The study on winter road maintenance by applying predicted friction index “GRI P Analysis”

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ABSTRACT

For winter road maintenance in expressways, anti-freezing and snow removal works are vital to assure safety and the number of staffs and machines are determined judging from the past experiences and weather forecast information. Winter maintenance is carried out based on empirical decision by the local staffs and that makes consistently proper maintenance level difficult sometimes. In order to grasp "Desirable road condition" and "Hazardous road condition", it is necessary to clarify the conditions and, the quantitative control index associated with the sliding friction. We focused on the components (temperature, water quantity, ice and snow quantity) on the road surface that seems to be correlated with friction. The control index "**GRIP Analysis**" was invented to predict friction of road surface indirectly. The model of the heat balance is introduced to predict the changes of the components on the road surface, and the amount of components is transformed to "GRIP Analysis" index in necessary time. It is found that there is a correlation between the number of traffic accidents and “GRIP Analysis” roughly in our research. The winter road maintenance standard for the “GRIP Analysis” index is planned within a couple years, based on the analysis of the correlation among measured values (friction , surface condition, surface temperature, salinity residual, effect of anti-freezing and snow removal) and "GRIP Analysis". From the analysis of statistical data of each region (road closure time, vehicle speed, number of traffic accidents) and “GRIP Analysis” , the index of winter road maintenance level and standard for each region will be established.

KEY WORDS

WINTER ROAD MANAGEMENT/FRICTION/CONTROL INDEX/ROAD CODITION

1. WINTER CLIMATE

Japan is located between latitude 30℃N and latitude 45℃N, which is in between southern France and southern Mediterranean Coast in Europe.

The Japanese chain islands stretches from the north to the south with a mountain range running along axis forming the backbone of chain islands.

As the seasonal wind in the winter from the Asian continent across the Japan Sea strikes the mountain range and brings the snow, the area on the northern side of the mountain range is subject to especially heavy snow fall making this area in the meteorological classification as snowy and cold region (10-year average maximum snow depth exceeds 30cm per year).

On the contrary, the southern side of the chain islands facing the Pacific Ocean enjoys a stable fine winter weather with abundant sunshine and little snow or rain fall, consequently the area on the Japan Sea side and Pacific Ocean side experiences quite different type of winter weather.

For this reason, the snow and ice control under consideration of the area weather conditions is essentially vital for road maintenance and traffic management of the expressway in winter.

2. EXPRESSWAY NETWORK

The construction of the Japanese expressway began in 1956 with the plan to construct a total length of 14,000km expressway.

In Japan, 8,700 km (as of the end of March, 2011) of the planned 14,000 km of construction is opened for traffic. The length of expressway running in the snowy and cold region is 3,700 km or 43% of the entire network.

The daily traffic volume of expressway network reaches 4million vehicle of which share in the national automobile transportation volume is 40% and it is one of the vital facilities in the socio-economic development of the nation.

