# A DISCUSSION OF ADVANCEMENTS IN DATA COLLECTION AND PROVISION USING NEXT-GENERATION ITS TECHNOLOGY IN REGIONS OF COLD AND HEAVY SNOW

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## ABSTRACT (200 WORDS)

Progress is being made in experiments in Japan aimed at making practicable intelligent road and vehicle wireless communications using the SHFband (5.8 GHz) DSRC beacons. Use of the DSRC beacons makes it possible to obtain information on vehicle behaviour in the form of probe data. In this paper we gather vehicle probe data using the DSRC beacons and DSRC vehicle-mounted units and study the precision of vehicle behaviour. Up to the present time information on expressways has been provided on the basis of information collected from patrols, reports and roadway observation equipment, but the aim is to improve the accuracy of the information provided through the use of the probe data. The experiments place particular emphasis on the travelling environment of snow-covered roads; simulation runs on expressways were carried out repeatedly in an attempt to test the validity (accuracy, reliability, limitations) of the probe data.

## KEYWORDS

PROBE DATA / DSRC / EXPRESSWAY / AHS / VEHICLE SENSORS / TROUBLE SPOTS

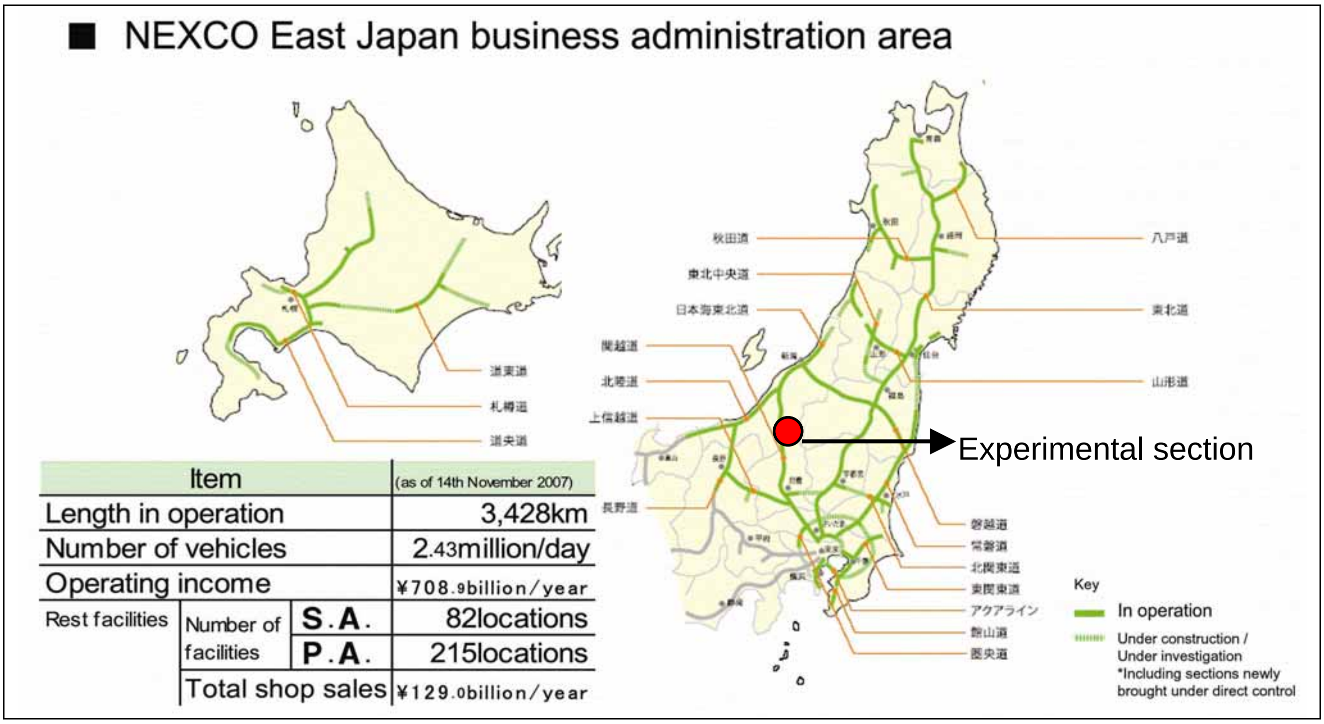
## 1. INTRODUCTION（BACKGROUND TO THE EXPERIMENTS）

