DISCUSSION ON THE PRACTICAL APPLICATION OF DSRC IN MEASURES TO COUNTER VISIBILITY HAZARDS IN COLD AREAS WITH HEAVY SNOWFALL

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ABSTRACT

Many of the routes administered by East Nippon Expressway Company Limited, Japan (hereafter NEXCO East) are in snowy regions. In order to ensure a safe, smooth and reliable flow of traffic, the task is to reduce road closures due to problems caused by snow and ice. The most frequent reason for road closure is poor visibility, and there is an urgent need for measures to tackle this problem. This being the situation, ITS technology has evolved rapidly in recent years; the DSRC Smart Highway Service in particular offers content that supports safe driving in the form of audio guidance and still images, and this technology has the potential to become one of the strategies for the reduction of road closures due to problems caused by snow and ice. This paper reports on the status of this undertaking.

KEYWORDS

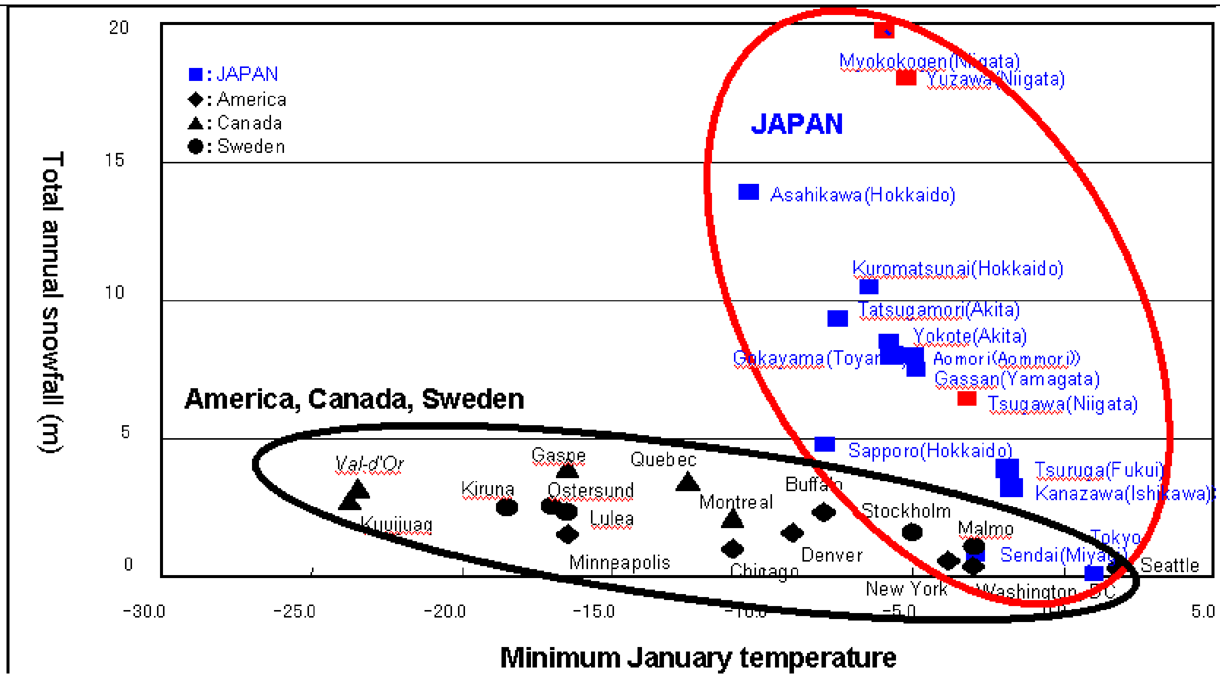
ITS / DSRC / SNOWY REGION/POOR VISIBILITY / ROAD CLOSURE / TRAFFIC ACCIDENT

1. THE SNOW AND ICE SITUATION IN THE AREA ADMINISTERED BY NEXCO EAST

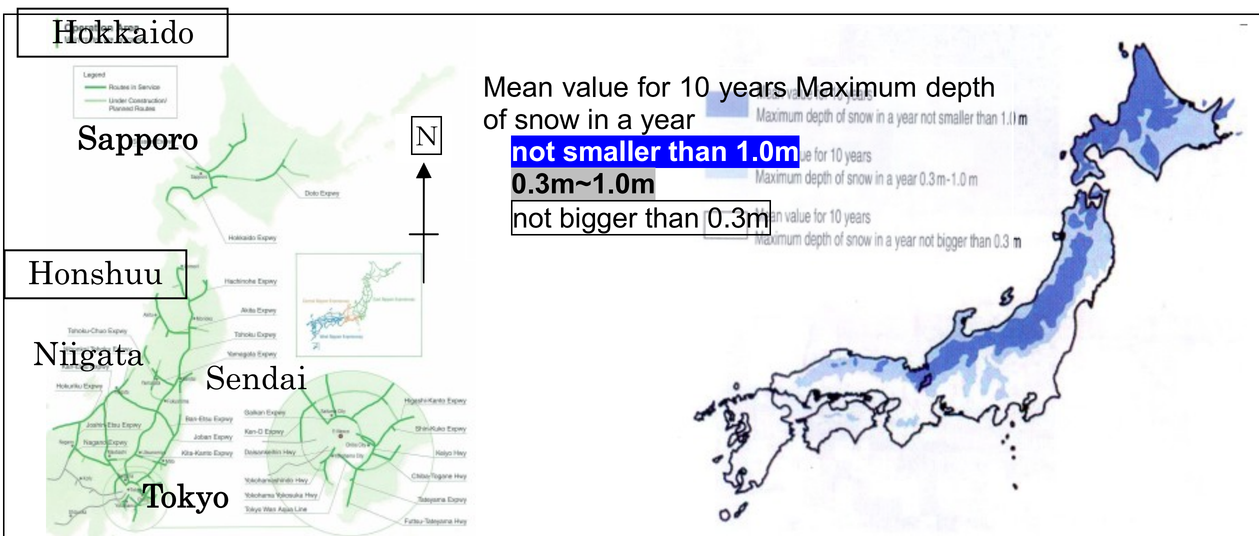
1.1 Snowy regions

Of the roughly 3,500 km of expressway managed by NEXCO East (East Nippon Expressway Company Limited, Japan), some 2,500 km, or 70%, are located in snowy regions; furthermore, roughly 2,000 km, or 60% of the total, run through areas where snowfall is very heavy, in excess of 100 cm annually. The Niigata district is an area with one of the heaviest annual snowfalls in the world, and the number of traffic accidents occurring there in the wintertime (December to March) is roughly three times the number occurring during the whole of the rest of the year (April to November): and road closures in winter are three times more frequent. In order to ensure a safe, smooth and reliable flow of traffic, ice and snow control measures are essential. Some 100,000 to 250,000 km-hrs of road closures related to problems caused by snow and ice are of necessity imposed annually. Impaired visibility is the reason for 80% of these closures, and there is an urgent need to deal with this problem.

