

DEVELOPMENT OF TRAFFIC ACCIDENT ANALYSIS SYSTEM USING GIS

Masayuki HIRASAWA
 Researcher
 Traffic Engineering Division
 Civil Engineering Research Institute of
 Hokkaido
 1-3 Hiragishi, Toyohira-ku, Sapporo,
 062-8602, Japan
 Fax: +81-11-841-9747
 E-mail: :hirasawa@ceri.go.jp

Motoki ASANO
 Director
 Traffic Engineering Division
 Civil Engineering Research Institute of
 Hokkaido
 1-3 Hiragishi, Toyohira-ku, Sapporo,
 062-8602, Japan
 Fax: +81-11-841-9747
 E-mail: :m-asano@ceri.go.jp

Abstract: Hokkaido has more traffic fatalities than any other prefecture in Japan. It is an urgent task to reduce these accidents by performing analyses and taking appropriate countermeasures. The Civil Engineering Research Institute of Hokkaido has developed a traffic accident analysis system that uses a GIS. The system links great volumes of traffic accident data accumulated for more than ten years with digital map data indicating accident locations. We added information on the following: road structure, road accessory facilities, and weather information. This system enabled us to extract accident data by road section and by specific condition. The system also allowed us to analyze accident frequency, accident rate, and fatality rate. In winter there are some days when the number of accidents jumps because of weather conditions. We analyzed the data of snowfall, temperature and accident rate, and added a function that predicts the accident rate using weather forecast information.

Key Words: GIS, Traffic accident, Accident analysis, Accident rate, Accident analysis system

1. INTRODUCTION

Traffic accidents in Hokkaido, northern Japan, show two principal characteristics: a high rate of fatal accidents, and a sharp increase in the last 10 years in winter-specific traffic accidents because of changes in road surface conditions. The high rate of fatal accidents per capita owes to the prefecture's sparse distribution of towns and cities. Hokkaido accounts for approximately 22% of Japan's area but only about 5% of its population. Travel speeds are high and national roads with only two lanes are prevalent -- two factors that contribute to the high fatality rate and to Hokkaido's record of having the most traffic fatalities of any prefecture in Japan. In addition, winters are as severe as those of Northern Europe, despite Hokkaido's location at the middle latitudes of 41° to 45° North, latitudes similar to those of major cities in the U.S. and Europe. In its central city, Sapporo, annual snowfall often exceeds five meters. The increase in winter-specific traffic accidents owes to a law that restricted the use of metal-studded tires in Hokkaido as of 1990. This resulted in a rapid proliferation of studless tires, which have tended to buff snowy and icy road surfaces to a state of extreme slipperiness.

Toward implementing traffic accident countermeasures effectively and efficiently, it is important to identify accident-prone locations and to analyze accident patterns so that the most appropriate measures may be taken for each location. Conventionally, accident locations and patterns have been plotted on paper maps. However, in recent years, software applications incorporating Geographic Information Systems (GIS) have been being developed in many fields. In addition to permitting linkage between various types of data and maps, a

GIS is able to manipulate and visually display numerous types of data for easy comprehension.

The ultimate goal of this research is to establish a GIS-based system to analyze factors contributing to traffic accidents in Hokkaido, and to devise accident countermeasures. Here we report the development of the GIS-based traffic accident analysis system, the results of its use, and its function of using winter weather forecasts to predict accident rates.

2. DEVELOPMENT OF TRAFFIC ACCIDENT ANALYSIS SYSTEM

GIS is a technology for managing and processing locational and related information. It visually displays the results of analyses, thus enabling sophisticated analysis and quick decision making. Recently, systems using GIS have been developed for use in various disciplines. Development of a system that uses GIS to analyze traffic accidents has been pursued toward improving the efficiency and effectiveness of traffic accident countermeasures. Consequently, the Traffic Engineering Division of the Civil Engineering Research Institute has developed such a system in which digital maps are linked with data of traffic accidents, roads and weather.