In recent years progress has been being made in Japan in experiments aimed at making practicable intelligent road and vehicle (wireless) communications through DSRC beacons using the SHF band (5.8 GHz) as one kind of ITS(Intelligent Transport Systems) . In this paper we explain the results of studies on the gathering of data needed to provide valid information using DSRC beacons and vehicles fitted with DSRC vehicle-mounted units, with the objective of fortifying road administration in snowy regions. Up until now the provision of information has been implemented by gathering data from reports made by members of the general public travelling on the expressways, patrols made by road administrators and the various types of observation (measuring) equipment set up at the edge of the road (shoulder), but this method presents problems; the time lag (delay), individual variation (differences in subjective perception), the scarcity of observation (measuring) equipment, etc.

On the other hand, using the DSRC beacons means that the probe data from moving vehicles can be collected with no time lag and in the form of an objective numerical value. Probe data refers to the travelling and behavioural history of a vehicle (position, vehicle orientation, speed, acceleration, angular velocity, direction, altitude). However, from the DSRC beacons only data exceeding the threshold value are collected. At the present time the standard threshold values are determined by the limits of the wireless transmission capacity of the Dedicated Short Range Communication (hereafter DSRC) beacons and the results of experimental studies on roads (including on ordinary roads). However, this does not reflect the results of experiments on snowy roads. Thus in this paper, in order to obtain an understanding of the behaviour of vehicles on expressways, simulation runs on expressways were carried out and the accuracy and validity of the probe data were assessed and verified. In addition simulation runs were carried out on snow-covered roads because of the large number of accidents that occur in the wintertime.

This experiment is ranked as one of the Smart Way regional corroborative experiments in the ‘ITS-Safety 2010 Large-Scale Verification Testing in 2008’ promoted by the Japanese government, and its results are shared with other participants.

## 2. THE STATUS OF EXPRESSWAY ADMINISTRATION IN WINTER, AND THE AIMS OF THE EXPERIMENT




| Item | | | (as of 14th November 2007) |
|---|---|---|---|
| Length in operation | | | 3,428km |
| Number of vehicles | | | 2.43million/day |
| Operating income | | | ¥708.9billion/year |
| Rest facilities | Number of facilities | S.A. | 82locations |
| | | P.A. | 215locations |
| | Total shop sales | | ¥129.0billion/year |

Fig.1-Map of the area administered by NEXCO East,
and the experimental section in this experiment

East Nippon Expressway Company Limited (hereafter NEXCO East) administers in the main the eastern part of Japan (Hokkaido, Tohoku, Kanto, part of Hokuriku).

The area administered is distinctive in that it contains many snowy regions. Hitherto strategies to maintain proper road traffic (snow removal by snow-remover vehicles, spreading of agents to prevent freezing of the road surface, self-illuminating delineators, guidance flags, snowbreak fences, visual guidance boards, snow and ice information

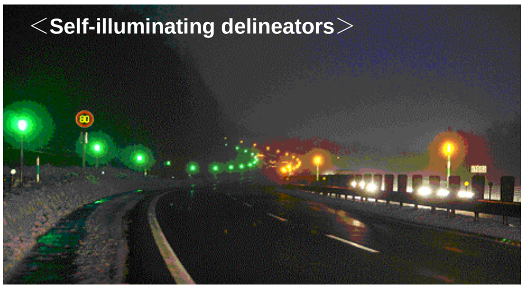



Fig.2-Strategies to support smooth, safe driving in snowy regions

boards, highway radio, snow and ice lighting, etc) have been implemented, but over half (53%) of the causes of roads being closed are snow-related, and 3 to 4 times more accidents occur in winter than occur at other times of the year. (Figures for 2005). There are also parts of ordinary roads that have no well-ordered system for snow removal; there is a social demand for a guaranteed smooth flow of traffic on the expressways in winter. Thus in order to reduce the incidence of road closures and traffic accidents due to snow, a study was carried out to gain a swift and accurate grasp of abnormalities in the traffic flow on snow-covered roads and to make that information available using DSRC beacons with an uplink function.

Since the standard threshold values for data collection (Table 1) do not reflect the results of experiments conducted on snow-covered roads, in carrying out the study it was decided to verify threshold values appropriate to expressways. In addition, the data on vehicle behaviour on snow-covered roads were also verified.