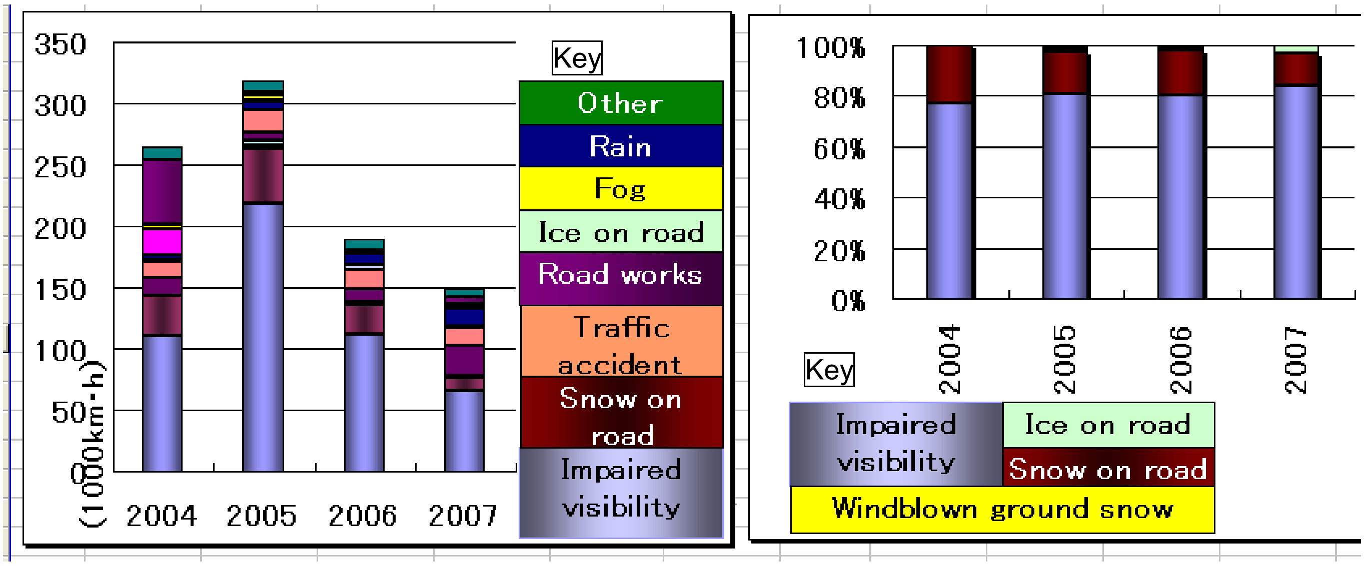
【Fig.1.1 -Snow conditions】



【Fig.1.2 -Total annual snowfalls (m) and average January temperatures (°C)】

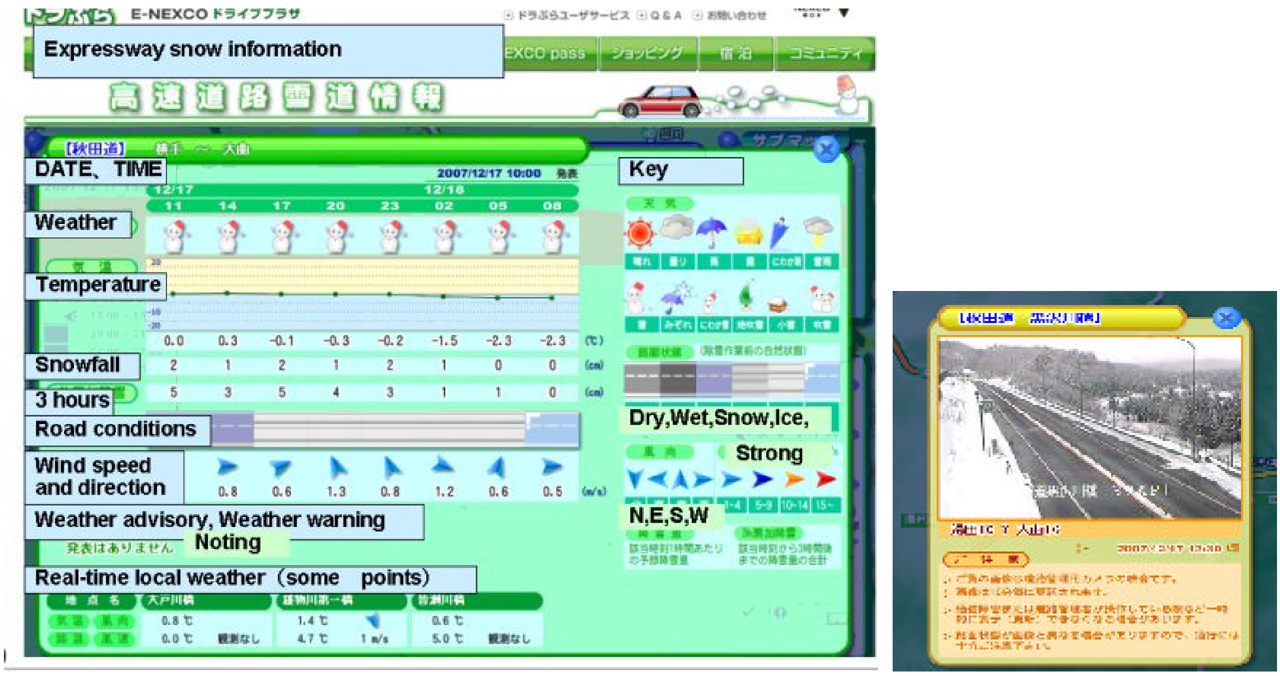


【Fig.1.3 -The highway network under the management of NEXCO East, and Japan's snowy regions】



