkaido was divided into three phases, as shown in Figure 1. At present, 85 percent of the total population and 85 percent of automobiles are subject to such regulation. Because the sale of studded tires stopped in 1991, the percentage of cars using studded tires has been decreasing, as shown in Figure 2. The data show that studded tires nearly disappeared in 1992 in the primary designation area of Sapporo and that the percentage of cars using studded tires dropped to almost 0 in 1993 in the secondary designation areas. In the tertiary designation areas and other areas that are not yet designated, less than 10 percent of cars used studded tires in 1994. Studded tires are disappearing from Hokkaido.

Environmental Survey Results

Density of Suspended Particulate Matter

Suspended particulate matter, which makes up about half the dust generated by studded tires and is feared to affect the human body, consists of microparticles

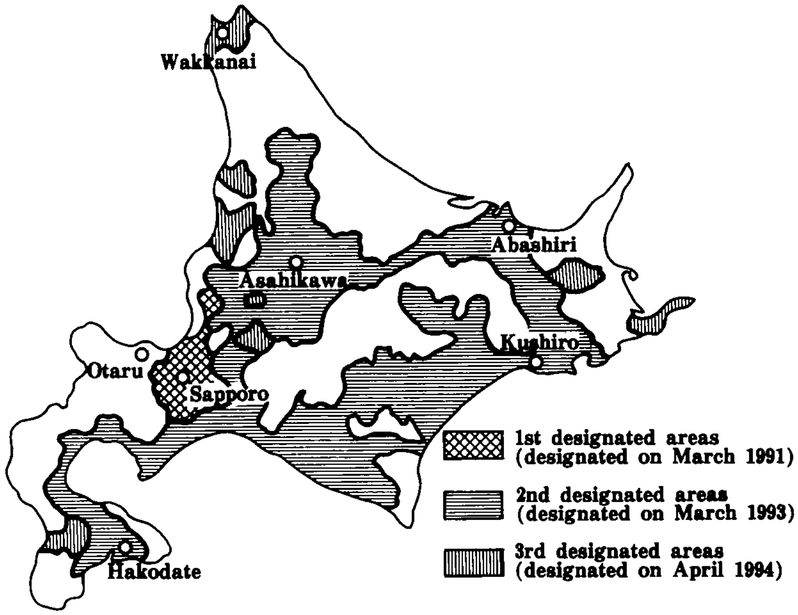

FIGURE 1 Designated areas in Hokkaido.

smaller than 10 μm in diameter. The microparticles are invisible, and when inhaled they enter the windpipe and the lung directly, without being stopped at the nose or the throat. Japan's Environment Agency conducted a survey of the effect of such dust on the human body and reported that although no carcinogenicity was identified, the dust may cause pneumoconiosis. Figure 3 shows the yearly change in the maximum density of suspended particulate matter in Sapporo. In 1984, when the equipping rate of studded tires was greater than 95 percent, the density was 171 $\mu g/m^3$, exceeding the environmental standard of 100 $\mu g/m^3$. After 1989, however, the density dropped below the environmental standard and has remained there. The density was 49 $\mu g/m^3$ in 1993, 30 percent of the 1984 value. Figure 4 shows the change in density of suspended particulate matter in late winter, when such density peaks. Figure 4 indicates that there were 3 days in March 1984 on which the density exceeded the environmental standard; at such times the air is considered to be badly polluted. Subsequently, however, the density of suspended particulate matter has decreased yearly and now there are no days on which the density exceeds the environmental standard, proof that clean air is returning.