Table 1-List of standard threshold values

| Collected data | Standard threshold values (Current specifications) | | Minimum unit |
|---|---|---|---|
| Run history | Running speed | Interval of data storage 100m | 0.1 sec cycle |
| Behaviour history | Longitudinal acceleration | －0.25G | 0.01G |
| | Lateral acceleration | ±0.25G | 0.01G |
| | Angular velocity | ±8.5deg/s | 0.1deg/s |

## 3. OUTLINE OF EXPERIMENT

In the experiment, the probe data collection system (the ‘system’) was first set up, and then experimental vehicles fitted with a DSRC vehicle-mounted unit were driven on simulation runs and the probe data were assessed (Fig.3). The system collects the probe data transmitted from the DSRC vehicle-mounted unit via the DSRC beacon wireless communications, stores the data on the server over the network, processes it on a computer, and detects abnormalities in the traffic flow (swerving to avoid an obstacle on the road ahead, speed reduction behind a snow-removal convoy, etc) with no time lag. The experiment verifies the validity of this method and of the data collected.

The merits of DSRC include: 1) microwaves are suited to high-speed data transmission, with the weather having almost no effect (attenuation or delay) on operation. The effective wireless distance is some 20m, and the use of wireless enables the exchange of information via non-contact data communication even while moving on the expressway: 2) the uplink function makes it possible to transmit wirelessly to the DSRC beacon the information (probe data) measured by the vehicle: 3) with a higher frequency band than the old VICS, modulation and transmission efficiency have been improved, so that the downlink function has also been expanded: and 4) the frequency used is 5.8 GHz (SHF band). This is the same as the frequency used by the Electronic Toll Collection System (hereafter ETC), so that the DSRC can also be used for ETC.

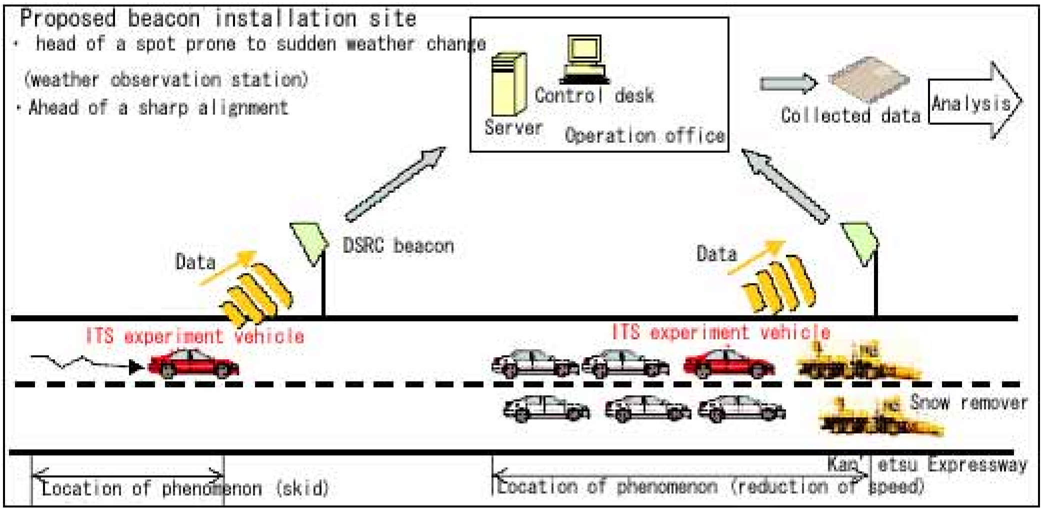



Fig.3-The probe data system

### 3.1 Experimental equipment

The equipment used in the experiment is given in Table 2.