【Fig.1.4 -Road closure km-hrs by cause
(Left: All causes, Right: Causes related to snow and ice)】

【Fig.2.1-Mechanical snow removal operations (top left), snow break fence (top right), improved self-luminous delineators (bottom left), meteorological observation apparatus and weather information board (displays wind speed, air temperature and road temperature in real time) (bottom right)】



【Fig.2.2-Weather forecast (left and real-time imaging of local conditions (right) over the Internet) >http://www.drivetraffic.jp/map.html<】

2. MEASURES TAKEN SO FAR TO COPE WITH POOR VISIBILITY

Strategies implemented by NEXCO East in snowy regions are as described below, centring on mechanical snow removal and the spreading of anti-freezing agent (salt: NaCl) for the purpose of preventing black ice.

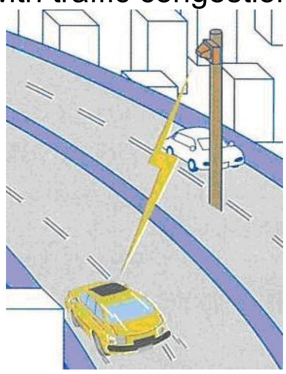
3. EXPECTATIONS FOR ITS

Japan's ITS technology was first put into practical use in the 1990s and has since become widespread. In the 2000s the technology entered a new phase, and R&D has progressed under the name 'ITS Second Stage'. One aspect of R&D that has seen progress is the DSRC (Dedicated Short Range Communication) Smartway Service via a vehicle-mounted unit that merges a car navigation system, VICS and ETC to provide a safe-driving support system with the aim of reducing traffic accidents. NEXCO East is considering the application of this technology in its strategy for snowy regions.

3.1. The present status of ITS in Japan

3-1-1. VICS

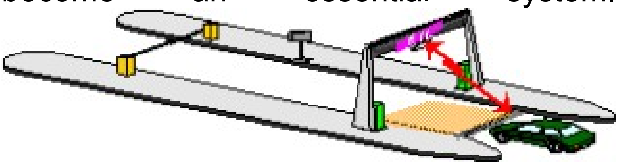
VICS (Vehicle Information & Communication System), which went into operation in 1996, provides drivers with road traffic information relating to traffic congestion, road closures, time to destination, etc., not only via FM multiplex broadcasts but also via data transmitted from roadside beacons to the vehicle-mounted VICS unit and displayed in the form of text messages or images through the car navigation system. Of the 3.5 million car navigation systems sold up to May 2009 roughly 2.4 million, or some 70%, have the system included. The system produces satisfactory results mainly in dealing with traffic congestion.



【Fig.3.1 -Illustration of road-vehicle communication (up) and examples of screen displays (line diagram (left) and map (right))】

3.1.2. ETC

Since being made practicable in 2001, the ETC (Electronic Toll Collection) system, which is capable of collecting the toll fares of different road toll enterprises via a single vehicle-mounted unit, has been introduced on all the major routes in Japan: and as of June 2009, of the roughly 7.6 million vehicles using toll roads every day, approximately 6.1 million (roughly 80%) are using ETC. In addition to greatly helping reduce congestion at the toll barriers, reduce administration costs and reduce CO2 emissions, it is also put to use in pricing policies (TDM etc) and has now become an essential system.


【Fig.3.2 -Artist's impression of ETC】

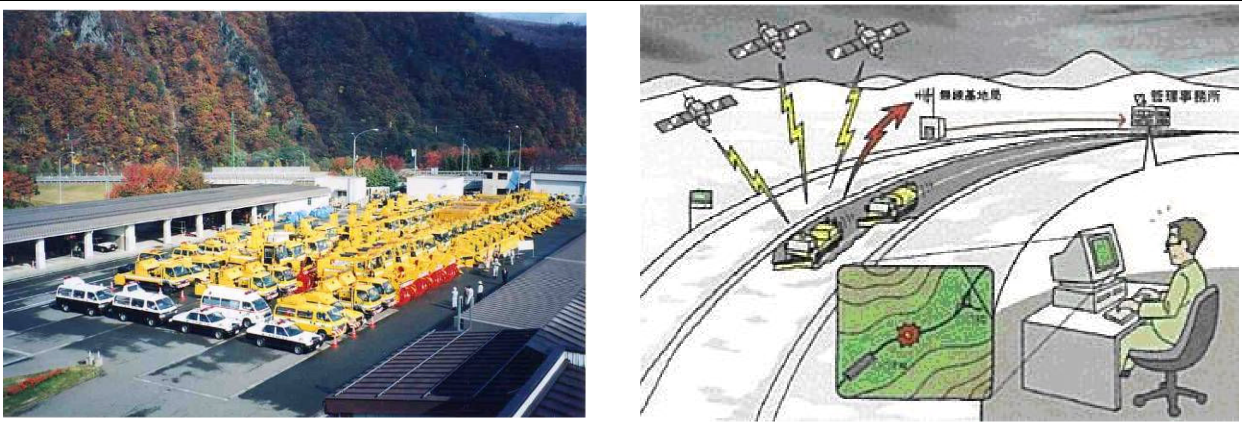
3.1.3. ITS in application

3.1.3.(1)The application of GPS in road management (Snow vehicle position monitoring system)