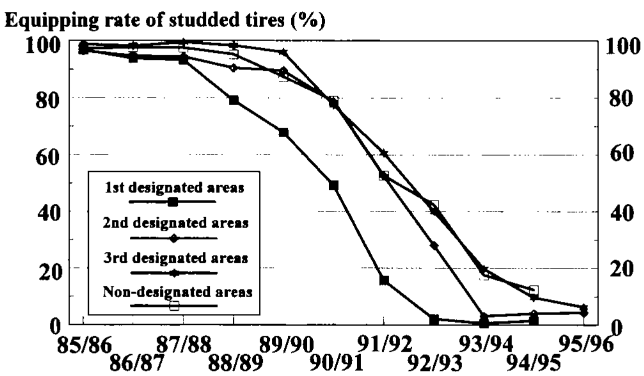

FIGURE 2 Studded tire equipping rate, by designated area.

Amount of Falling Dust

"Amount of falling dust" (often consisting of particles more than 10 μm in diameter) is a measurement of the dust falling on the ground because of gravity or rain. The majority of such dust in the winter consists of the dust of asphalt abraded by studded tires. The amount of falling

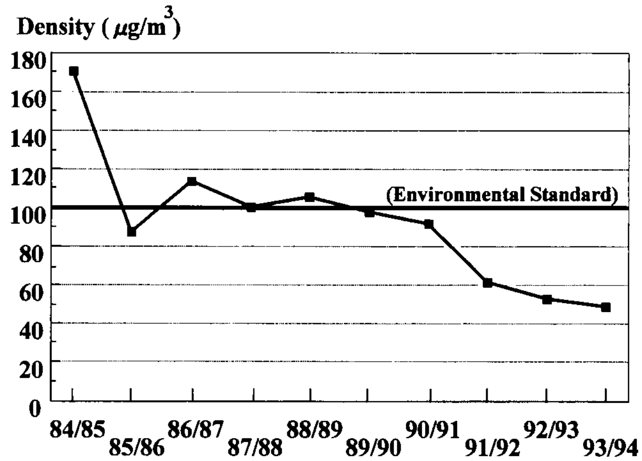

FIGURE 3 Annual changes in maximum density of suspended particulate matter (*1*).

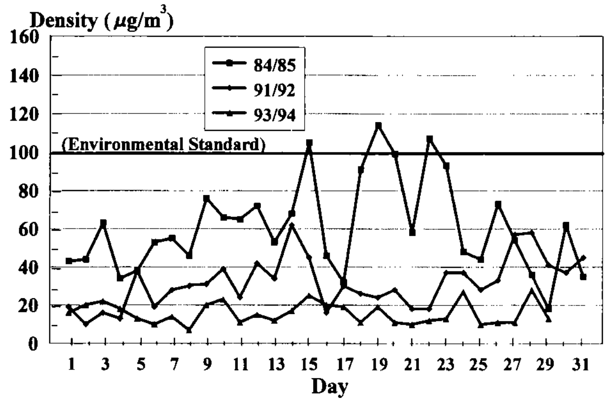

FIGURE 4 Changes in density of suspended particulate matter in March (*1*).

dust in the air tends to increase in early spring when snow melts and in early winter when snowfall begins. Figure 5 shows the monthly change in the amount of falling dust in Sapporo. As indicated, March always has the highest value for the year, 131.8 t/km^2/month in 1988, 7 times the amount of each summer month. The amount was 63.5 t/km^2/month in 1991. However, in 1993, when the equipping rate of studded tires approached zero, the amount of falling dust decreased to 22.1 t/km^2/month. Also, 1993 not only showed a low value each month but also showed no great seasonal differences, indicating that the Sapporo area regained a "white winter" with the decline in the use of studded tires.

Road Abrasion

For the survey, a lane of National Route 12 in Sapporo where no special measures for wear resistance or plastic flow resistance are employed was chosen. Standard pins were buried perpendicular to the road from one roadside to the other, and abrasion was measured with a cross road profile meter with an accuracy of 0.1 mm at 10-cm intervals. The average amount of abrasion for each year and the equipping rate of studded tires are shown in Figure 6. As indicated, the value in 1989 was 6.1 mm with an equipping rate of studded tires of 63 percent. The value in 1992 fell to 1.1 mm when the equipping rate of studded tires approached 0 percent. Figure 6 shows that the decrease in the equipping rate of studded tires directly leads to a decrease in road abrasion. This is also reflected in the decline in the amount of falling dust, which was 92 t/km^2/month in March 1989 but fell to 45.7 t/km^2/month in 1992, or about half the 1989 level.