Establishment of the system requires a design that enables constructed databases to be used efficiently by GIS. Toward developing a flexible system that achieves this goal, we have combined Arc View GIS Ver.3.2, a GIS software application from ESRI, with Access, a database management software application from Microsoft Corp. Since various kinds of data are handled, Open Database Connectivity (ODBC), a world standard, is used to connect Arc View and Access. It is possible to customize menus by using Visual Basic, for enhanced user-friendliness. In such case, Dynamic Data Exchange (DDE), a Windows standard, can be used for the connection.

Table 1 shows the system databases, which are those of digital road map, traffic accident, road, traffic volume and weather. The road data were extracted from a road management data system already in operation. Data items include road structure (longitudinal grade, horizontal alignment, width) and road accessory facilities (center strip, guard fence, roadway lighting). Weather data are from the meteorological authority of each area and they include temperature, rainfall, snowfall, and hours of sunshine. Traffic volume data is linked with 12-hour traffic volume and day-night ratio.

Because the system is intended for a wide spectrum of users, we designed a simple Graphic User Interface that relies on buttons to achieve ease of use. The in-depth analysis required for our study depends on the many functions inherent in the GIS software.

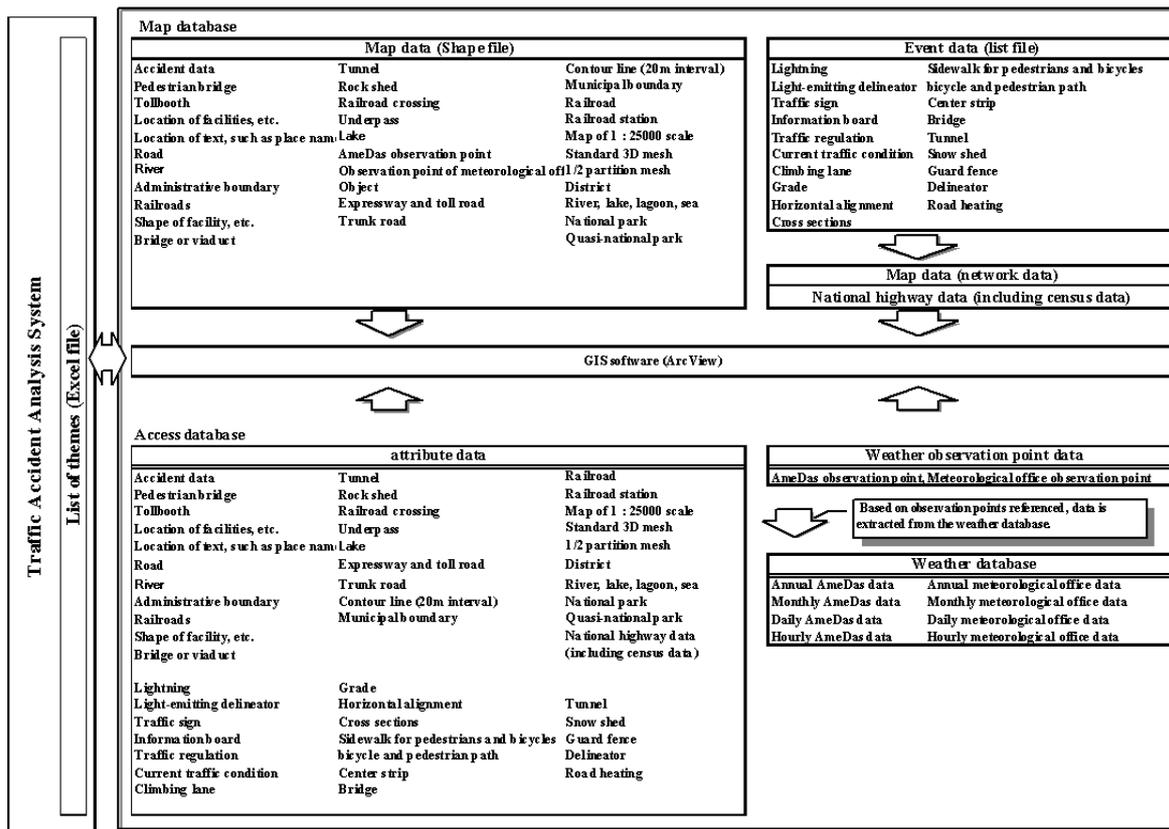


Table 1. Databases of the GIS-based traffic Accident Analysis System

3. ANALYSIS CAPABILITIES AND RESULTS OF THE TRAFFIC ACCIDENT ANALYSIS SYSTEM

The analysis capabilities of the system include data search, display of accident rate and fatality rate, and data export to Excel. Data search can be performed separately for accident, road and weather data. Accident locations obtained by search are plotted on a map that displays data on the accident. The system can display the analysis results, such