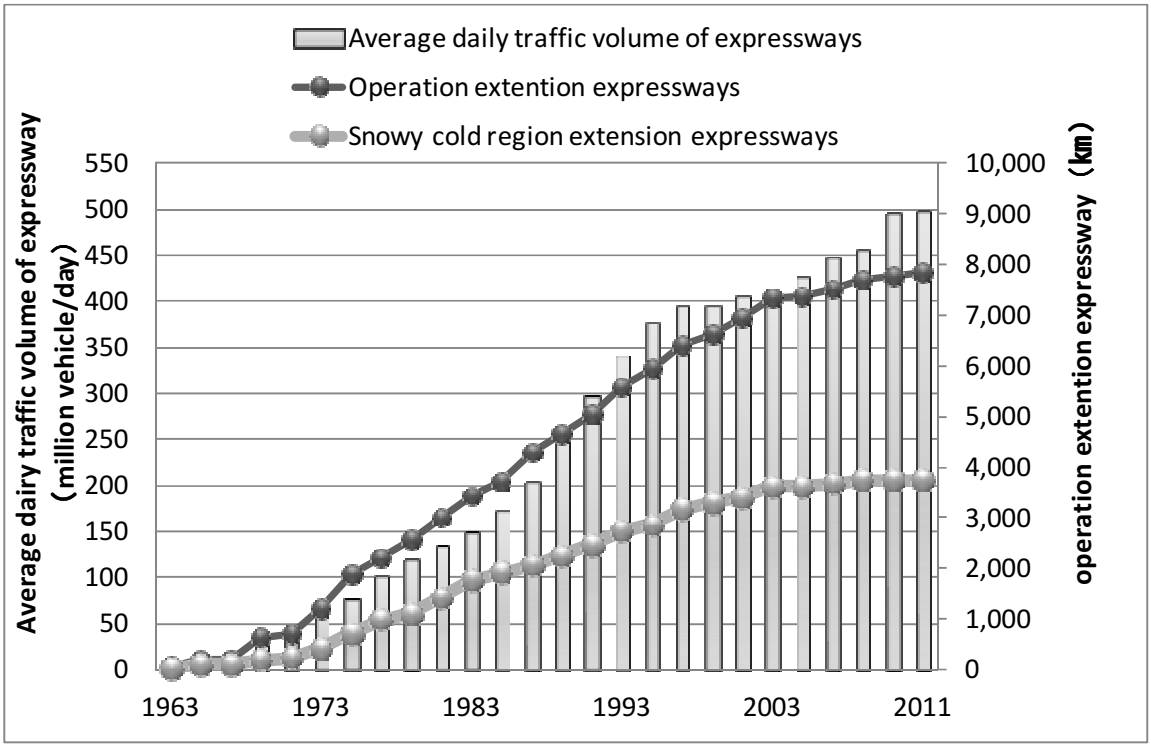

Fig.1 Average daily traffic volume, Operation extension expressways

3. SNOW AND ICE MANAGEMENT

For winter road maintenance in expressways, anti-freezing and snow removal works are vital to assure safety and the number of staffs and machines are determined judging from the past experiences and weather forecast information.

The snow and ice control operation offices cover at the interval about 100km of the expressway and carry out control work around the clock.

And each office has its own standard operation manual for the snow and ice control.

The arrangements for deployed facilities and number of staff are decided based on the weather forecast, according to the standard operations manual.

For example, for organizing snow removal, number of the vehicles at each base is determined by the combination of snowfall duration and total volume. For anti-icing countermeasures, the deployment of vehicles is determined by the temperature forecast for the road's surface.

Furthermore, the increase/decrease in the number of staff needed is decided by according to the conditions (snowfall and traffic) at a particular location.

In order to cope with the demands of a severe winter, staff are on standby in case of unexpected sudden changes in the weather, and a night duty is always stationed so additional staff can be called in as needed. Organizing snow removal is decided by the amount of snow of the road-shoulder checked by patrols and weather forecasts.

As Japan extends from south to north, road condition in expressways varies greatly on the location of the route and it changes every moment.

Because of this situation, it is very difficult to set an objective control index for the winter maintenance.

Winter maintenance is carried out based on empirical decision by the local staffs and that makes consistently proper maintenance level difficult sometimes. Since it is indefinite whether the work is enough, working as much as possible on a daily basis is determined by the organization.

The problem is produced in each stage, operations start, snowfall, traffic stoppage on the road.

Expressway administrator judges an operation start based on the reports from patrols, weather forecasts, air temperature, and road surface temperature, snowfall, live-camera images, and the lapsed time from pre-snow removal operations or anti-icing work.

Judgment by experience varies greatly depending on the staff involved.

Therefore, there is no quantitative index for whether the operations are too early or too late, and evaluation is impossible.

Expressway administrator has to consider the type of operation for recovering a road surface to drivable conditions during snowfall.

Spreading anti-icing in order to maintain the best possible road surface has a tendency to increase the amount of rock salt used.

Since it is unclear whether the operation is enough, snow-removal is repeated as much as possible so that the state of a road surface may be kept as safe as possible.

Even if the conditions on a road get worse (except for the case of freezing), many cases are difficult for expressway administrator to make a judgment to Road closed.

It is because the conditions on the road surface (lower level of management) that demands Road closed is not fixed.

On the road where the conditions worsen, there are more than a few cases where many cars cause an accident, and then the road has to be closed.

4. DETERMINING THE STATE OF EXPRESSWAY SURFACE

The friction of the road surface is one of the important performance to ensure the safety of road users, particularly in winter.