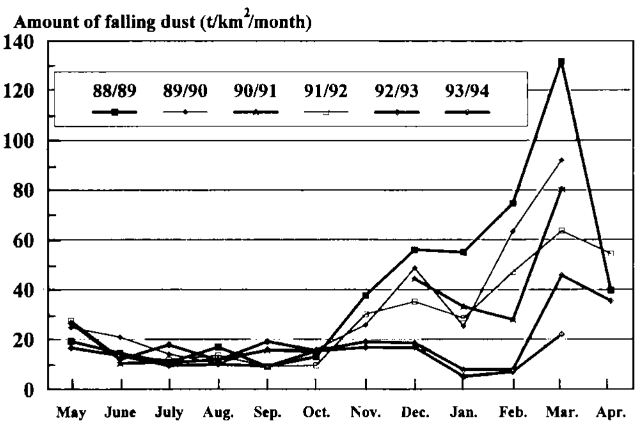

FIGURE 5 Monthly changes in amount of falling dust in Sapporo (*1*).

Changes in Nature of Surfaces Covered with Snow and Ice

Studless tires have been gradually popularized in the last several years, as shown in Figure 2. The use of studless tires had been promoted in a relatively smooth way until 1991 despite a variety of opinions and criticisms. In the winter of 1992, however, extremely slippery surfaces (Figure 7) appeared suddenly, which created a stir in the smooth transition. As people in Hokkaido had never experienced roads covered with snow and ice to be slippery so frequently, this problem gave rise to sensational controversy. Criticism against road administrators was strong, and technically more-sophisticated measures of road management in winter were required because skidding accidents increased and traffic congestion in urban areas was aggravated.

Slippery roads are categorized into frozen road surfaces, surfaces with black ice, and those covered with compacted snow. Compacted snow–covered surfaces that have been affected by climate and traffic conditions caused by studless tires are much more slippery than they were before the elimination of studded tires. These can be considered new and fundamental characteristics of winter road surfaces. As an example of the structure of slippery roads, Figure 8 (prepared by the Disaster Prevention and Snow Engineering Section, Civil Engineering Research Institute) shows that the traffic of cars with studless tires affects the surface of compacted snow to form a thin top layer of ice, about 1 mm thick, with a crystal structure different from the middle and bottom layers.

When studded tires were still used, drivers using studless tires presumably must have had very few opportunities to drive on extremely slippery roads, whether frozen surfaces, black ice, or surfaces covered with compacted snow, because studs of other cars created adequately coarse surfaces.

Although braking and other types of performance of winter tires, especially studless tires, on road surfaces covered with snow and ice have been improving through the efforts of manufacturers, there has been little serious discussion about the problem of slippery surfaces result-

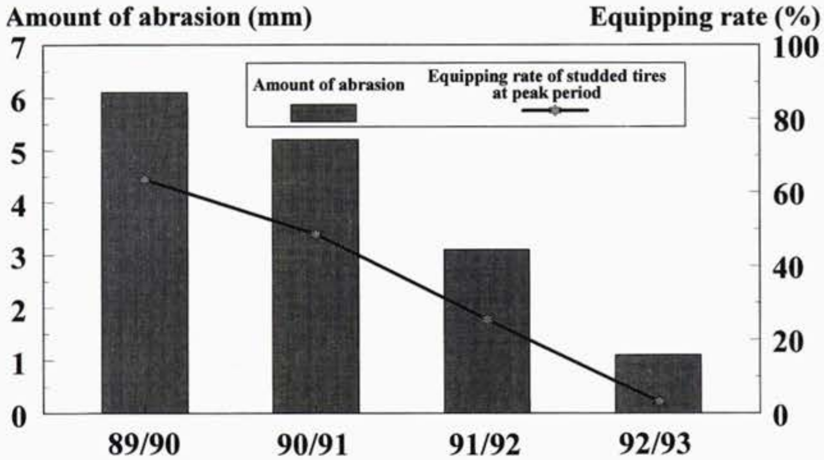

FIGURE 6 Equipping rate of studded tires and amount of abrasion (2).

ing from the use of studless tires and the elimination of studded tires. The changes in the nature of road surfaces covered with snow and ice are actually a new problem for road traffic in winter, because the slipperiness of roads depends on both the performance of tires and the condition of the road surfaces.