as accident and fatality rates, in an easily understandable form. The next step is exporting the results to Excel, searching again using new parameters, or calculating and displaying the accident rate or fatal accident rate. It is also possible to directly input route numbers and kilometerposts for analysis in before/after studies of specific sections where accident countermeasures have been taken. Figure 1 shows locations of fatal head-on collisions from 1990 to 2000. Figure 2 shows a display of the accident rate.

The ability to display results visually is the most significant feature of the system. Sections with high risk of accident can be so identified. These functions are useful in devising accident countermeasures and are helpful for local administrations in making budgetary requests. In addition, comparison of accidents before and after countermeasures allows the evaluation of effectiveness in terms of accident reduction. In the past, plotting accident data on paper maps was extremely arduous. This system not only shows the locations of accidents promptly and easily, but it also performs various analyses and displays the results in an easily understandable way.

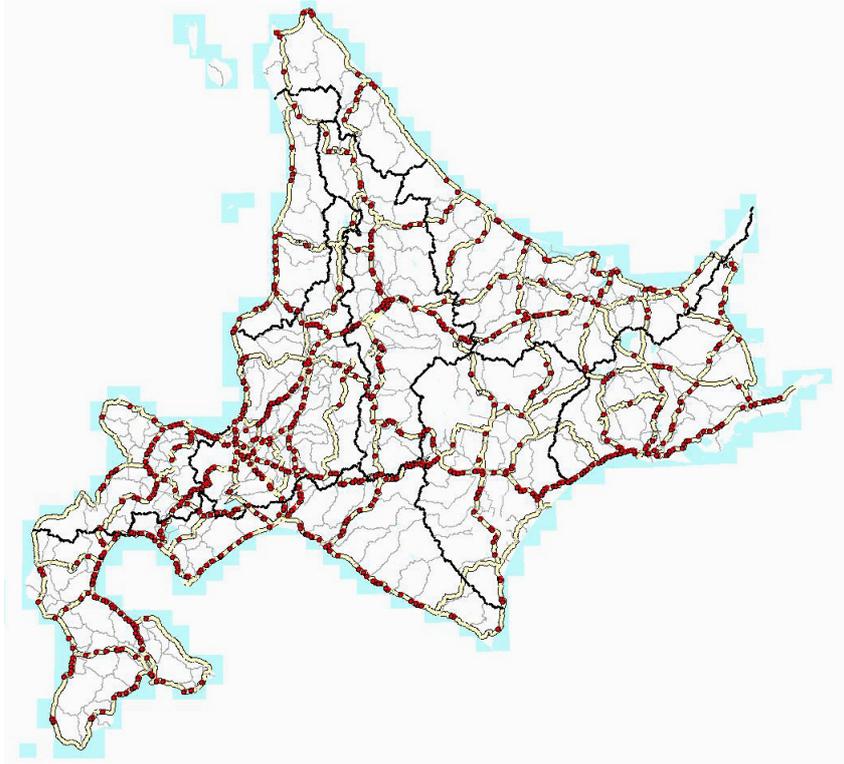


Figure 1. Map display of fatal head-on collisions



Figure 2. Map display of fatal head-on collision rate

4. ANALYSIS OF WINTER-SPECIFIC ACCIDENTS AND EXAMINATION OF FORECASTING FUNCTION

Accidents in winter relate closely to sudden changes in the road environment caused by temperature change, snowfall, and other factors. In winter, many accidents occur at around -4 °C, a temperature at which the road is most slippery. Figure 3 shows the rate of winter-specific accidents in Sapporo. The accident rate of the red sections is the highest of any sections. The traffic accident analysis system allows us to identify sections with a high accident rate by a search for certain ranges of temperature or snowfall. Based on this, snow removal and deicing can be performed more effectively and efficiently.