It is thought that the friction of the road surface directly in contact with a tire and affecting driving and braking is the most important consideration. However there are other important elements, such as the range of visibility and the inclination of a road surface.

It cannot be overemphasized that the cause of most traffic accidents on winter road surfaces is slipperiness. The friction of a road surface also is related to a large vehicles ability to climb steep roads.

In order to grasp "Desirable road condition" and "Hazardous road condition", it is necessary to clarify the conditions and, the quantitative control index associated with the sliding friction.

Since 1997, implementation of the efforts for making friction measurement the basis of judging road conditions has suffered setbacks.

The component that measured the friction on the patrol vehicle indicated the condition of the road for making judgment numerically. Road management was planning to base evaluations for satisfactory road conditions above the fixed standard.

However, the measurement by a friction measurement vehicle is intermittent.

Even if it takes measures over a limited area for a brief period, the road surface will change immediately, and data will become obsolete.

Depending on the time and location, the road conditions can easily change drastically on Japanese expressways, so in order to make operational judgments and evaluated their results, monitoring for friction using sensor-equipped patrol vehicles over a wide area requires many vehicles and drivers to get detailed data.

As mentioned above, the road condition in winter is likely to change greatly by the time and location, and measurement of the friction over expressways directly is not realistic.

The measurement of the slipperiness required for management of a winter road surface needs to be able to detect the following samplings of data:

1) The time variation of a road surface situation
2) Road surface conditions over a wide area
3) Methods for evaluating the number of traffic accidents, driving speed, and traffic stoppage time

Therefore, we focused on the components(temperature, water quantity, ice and snow quantity) on the road surface that seems to be correlated with friction.

The control index "GRIP Analysis" was invented to predict friction of road surface indirectly.

GRIP Analysis is an index of road surface slipperiness computed using the judgment type from the estimate of the weather conditions (temperature, the amount of moisture, and an ice quantity) on the road surface by weather prediction.

From calculation of the quantity of heat by weather prediction or law of conservation of mass, increase and decrease by time progression of the weather conditions (temperature,

the amount of moisture, and ice coverage) on a road surface are computed, and estimates the continuous slipperiness extracted from the GRIP Analysis.

Having a quantitative index eliminates the inconsistencies of operational judgment for snow removal or spreading anti-freeze compounds, and stable road surface management becomes feasible.

For changes in road surface conditions required in order to extract an GRIP Analysis index, we used a computational model for the amount of condensation in the air, concerning quantity-of-heat and water in the quantity of heat computed by the law of conservation of mass, such as a present condition value of forecasts, such as rain and snowfall, and air temperature and road surface temperature, and an estimate of the vehicles heat from traffic. A calculation result is extracted from the depth of water, ice and snow, and determines road surface conditions from these ratios. Regarding changes in road surface conditions, there are also anthropogenic influences besides the change under the natural influence of snowfall, a temperature fall, etc. We put into the computational model the effects of spreading anti-icing compound, and recovered road drivability from snow removal for the snow removal operations and effects of sodium chloride from anti-icing operations, and then made comparisons of actual conditions versus extracted values. By taking into account an operational situation into a computational model, it can get closer to actual road surface conditions.

The frozen snow measurement operations on a highway must be carried out by correlating to the change of conditions between interchanges, and other demarcation points. For this reason, what is needed is not observation data from fixed points, but a continuous line extracted from the data at these points. In order to fill the gaps between sensors, we used thermal mapping and decided to make an analysis and prediction of change of conditions versus road surface temperature changes along the road.

Forecast flow chart in fig. 2 and fig. 3.