Extremely slippery roads are now problems all over Hokkaido, but the problem is most apparent in the area centering in Sapporo in which snow falls on many days and the average daily temperature is between 0 and –5°C from December to February. Road administrators in this area have been trying to use correct measures, relying mainly on deicers or other physical measures such as sand, to improve the conditions of surfaces covered with snow and ice in critical areas.

Among all the snowy and cold regions in Japan, Hokkaido is characterized by heavy snowfall and low temperatures, and in many places snow and ice on roads rarely melts naturally even after snow clearing operations. Because Hokkaido's climate does not allow complete snow removal from road surfaces, studless tires affect the condition of roads covered with snow and ice more markedly than they do on the main island of Honshu.

CHARACTERISTICS OF WINTER TRAFFIC ACCIDENTS

The use of studless tires has been greatly promoted in Hokkaido in recent years, and a major characteristic is

FIGURE 7 Extremely slippery road covered with snow and ice.

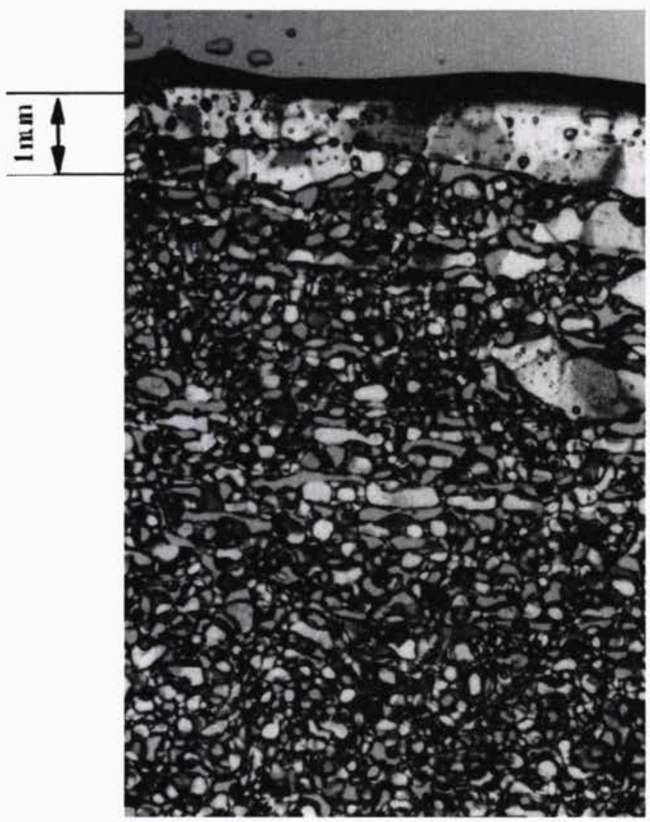

FIGURE 8 Thin layer of compacted snow from extremely slippery road observed through a polarizing microscope.

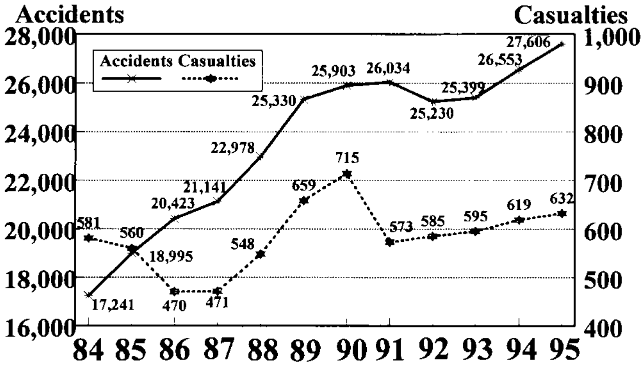

FIGURE 9 Change in number of traffic accidents in Hokkaido (all roads included, by year).