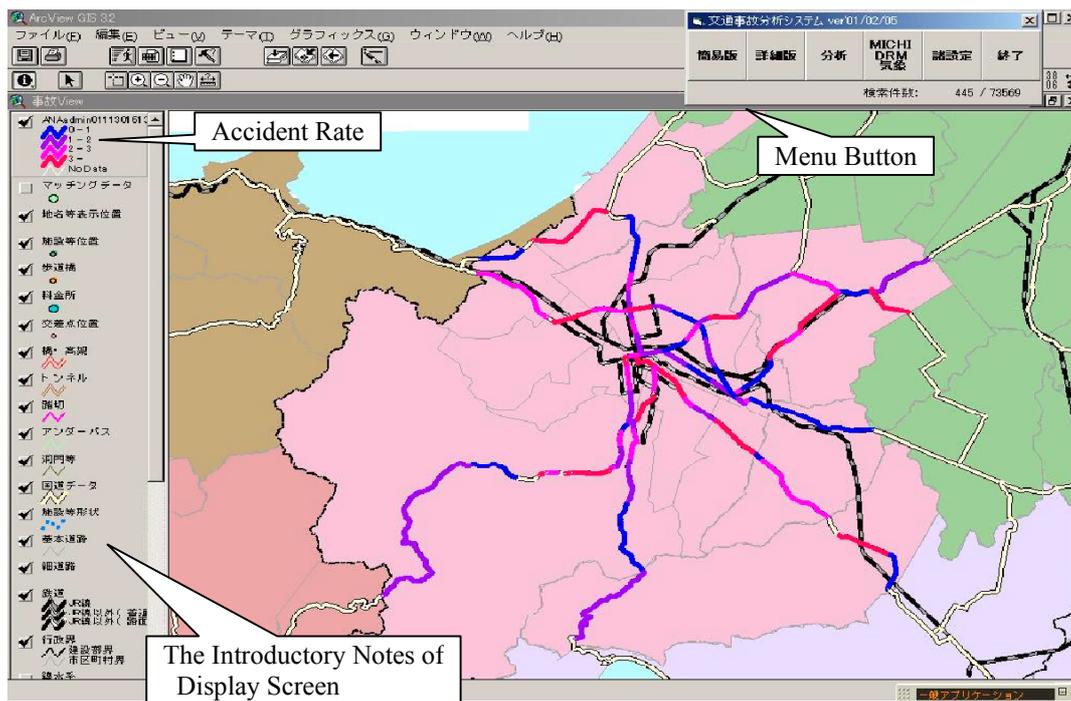


Figure 3. Rate of winter-specific accidents in Sapporo (445 accidents at -4 °C to -2 °C (fiscal 1992 to1998))

Winter-specific accidents tend to increase rapidly under certain conditions of temperature and snowfall. Figure 4 shows the daily number of skid accidents vs. daily mean temperature and daily snowfall in Sapporo in December 1998. The number of winter-specific accidents is large on some days due to weather conditions. We have attempted to estimate the accident rate using weather forecast data. If drivers could be made aware of the next day's accident risk or hazard spots, it would be extremely useful. If such information were available via Internet, as are weather forecasts, drivers might change their routes and departure time -- or even decide not to drive. Furthermore, a search of accident risk might raise a driver's awareness of safety, consequently prompting safer driving.

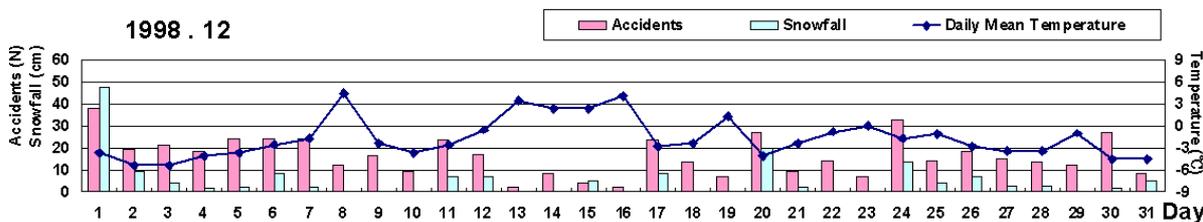


Figure 4. Daily number of skid accidents vs. daily average temperature and daily snowfall in Sapporo