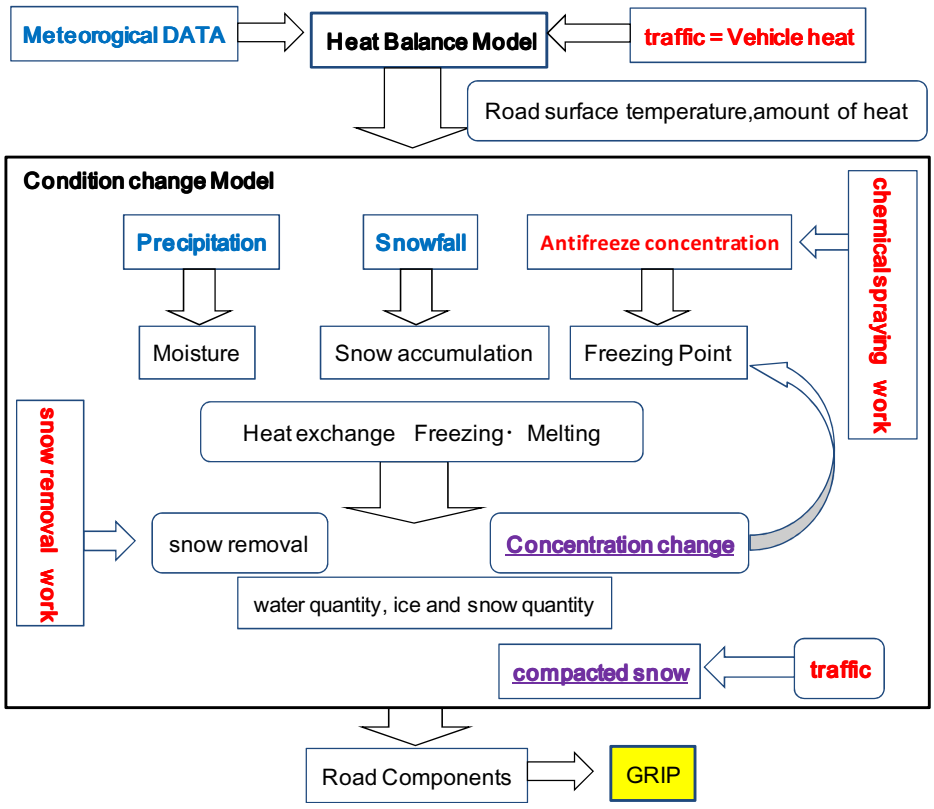

Fig.2 Forecast flow chart “GRIP Analysis”

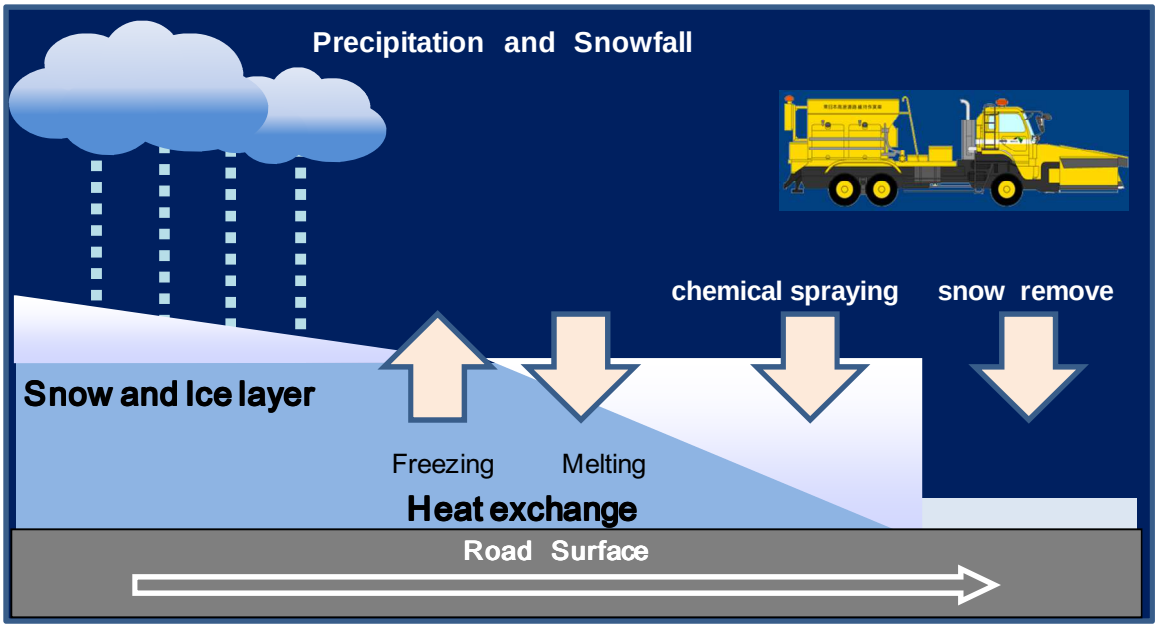

Fig.3 Road components change model

Proprietary innovations in this flow chart:

- The weather, a road surface conditions, and GRIP Analysis are integrated.
- Snow management operations are reflected.
- Observational data is reflected in real time.
- Supposition reflection of traffic conditions.
- It corresponds to changes and prediction of the weather situations.
- Not a point but a line performs analysis and prediction, aimed at supporting operations.
- Supposition of real time usage.
- Supposition of evaluation and feedback of road surface management level and operations results in real time usage.