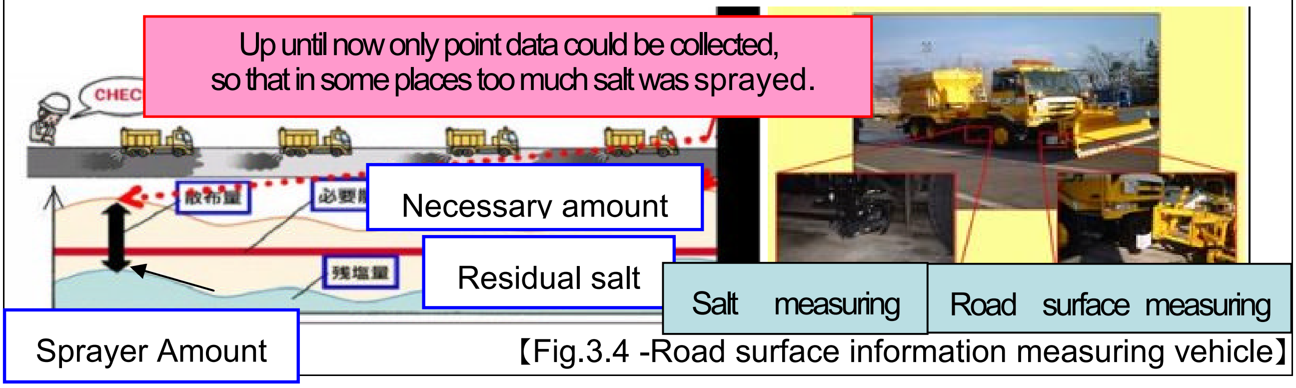
In addition to being used in car navigation systems, GPS is also used by NEXCO East in monitoring the positions of its snow vehicles. When heavy snowfalls continue, snow removal and the spreading of anti-freezing agent (salt) are carried out every 20 minutes: over a hundred vehicles are used. When such a condition continues over tens of hours it is important to properly supervise their positions. It is the ‘Snow Vehicle Position Monitoring System’ using GPS that has made this possible. It is also expected that this system can be further applied to controlling the amount of salt on the road surface, optimal management of anti-freezing agent stocks and keeping costs to a minimum.

3.1.3.(2) Road surface information measuring vehicle

In order to understand the state of the snow-covered road surface in real time, various sensors to measure the temperature of the road surface, air temperature, salinity concentration, etc., are installed on a number of snow and ice control vehicles and the data automatically transmitted to the snow and ice control communications room; this has made it possible to regulate the amount of anti-freezing agent spread at each location, in accordance with the concentrations of salt remaining on the road as indicated by this data.



【Fig.3.3 -Snow vehicles at a start-of-operations ceremony prior to the snowy season (Left): The snow vehicle position monitoring system (artist's impression) (Right)】



【Fig.3.4 -Road surface information measuring vehicle】

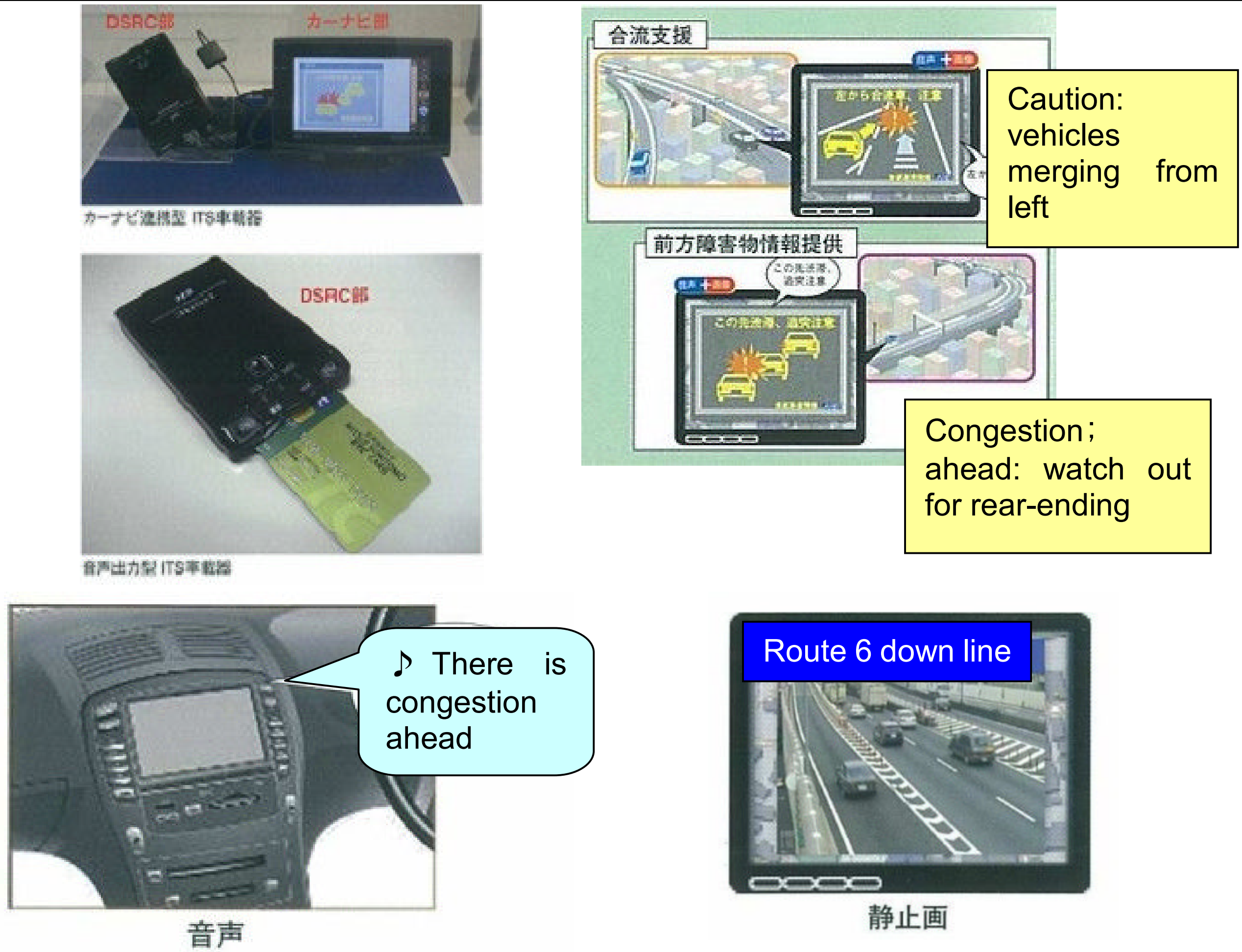
3.2. Expectations for ITS (DSRC Smartway Service)