To predict winter-specific accidents, we first extracted the weather data, such as temperature and snowfall, based on accident data on the time of accidents. We combined the weather data with the accident data to create a new database. Then, according to the numerical weather forecast data, the relevant accident data were extracted. The obtained accident data were displayed by the analysis system as the accident rates. Types of data extracted included weather station location, time, temperature, and snowfall of the day and the day before. Figure 5 shows accident rate found by extracting accident datasets that meet the following conditions:

Conditions for extraction

- 47412: Weather station number (47412 is the number of Sapporo District Meteorological Observatory)
- 6: Time (data on one hour before and after the specified time is extracted)
- 5: Temperature (data on the temperature 2 °C above and below the specified temperature are extracted)
- 10: Snowfall of the day (data on snowfall 10 cm above and below the specified snowfall of the day are extracted)
- 10: Snowfall of the day before (data on snowfall 10 cm above and below the specified snowfall of the day before are extracted)

In the immediate future, it will be possible to enter weather forecast data to extract these types of data according to their conditions. The forecast accident rate will be provided via the Internet.

The advantage of this method is that accident-prone sections, such as shady sections or bridges, can be identified on the map because the estimation is based on the past data. However, since this is an expert system, it will be necessary to examine whether the predicted values should be adjusted by regression after observing their appropriateness. In the future, we must consider the method of obtaining and inputting weather forecast data and data provision via Internet.

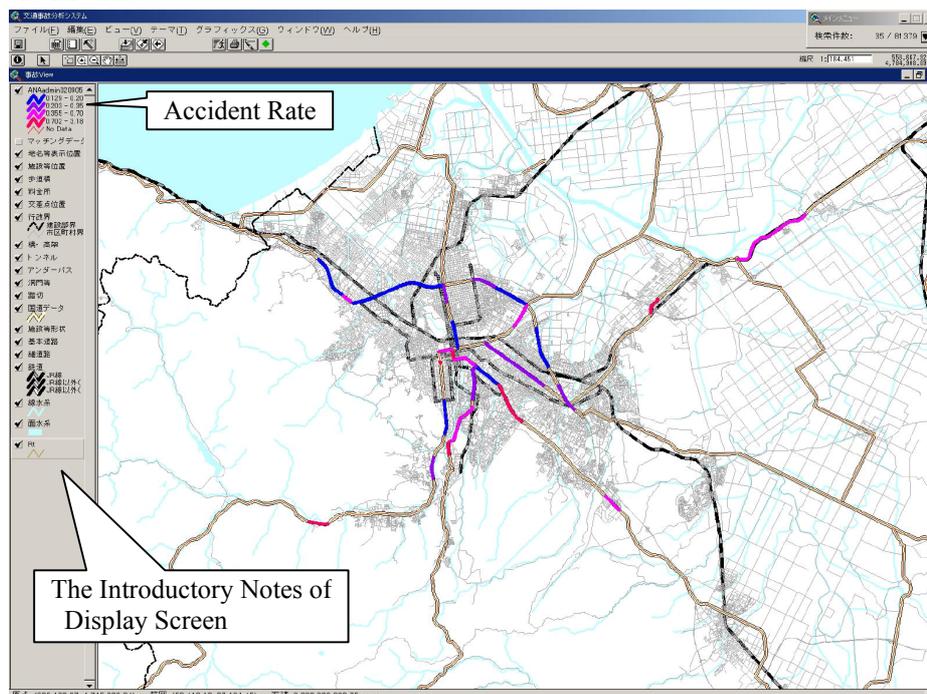


Figure 5. Predicted rate of winter-specific accidents in Sapporo

5. CONCLUSION

Traffic accidents are an unfortunate legacy of the 20th century transport revolution. Although various accident countermeasures are being taken, none have proven decisive. In addition, growing budget deficits are necessitating more effective and efficient infrastructure development. The traffic accident analysis system now under development is a promising analytical tool that addresses the above situation.

We plan to pursue development by separating the system into three specialized models: one with advanced functions, geared to researchers; one with simplified functions, geared to road-related administrators; and one that can provide analysis via Internet, geared to ordinary road users.

REFERENCES

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