Current issues are as follows below:

- The means of acquisition of the data (anti-icing and snow-removal operations, salinity concentration, and traffic) used for prediction is unfixed.
- The parameters (salinity concentration change and hardened snow) used for predictions is unfixed.

For the acquisition of data, we are refining component techniques using advanced observation methods like traffic volume and traffic counters, and development of salinity sensors and GPS equipment onboard vehicles uses for snow removal/anti-icing operations.

Collecting data from the field, we have plans to set parameters based on these observations.

5. VERIFICATION OF GRIP ANALYSIS

Regarding traffic accidents following changes using GRIP Analysis of road surface, in the Tokoku region where we conducted our survey, the ratio of traffic accidents was less when the GRIP Analysis index predicted safe conditions.

When the GRIP Analysis index prognosis was negative, the number of accidents was many at junctions. Accidents at other locations increased, too.

Fig.4 Safe condition Accident Map

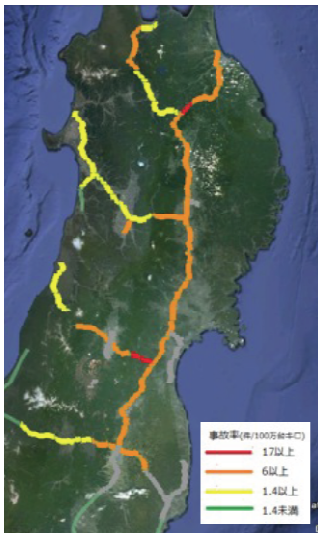

Fig.5 Negative condition Accident Map

We carried out a survey of driving speed correlated to the GRIP Analysis.

There are also particular characteristics of drivers at high speeds, and basically this does not correlate to the GRIP Analysis index. However, if the outlook from the GRIP Analysis index worsens, we understood the trend of driving speed dropping.

Regarding driving speed distribution for GRIP Analysis in a fixed area, we plan to carry out surveys continuously since we can also consider the influence of speed limits.

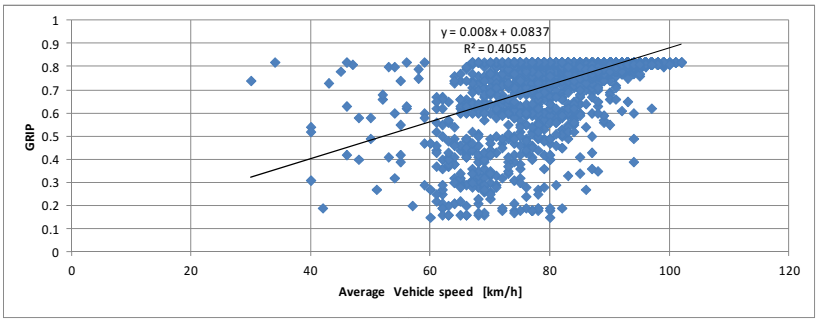

Fig.6 Average vehicle speed, observd GRIP (daytime)

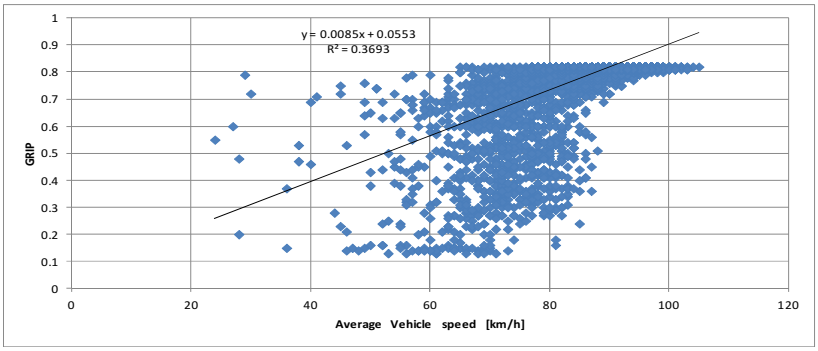

Fig.7 Average vehicle speed, observd GRIP (night)