The DSRC Smartway Service conducts two-way road-vehicle communication using the 5.8Ghz band. Compared to the old one-way, 2.5Ghz VICS, it is possible to obtain (upload) from the vehicle data on its travel history, vehicle behaviour, etc, and the use of this data to provide estimated time-to-destination information etc., is being studied. In addition, since it is possible to provide information from the road in the form of images and voice audio, in addition to the provision of the usual road traffic information, safe driving support systems providing information of the situation on the road ahead and information on obstacles in the road ahead, aimed at reducing traffic accidents, are being considered, as are payment services for car parks, service stations, drive-through restaurants, etc., using ETC. NEXCO East is considering the use of this technology to gather information on traffic obstructions in snowy regions and provide optimally-timed information to warn drivers to avoid danger, and so to reduce road closures caused by poor visibility.【Covered in detail in Section 4】

3.3. Experiments with milliwave radar

3.3.1 Overview

When it was still the Japan Highway Public Corporation (JH), NEXCO researched and developed a 'system to aid driving in times of poor visibility' that was a combination of technologies to detect obstacles on the road ahead using 'milliwave radar,' which is not easily affected by snow or weather conditions, DGPS and road alignment CG (a road alignment support system). This was a strategy to cope with poor visibility caused by locally-occurring extreme dense fog (visible distance: approximately 10 to 50m) or drifting snow; the aim was to mount the system on a road management vehicle which would then travel at the head of a group of ordinary vehicles and guide them through at low speed.



【Fig.3.5 -DSRC vehicle-mounted unit〔Car navigation combination type ITS vehicle-mounted unit＆Audio output type ITS vehicle-mounted unit〕(top-left) and the Smartway Service (Safe Driving Support Service〔Merge support＆Provision of information on obstacle ahead〕(top-right), Voice audio(bottom-left), still image(bottom-right))】

3.3.2. The results of the experiments were as follows.

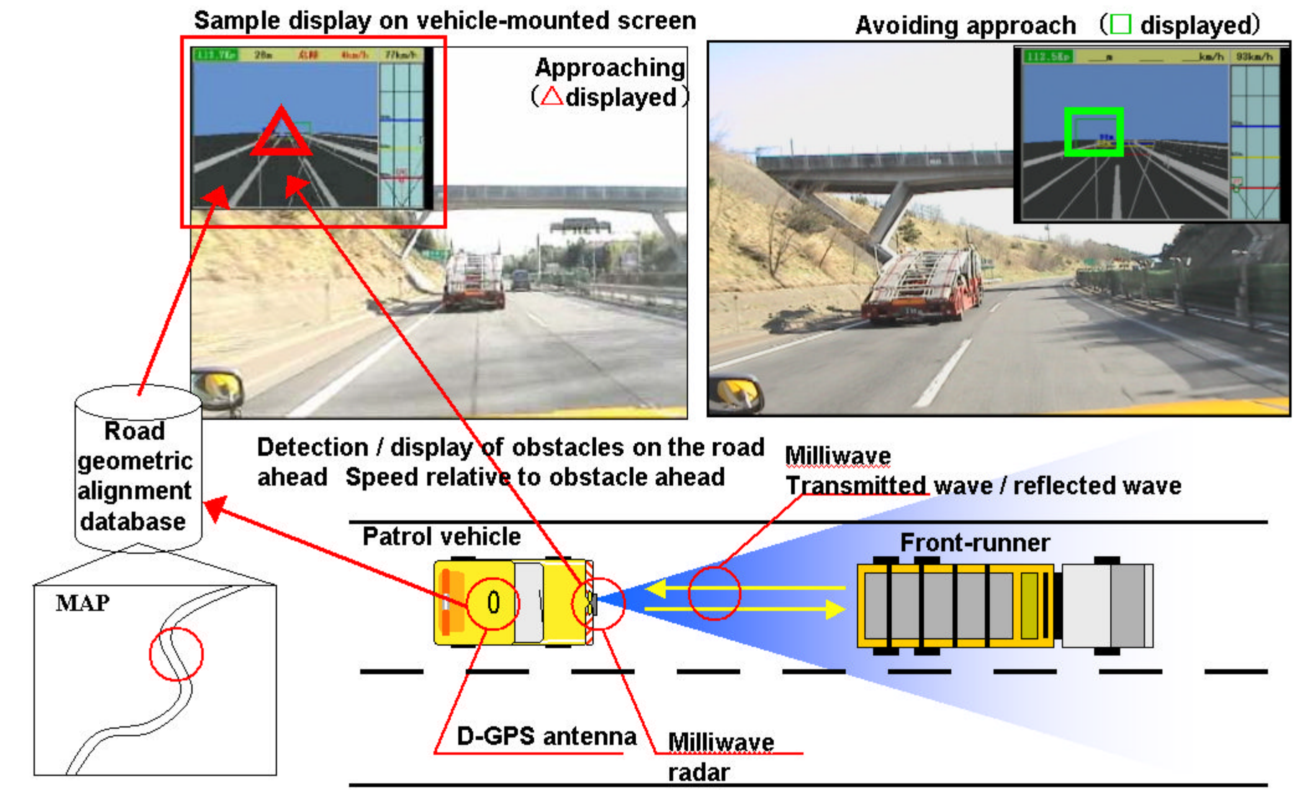
(1) The ability of the milliwave radar to detect obstacles was by and large good; it could differentiate between guardrails, traffic signs, etc., and vehicles approximately 100 m ahead on the road.
(2) While the DGPS (Differential GPS) was less accurate than RTK-GPS (Real Time Kinematics-GPS) in terms of location, relatively stable positioning was possible with almost no missing time.
(3) Taken overall, the cost was high, and cost reduction was an issue.

4. POOR VISIBILITY STRATEGIES USING DSRC

4.1 Experiments in collecting probe data

4.1.1. Overview

In February 2009 driving and behavioural data histories on an icy road surface between Minakami and Yuzawa on the Kan'Etsu Expressway were collected, the focus being technologies for the collection of probe data from the DSRC vehicle-mounted unit. The site in question is in an area that gets some of the heaviest snowfalls in Japan: while conditions of extremely poor visibility do not occur there are heavy snowfalls, and a 4% downward gradient that continues for some 10 km means that there is a comparatively large number of traffic accidents on the icy road; it is a suitable place in which to obtain data on potentially dangerous vehicle behaviour.