Table 2

| Equipment | Features / Outline of apparatus / system |
|---|---|
| DSRC beacon | The DSRC beacon has a low rate of breakdown, uses electrical power economically, is easy to manage and easy to install. It is compact in terms of both weight (less than 10 kg) and size (less than 25 cm on each side). The power line and communications line can be taken from a CCTV(Closed-circuit Television), emergency telephone, etc. Installation is completed in about half a day, the unit being attached by a metal fitting to an existing CCTV post (at a height of 7.5m). |
| DSRC vehicle-mounted unit | As the unit is combined with ETC (Penetration rate77% (As of March 2009. NEXCO East average), it is possible to receive both ETC service and the DSRC beacon service with the one vehicle-mounted unit (interface). The display interface has also been made public, enabling a link with the car navigation system. In addition, measurement sensors (for speed, acceleration, GPS) are built into the unit casing. Like a car navigation system, installation requires merely that the power line and line for the vehicle speed pulse signal be attached to a harness. Units were installed in 6 administrative vehicles. |
| Network (Data circuit) | An independent network (metal cables / optical cables) has already been laid under the expressway (along the shoulder) and is used as appropriate for emergency telephones, variable-message sign boards, LAN, etc. There are also reserve circuits that can be extracted from each facility for use as a communications circuit. The system uses a DSL modem to raise the data circuit transmission rate (approximately 2M up, 500 K down) |
| Data center | The probe data are stored on the data server via the network. The data server is located at a distance of some 10 km from the DSRC beacon, in the Yuzawa Operation Office which has a permanent maintenance staff. The probe data are processed by the data server (computer) to detect abnormalities in the flow of traffic. However, depending on the state of the network the location of the data server is optional; for a large-scale network there needs to be plenty of scope for expansion. |

3.2 Experiment site

The site of the experiment was a stretch of the Kan'etsu Expressway roughly 26 km long, between the Minakami Interchange (Gunma Prefecture) and the Yuzawa Interchange (Niigata Prefecture), (Fig.1)a region outstanding in the area covered by NEXCO East for its heavy snowfall and well-equipped with snow and ice control machinery and observation equipment. The experiment was conducted on the down line on the Niigata side, where many accidents occur in winter. The characteristics of the surrounding area are described below.

1) An area of particularly heavy snowfall compared with other parts of the world（Fig.4）.

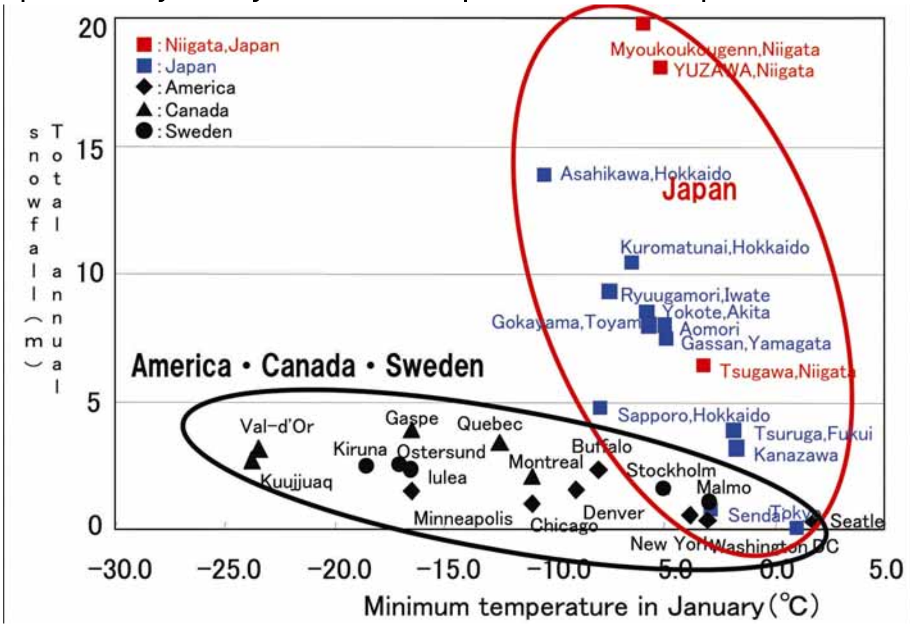


Fig.4-Snowfall and temperature

2) This is a snowy area (annual snowfall approx. 20m: annual number of snowy days, approx. 100) where the condition of the road surface goes through many changes – black ice, compacted snow, snow coverage, slush, etc – presenting a varying road environment.
3) Weather changes are rapid (including the Kan'etsu Tunnel on the border of Gunma and Niigata Prefectures), and there are huge changes in the road environment.
4) Two-lane traffic on each side, speed limit 80 km/hr. Volume of traffic approximately 15,000 vehicles per day.
5) There is a high incidence of accidents in winter.
6) The area is relatively well-equipped with snow and ice control machinery and observation equipment (in 3 locations), and snow removal is carried out every thirty minutes. (Fig. 5)