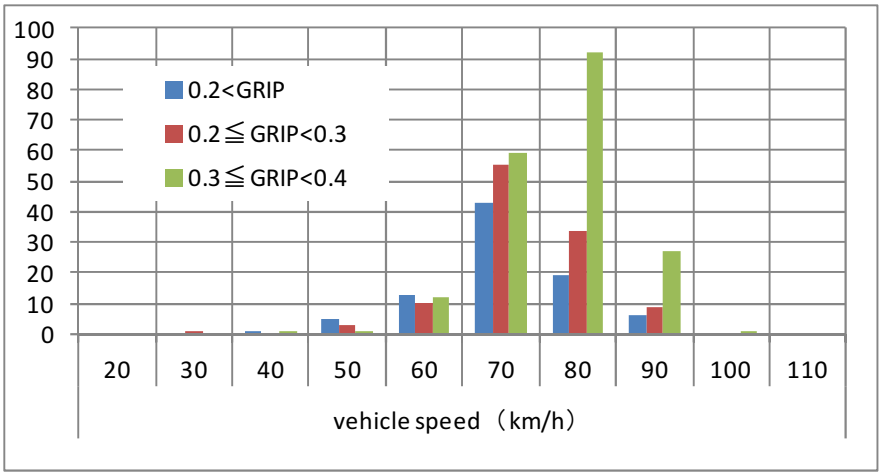

Fig.8　Average vehicle speed, volume of vehicle　(GRIP 0.2-0.4)

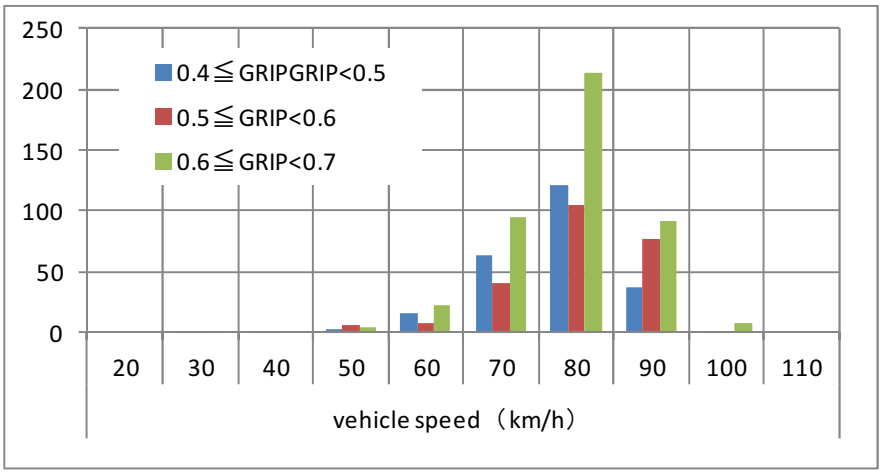

Fig.9　Average vehicle speed, volume of vehicle　(GRIP 0.4-0.7)

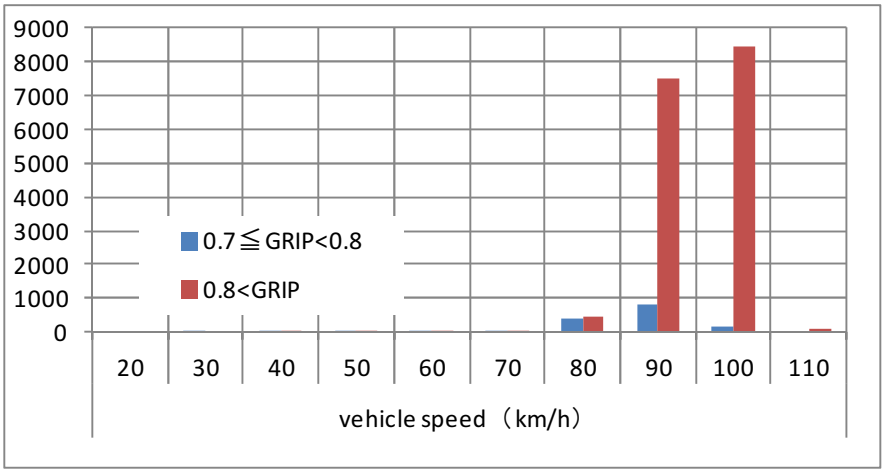

Fig.10　Average vehicle speed, volume of vehicle　(GRIP 0.7-0.8)