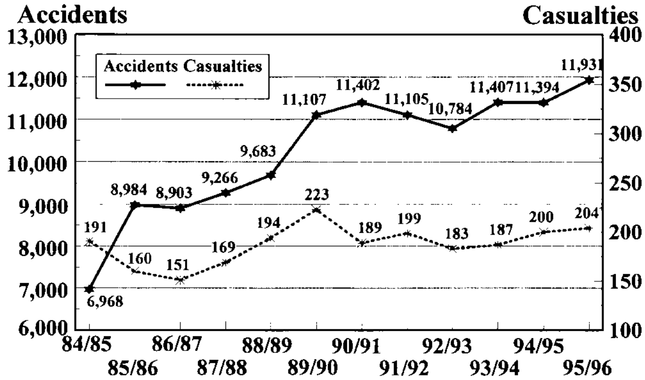

FIGURE 10 Change in number of traffic accidents in winter in Hokkaido (all roads included).

noticeable in winter traffic accidents. Figures 9 and 10 show the changes in the number of traffic accidents per year and per winter (November to March), respectively. The number of the accidents resulting in injury or death did not change greatly between 1989, when drivers began to use studless tires, and 1994, when almost all studded tires disappeared, although the numbers fluctuate slightly year by year and winter by winter.

On the other hand, analysis of accidents in winter in Figure 11 shows that one particular type of accident peculiar to winter has increased rapidly with the increased use of studless tires. Most of the accidents were caused by skidding, and others were caused by reduced visibility and ruts. Additionally, the number of casualties in serious accidents has been leveling off. For Hokkaido in general, the number of accidents caused by skidding that have resulted in injury or death reached a peak in 1993, when almost all cars in Hokkaido used studless tires, and the number decreased gradually and slightly in 1994 and 1995.

Figure 12 shows that annual changes in the number of skidding accidents are much greater on municipal roads than on trunk roads, such as national roads. Initially, it was expected that the traffic accidents would increase significantly on trunk roads with heavy traffic, but the analysis shows the opposite. As mentioned, it is difficult to completely remove snow and ice from roads in such a cold and snowy region as Hokkaido, and the snow and ice remaining on the surface tends to be affected by weather and studless tires. Consequently, it is possible that a difference in road management is largely reflected in the increase in skidding accidents.

Figure 13 shows that the number of accidents increases in the beginning and in the depth of winter, namely in December and January, and that it is greatly influenced by weather conditions in winter. Figures 14, 15, and 16 indicate that rear-end colliding accidents in