Fig.5-Photographs of snowfall situations

### 3.3 Experimental method

Using a combined car-navigation/DSRC vehicle-mounted unit, simulation runs incorporating different patterns of driving behaviour for different running speeds and road surface types ands conditions were planned and carried out. (Fig.6)

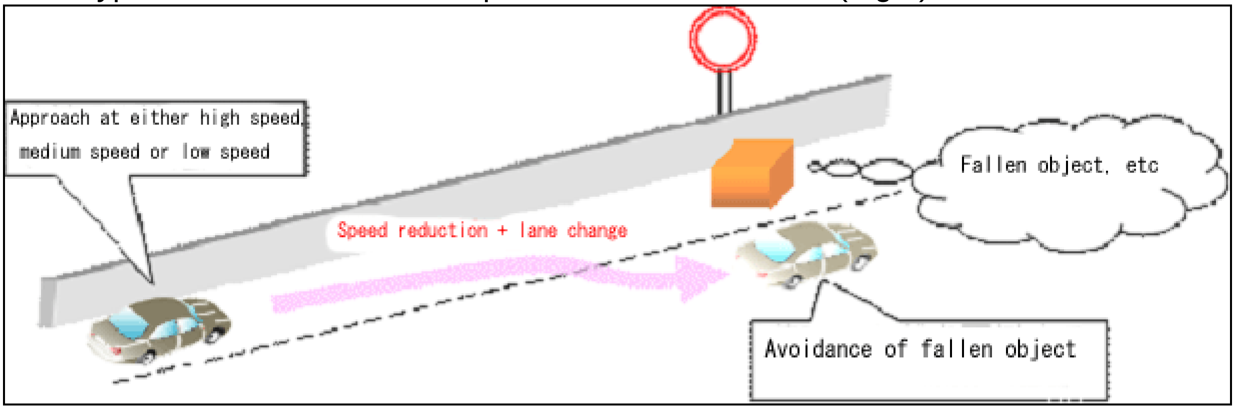



Fig.6- Artist's impression of simulation run

1) Number of experiment vehicles　6
2) Period of experiment　End of December 2008 to end of February 2009
3) Number of experiments　18 simulation runs

Examples of simulation runs on a snow-covered road surface are shown in Table 3.

Table 3-Examples of simulation runs on a snow-covered road

| Phenomena to be detected | Simulation run method and content | Sample size |
|---|---|---|
| Detection of sharp speed reduction (due to poor road conditions or obstacles on the road ahead) | Sharp speed reduction from actual speed to 20 kph<br>Pattern 1, high speed: Pattern 2, medium speed: Pattern 3, low speed | 2 runs per each pattern (1 run performed 3 times, total sample size 18) |
| Detection of evasive action (due to a breakdown or other obstacle on the road ahead) | Sharp speed reduction from actual speed to 20 kph + abrupt turn of steering wheel<br>Pattern 4, high speed: Pattern 5, medium speed: Pattern 6, low speed | ditto |
| Gradual lane-changing, gradual reduction of speed (early discovery of an obstacle on the road ahead, or following behind a snow-removal convoy) | Normal running: Driving at normal speed and with standard handling of the vehicle | 2 runs |
| Detection of hazard （potential accident） spots | Set-speed run: Driving at a set speed of 60 kph in the nearside lane | ditto |

※ The actual speed was set at three levels, high speed, medium speed and low speed, to match the conditions of the road traffic environment (snow-covered road surface).
〇High speed（85th percentile）：65km/h: medium speed（$50^{th}$ percentile）：55km/h: low speed（$15^{th}$ percentile）：40km/h

### 3.4 Items assessed and verified

As shown in Table 4, each of the items measured on the DSRC vehicle-mounted unit was assessed and verified with regard to the sampling interval and default threshold value. In addition the accuracy of the GPS and the effect on accuracy of the running speed and road conditions were used to consider improvements in the validity and accuracy of the collected data. The detection of hazard spots from the uplink data was also considered. (The items assessed and verified are shown in Table 4.)