6. ADVANCED WINTER ROAD MANAGEMENT

Aiming to fix standards for road surface management using the GRIP Analysis, we continuously measured the friction of roads, road conditions, surface temperature, salinity concentration and snow/ice operating conditions at positions on five highways starting with Tohoku expressway for three seasons from winter 2012. We started arrangements and analysis, surveying related correlation to each measurement value.

It is planning creating the road surface management index which considered regionality based on the results of an investigation in each area from correlation with the number of traffic accidents, a driving speed, the number of traffic stop time, and sliding friction.

Driving technique of a driver (driving experience on a snowy road), the attach rate of winter tire, etc. change with areas. It is reasonable to change a road surface management index by the area.

In order to achieve the common index (an accident rate in winter, a secured rate of winter utilization time, customer satisfaction of winter road surface) in concrete, it considers setting up a road surface management index required in order to define target “number of traffic accidents”, ”vehicle speed”, “road closure time” according to the area, to verify correlation with sliding friction and to achieve an aim.

The level of " GRIP Analysis" was provided in the range of “good” and”fair”,”poor”,“very poor”, and it is considered so that it can synthetically evaluate in the time from a snowfall start to an snow/ice removal operation start, the appearance ratio of an deteriorated road surface, and time from the end of snowfall to road service condition recovery.