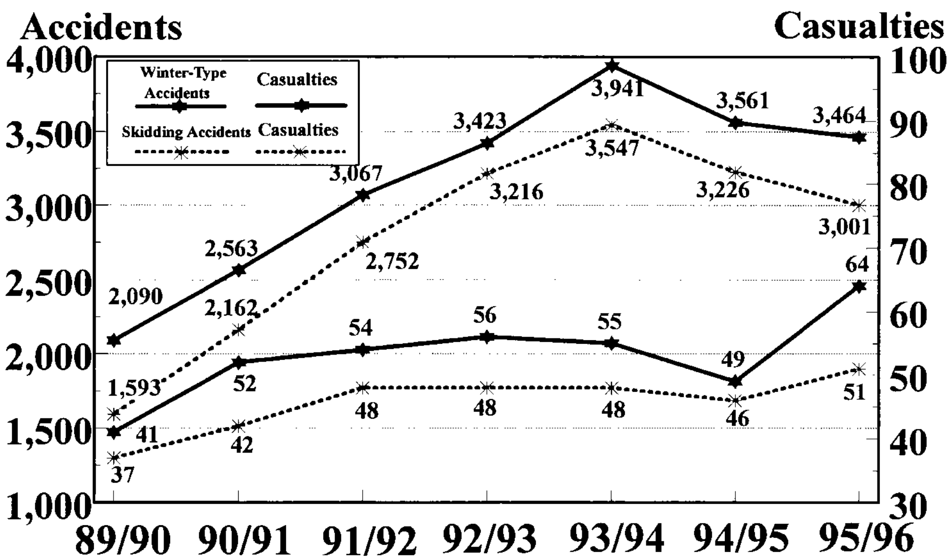

FIGURE 11 Change in number of winter traffic accidents and skidding accidents in Hokkaido (all roads included).

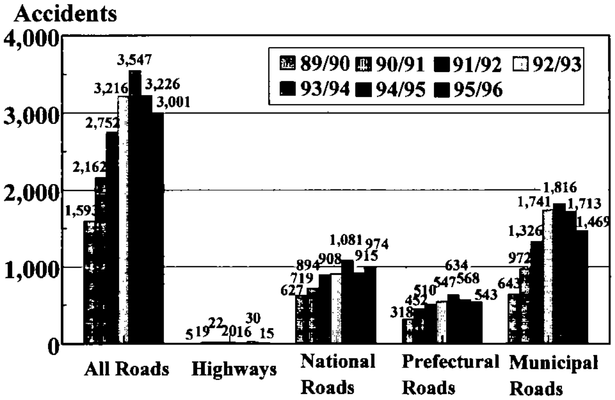

FIGURE 12 Number of skidding accidents classified by road category.

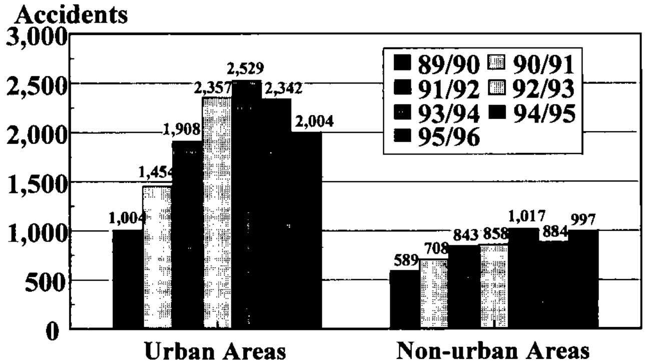

FIGURE 14 Number of skidding accidents classified by geographic features (all roads included, winter).

intersections in urban areas are rapidly increasing with the popularization of studless tires. In other words, accidents on roads covered with snow and ice increase conspicuously in the places where drivers must start and stop their cars frequently, which is likely to cause unexpected behavior such as skidding. This must be kept in mind by both road administrators and drivers. Road administrators must improve their management standard regarding not only trunk roads but also wider areas. This means that road administrators, especially local governments in cold and snowy regions must overcome difficulties in systems and budgets for road management. This situation also suggests that drivers must be more careful and drive according to surface conditions when driving both on streets with relatively little traffic and on trunk roads.

Because the total length of national, prefectural, and municipal roads combined is tremendous, it is impossible to apply an ideal, real-time management system to each individual road subject to harsh climatic conditions and changes in winter. Therefore, drivers are required to drive with deliberation and appropriate consideration, and road administrators must continue to look for the most efficient ways of management based on analyses of past traffic accident data as well as on limited financial resources and existing systems.

Winter Road Management

In Japan, particularly in Hokkaido, antifreezing or antislipping agents had not been used in road management except for in special areas such as mountain passes, because of the large amount of snow in winter and the use of studded tires by most vehicles. However, the spread in the use of studless tires, promoted by the regulation of studded tires, has led to very slippery frozen road surfaces, and it has become important to upgrade road management. During the last several years, therefore, road administrators improved machine snow removal and gradually promoted the use of antifreezing and antislipping agents, especially on major roads.