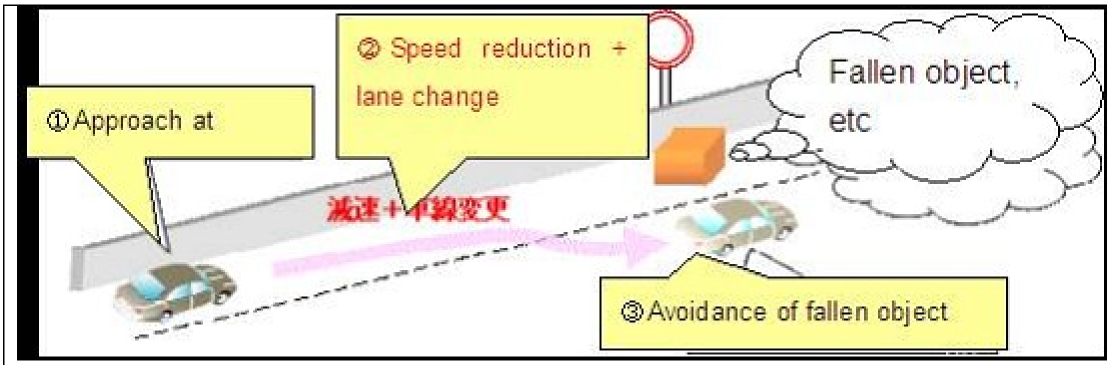


【Fig. 3.6 -Overview of the milliwave radar system to aid safe driving in times of poor visibility】
(Left) The screen shows a large truck running 50 meters ahead. The triangle mark (Δ) is the warning about an approaching truck.
(Right) The mark has changed to a square (□) because the monitor vehicle has changed lanes to avoid danger.

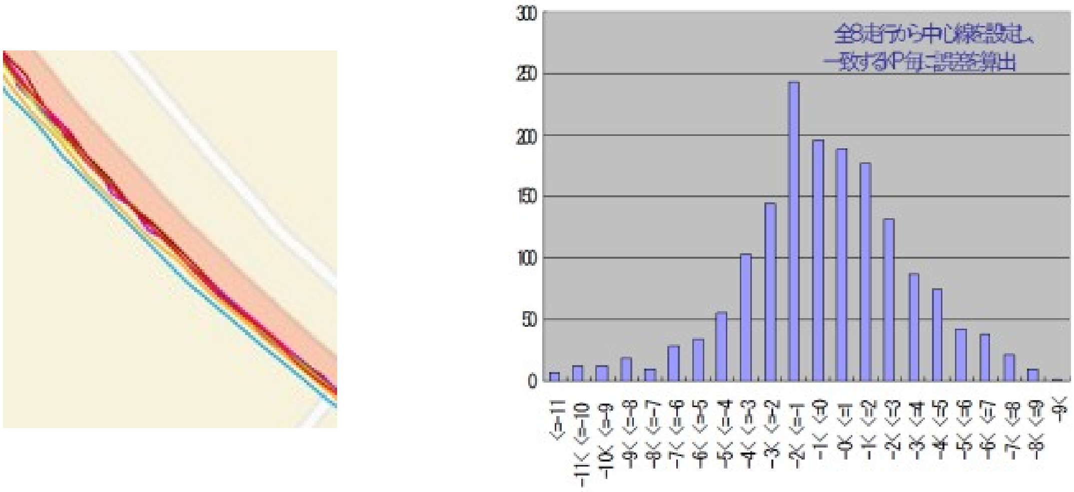
The experiment consisted of running the monitor vehicle at different speeds on different road surfaces and gathering via DSRC data on (1) position (positioning by GPS every 100 m), (2) speed, (3) linear acceleration (acceleration and deceleration), (4) lateral speed (skidding) and (5) yaw angular speed (angle of turn of steering wheel). The results were that (1) it was possible to obtain a more or less accurate reading, but matching with a digital map showed that the reading was up to several tens of metres out, making it difficult to identify a lane changing position: (2)(3)(4)(5) it was possible to tell definitely that there were clear variations in numerical data of vehicle behaviour compared to normal driving .
It must be noted here that these obtained values sometimes did not meet the standard values set in the vehicle-mounted unit ahead of the experiments, indicating that there is room for improvement. This is because some of the standard values were set to restrict gathering of data via DSRC due to limitation on the size of transmitted data. It is necessary to further accumulate data in order to determine optimal standard values based on more data. [Fig. 4.2 and 4.3]

4.2. Examination of poor visibility measures using DSRC

Road closures caused by poor visibility depend on how poor visibility is, but in many cases the road has to be closed because an accident has occurred. It is thought that if drivers can



【Fig.4.1 -Illustration of experiment】



【Fig.4.2】
(Left) The plot of latitude/longitude data for all 8 runs on the down-lanes of a 4-lane road. As each run is drawn as a line, different runs have different lines.
(Right) The standard error deviation σ is 3.8. This corresponds to an error of ±8 meters if a reliability of 95% is assumed. Therefore, it is difficult to determine which lane the car ran in based on the travel history data obtained via DSRC.(The center line was set for all 8 runs and the error calculated for each corresponding KP.)