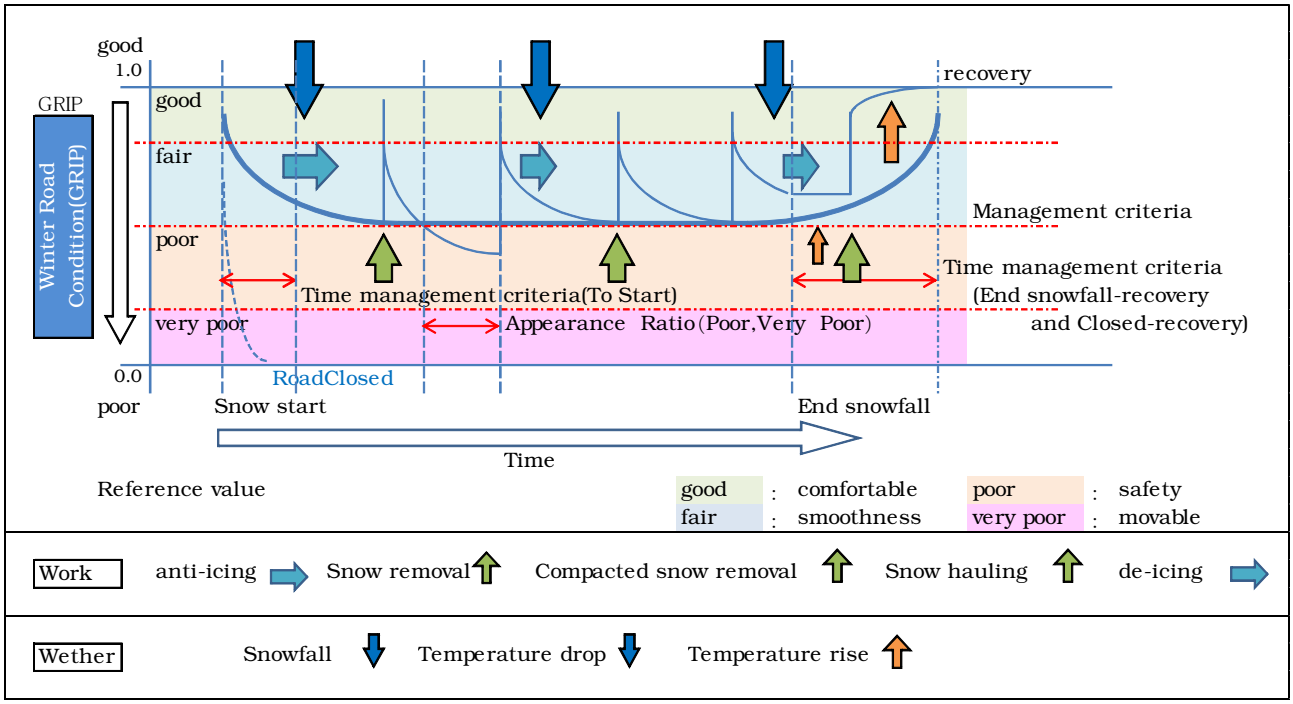

Fig.11 The level “GRIP analysis” Winter road management

A road management should become better, if a road service condition is manageable within a low accident rate, or if preparation and enforcement of traffic stop can be performed in advance when it is predicted that an accident rate is high.

If there is a road service condition where a running speed becomes slow, and possibility of traffic stop on the road, by being opened these, it seems to give a driver choice of the roads.

Also, excessive snow/ice removal operation will be screened by a road surface management index being compared with the actual condition.

We think that we would like to consider the contract and the formation of performance regulation to payment which are connected between the road administrator who order a snow/ice removal operations and the ordering person of the operation by putting the road surface management index which set up upper limit and lower limit in a contract.

If we can predict the frequency of this occurrence from this road surface management index that quantifies either " Desirable road condition " and " Hazardous road condition", there are possibilities for evaluating the cost-benefits of snow/ice countermeasure operations.

It is a big issue for toll road administrators that how many travelers stop a travel according to deterioration of a road service condition or whether it bypasses to a general way.

About the influence on the traffic by deterioration of a road service condition, it has just been going to start to research.

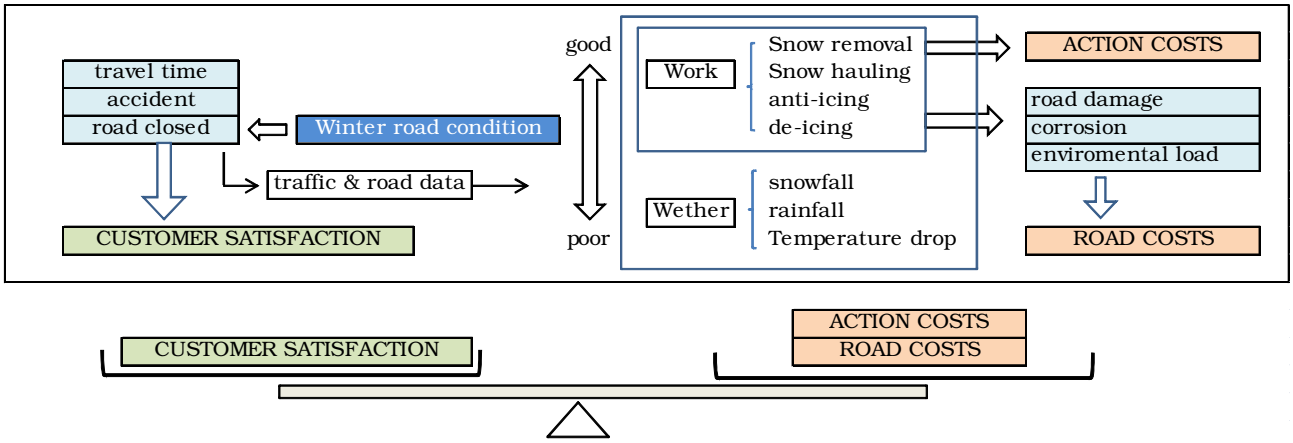

Fig.12 Winter road management outline

7. CONCLUSION

The weather of Japan has much snowfall, and air temperature and road surface temperature go up and down around Freezing point.

Expressway in Japan is heavy-trafficked and there are many drivers who are unfamiliar to a snowy road in the route which connects between cities.

Expressway administrator think “How far do we do snow/ice removal operation?”, it works as much as possible and is trying for an accident not to occur.

If we can quantitatively monitor the snow/ice covered roads, and clarify whether the state of the road surface is desirable or slippery, we can use that as a basis for explanations of applicability and quantitative evaluation of snow/ice countermeasure operations, and expect to make advance the optimization of snow removal and anti-icing operations.