Using the results of analyses of traffic accidents, road administrators have selectively and intensively con-

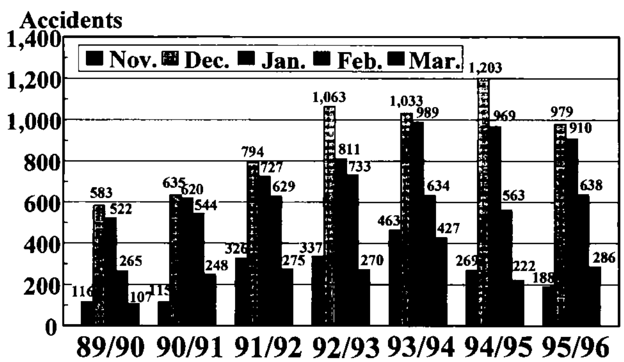

FIGURE 13 Number of skidding accidents by month (all roads included, winter).

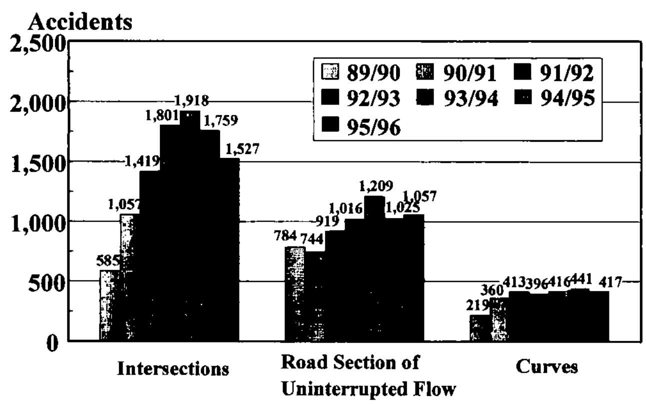

FIGURE 15 Number of skidding accidents classified by road feature (all roads included, winter).

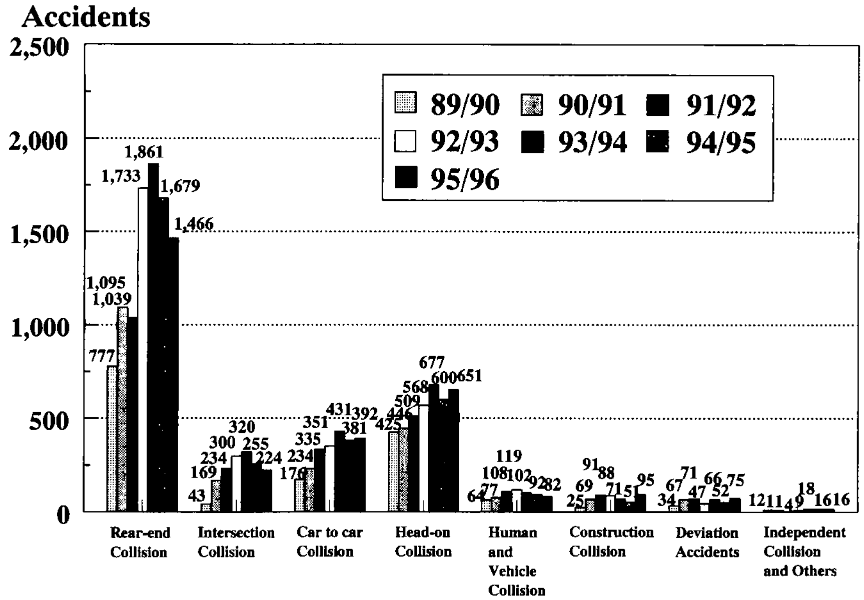

FIGURE 16 Number of skidding accidents classified by type of accidents (all roads included, winter).