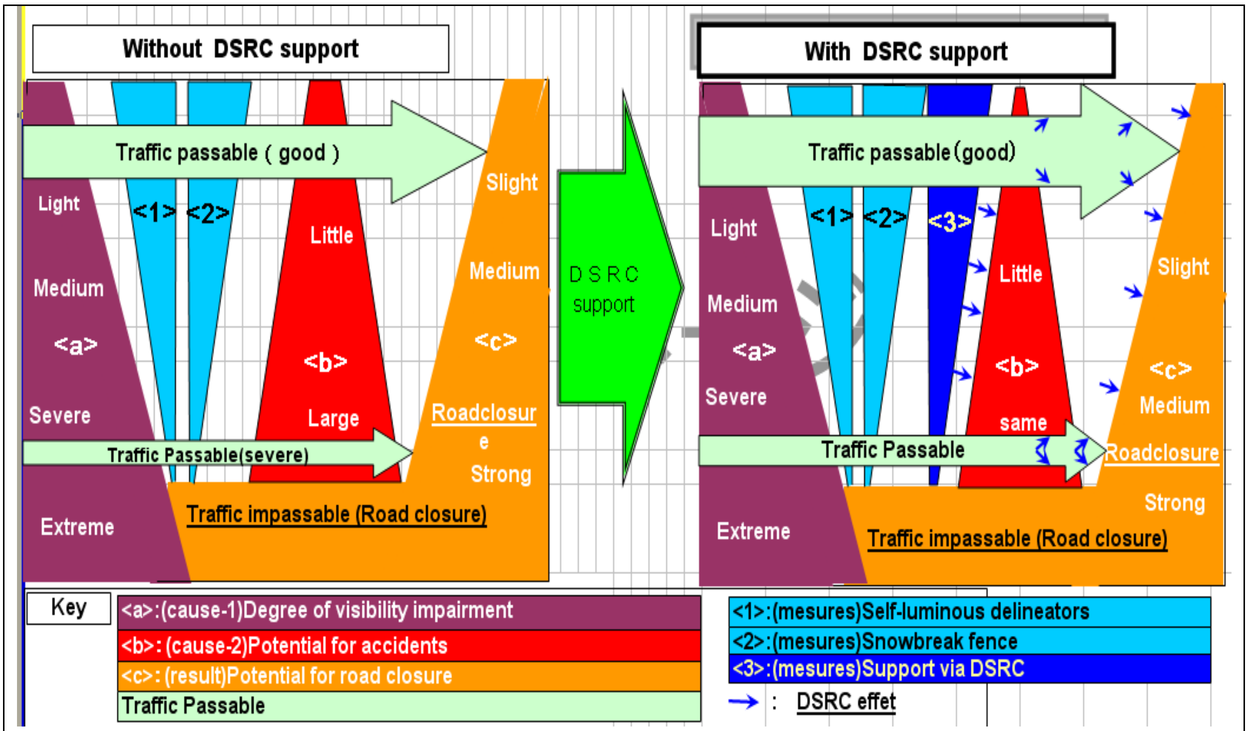
be alerted to difficulties on the road ahead through the appropriate provision of information, they will be able to detect the danger and avoid it; this will suppress and reduce the occurrence of traffic accidents and thus lead to a reduction in road closures. The use of DSRC is an effective strategy for providing drivers with information via well-timed voice audio or visual messages and alerting them to the situation.

4.2.1. Concept

Fig. 4.3 illustrates the concept of driving support by means of DSRC in times of poor visibility.
Up until now, the poorer the visibility, the greater the possibility of accidents occurring, resulting in a greater possibility of road closure. The use of DSRC support in addition to the usual ice and snow control measures such as snowbreak fences, self-luminous delineators, etc., reduces the probability of accidents and thus the need for road closures.

4.2.2. Expectations for DSRC

It is conceivable that in addition to the existing ITV cameras, highways patrols,



【Fig.4.3 -Thinking behind support by DSRC】

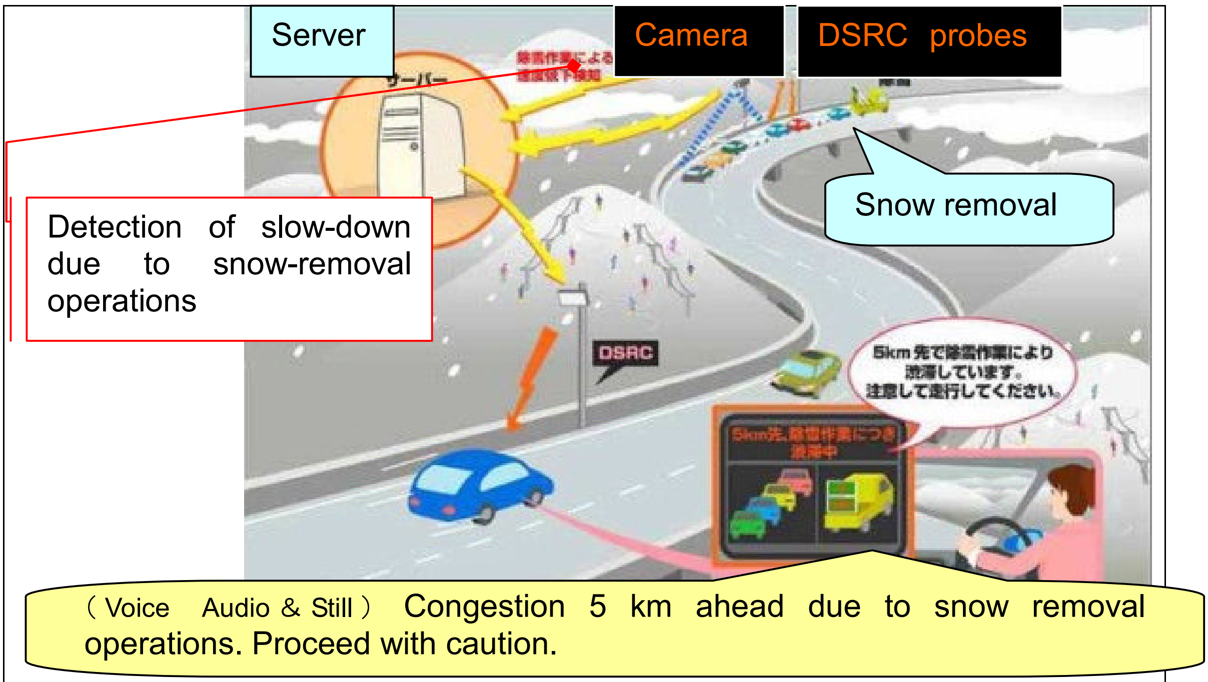
meteorological observation apparatus, etc., the technology to obtain DSRC probe data and provide alert messages can be used for the detection of these obstacles. In particular, the probe data can indicate hidden actions to avoid danger through deceleration (made either consciously or unconsciously on the part of the driver) or steering activity that may indicate the possibility of an accident having occurred. Passing this information on to vehicles coming up behind as driver support information in the form of voice audio or visual messages from the roadside DSRC and alerting them to the danger will enable drivers to detect the danger and avoid it, which will lead to fewer traffic accidents and thus fewer road closures.