ducted road management for, among other sites, sections with poor alignment such as mountain passes, shaded sections of road, sections near structures such as bridges and tunnels, and urban intersections. Road management for these sections of road has been conducted not only to improve the safety and smoothness of road traffic, but also to minimize secondary effects of antifreezing agents used in winter road management. Figure 17 shows changes in quantities of various agents used, including antifreezing ones, on national roads, and Figure 18 gives skid resistance coefficients for frozen road surfaces (measured values on National Route 230, in the suburbs of Sapporo, during 20 days between late December 1994 and late February 1995 on which frozen road surfaces occurred). Skid resistance coefficients have been improved for sections of road (especially at intersections in urban areas) over which the various agents are intensively distributed. Road administrators are considering to what extent these agents should be used, based on the relationship between road management levels and road user needs.

Summary and Conclusions

With regulation of studded tires, the spread of dust was greatly reduced and a "white winter" was regained, but with the spread of studless tire use, extremely slippery frozen road surfaces occurred, resulting in an increase of skidding accidents. Skidding accidents occurred more frequently in urban areas than in suburban areas. Rear-end collisions at intersections, where vehicles apply their brakes, particularly, occurred more frequently than on other sections of road. Furthermore, accidents

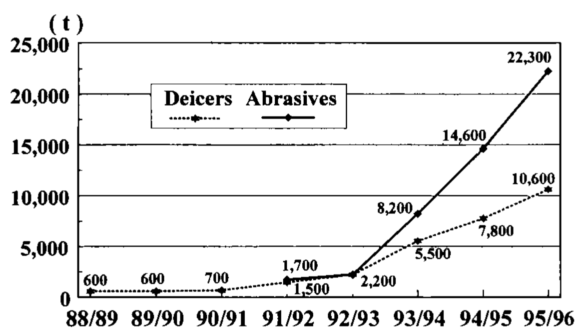

FIGURE 17 Use of deicers and abrasives on national roads in Hokkaido.

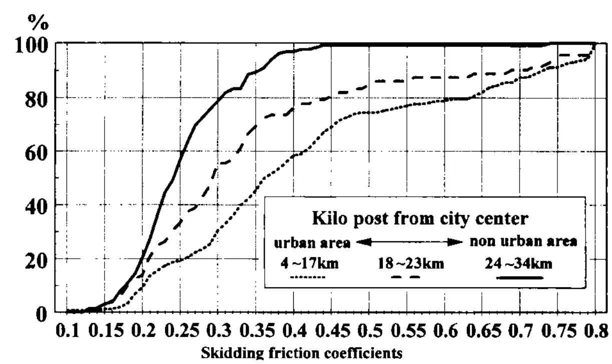

FIGURE 18 Cumulative curve of skidding friction coefficients on Route 230 (*3*).

occurred more frequently on nonmajor roads, where snow was always compacted, than on major roads. It is believed that this was because of differences in road management levels. To improve management for major roads, road administrators conducted various measures, including the improvement of machine snow removal and the use of antifreezing and antislipping agents. On sections of road over which antifreezing and antislipping agents are intensively distributed, skid resistance has been improved. The next challenge is to expand the use of these agents to, among other areas, suburban sections of road.

Comprehensive examination of recent changes in various types of data on road environment problems, traffic accidents, and winter road surface countermeasures, all of which are associated with the regulation of the use of studded tires in Hokkaido, indicates that to ensure safer, smoother winter road traffic in cold, snowy regions, rational measures and improved road management based on the winter pattern seen in Hokkaido in 1991 are effective. In areas in which climate make it difficult to completely remove snow and ice from road surfaces, the occurrence of extremely slippery frozen road surfaces can be prevented by allowing, for example, 20 percent of vehicles to use studded tires, because these vehicles make frozen road surfaces appropriately rough. The use of studded tires in this proportion would not create serious dust problems. In early and late winter, it is imperative to thoroughly clean road surfaces. Road management can be improved through the combination of upgraded machine snow removal and, as conducted in past road management practices, prudent use of combined antifreezing and antislipping agents. The road weather forecast system can be used to improve road management and the information provided to road users.

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