4.2.3. Care by the driver

DSRC is of course no more than an aid to the driver; DSRC alone cannot solve every problem. It works on the assumption that the driver drives with the utmost care and attention. It goes without saying that drivers must maintain a safe speed appropriate to the situation, and absolutely avoid sudden braking or swerving; it is also essential that they pay attention to the movements of the vehicles in front of them and behind them. There is also a need, when the weather (or the weather forecast) is markedly bad, for them to help reduce the volume of traffic on the road in question by modifying their route, cancelling their journey, travelling at a different time, etc.

4.2.4. Points to note

It must also be noted here that when visibility is poor in the extreme (when the road ahead cannot be seen at all) driving is not possible. In this kind of situation it is not possible to allow traffic on the road, even with the aid of DSRC. It is essential that the Road (Traffic) Administrator monitor the ITV cameras, road patrols, meteorological observation apparatus, etc., and take the appropriate measures, including road closure when visibility is poor enough. In order to be able to deal with situations where visibility is poor in the extreme (when the road ahead cannot be seen at all) we must wait for technological innovations such as vehicle-to-vehicle communication, the next-generation technology in which research is presently being conducted.



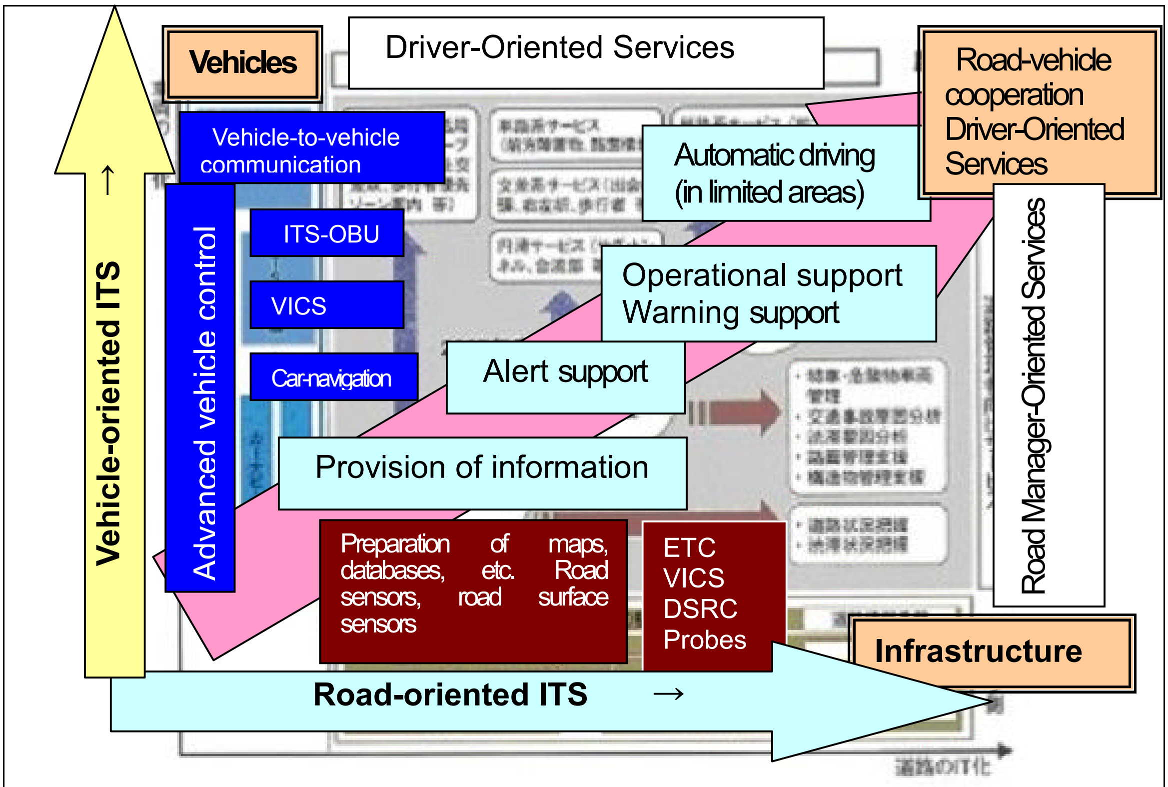
【Fig.4.4 -Artist's impression of probe data being put to use】

5. TRENDS AMONG VEHICLE MANUFACTURERS AND OTHERS

・ While R&D of DSRC is not particularly aimed directly at measures to counter poor visibility, it is thought that a combination of a number of technologies, such as ABS (Anti-lock Braking System), anti-skid braking and driving control systems (traction control), night time forward information provision systems, vehicular distance warning systems, collision-damage reduction braking systems, etc., could be used in strategies for snowy regions and poor visibility. If in the future it becomes possible to obtain information from these systems at the roadside as part of the probe data and provide it to other vehicles, it could, it is thought, lead to better safe-driving support, a reduction in traffic accidents and thus a reduction in road closures.

Name of device	No of models fitted with device	Installation rate（%）
ABS（Anti-lock Brake System）	188	100.0
Antiskid braking and driving control system	79	42.0
Night time forward information provision system	6	3.2
Vehicular distance warning system	7	3.7
Collision-damage reduction system (Damage-reduction braking)	15	8.0
Navigation-linked shift control system	12	6.4
Wheel slip braking and driving control system	83	44.1

【Fig.5.1-Development of vehicle safety systems and their adoption in commercial vehicles（January 2006 to December 2006）】



【Fig.5.2 -Roadmap to a road-vehicle communications system】

6. CONCLUSION

Consideration by NEXCO East of the use of DSRC in snowy region strategies has only just begun, and there are a great many issues to be overcome in resolving the problems attendant on measures to cope with impaired visibility in winter. The examination of specific methods of support using DSRC is yet to be undertaken, but since DSRC makes it possible to alert drivers by means of well-timed voice audio and visual messages, it is hoped that experimentation will reveal effective techniques. DSRC will not resolve every problem, nor will a DSRC on-board unit be fitted to every vehicle: but overcoming the problem of impaired visibility in winter will lead to a reduction in traffic accidents year-round: and that is consistent with one of the targets of NEXCO East, ‘Safe and pleasant expressways, 24 hours a day, 365 days a year’.

NEXCO East will consider methods that make full use of the merits of DSRC, and will continue to work on resolving the vital issue of strategies to deal with impaired visibility in winter.

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