Table 4-Items assessed and verified

| Phenomena to be detected | Items assessed and verified |
|---|---|
| Detection of sharp speed reduction (due to poor road conditions or obstacles on the road ahead) | Speed, longitudinal acceleration |
| Detection of evasive action (due to a breakdown or other obstacle on the road ahead) | Speed, angular velocity, lateral acceleration, longitudinal acceleration |
| Gradual lane-changing, gradual reduction of speed | Speed |
| Detection of hazard（potential accident）spots | Angular velocity, lateral acceleration, longitudinal acceleration |

※ With regard to each item to be assessed and verified, the effect from the running speed was verified with a high speed of 65km/h and a low speed of 40km/h, and the effect from the road conditions was verified with a high speed of 65km/h and a low speed of 40km/h on a dry road surface and on a slushy road surface.

※ The accuracy of the GPS was verified by plotting the positional data for each run and verifying whether it was possible to distinguish lanes and detect lane changes.

## 4. RESULTS OF ASSESSMENT AND VERIFICATION

Verification was made of the connection between the standard threshold values relating to measurements taken from runs on a snow-covered expressway (Table 1), and the probe data.

### 4.1 Speed

Observation was made of the changes in speed when braking (acceleration) was applied in a simulation run (Pattern 3). The speed history was measured at different sampling intervals (0.1sec, 50m, 80m, 100m), and is shown in Fig. 7. The point at which the brakes were applied in the simulation run is indicated by the symbol ▲. When the sampling cycle was set at 100m, on a number of simulation runs it was impossible to detect the condition of the run. At intervals of 80m and 50m, however, detection equal to that on a 0.1 sec cycle was possible, and in view of the amount of accumulating data, the interval was set at 80m.

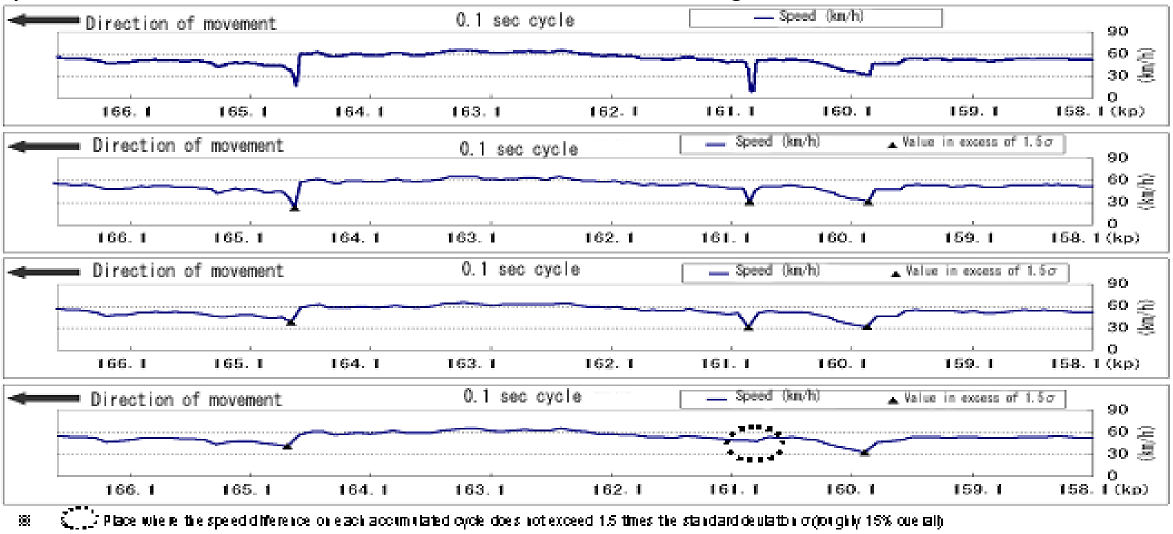



Fig.7-Chart of the speed history on an accumulated cycle in a Pattern 2 simulation

### 4.2 Angular velocity

The angular velocity indicates the vehicle's state of rotation (in relation to the direction of movement) and is measured using an angular velocimeter built into the DSRC vehicle-mounted unit. The angular velocity is measured in the yaw direction only. Fig. 8 shows the simulation run data. In Patterns 4 to 6, in which the steering wheel was turned in order to avoid a fallen object, the fact that the body of the vehicle changed direction is recorded and it is further possible to ascertain that the recorded values exceed the threshold value.

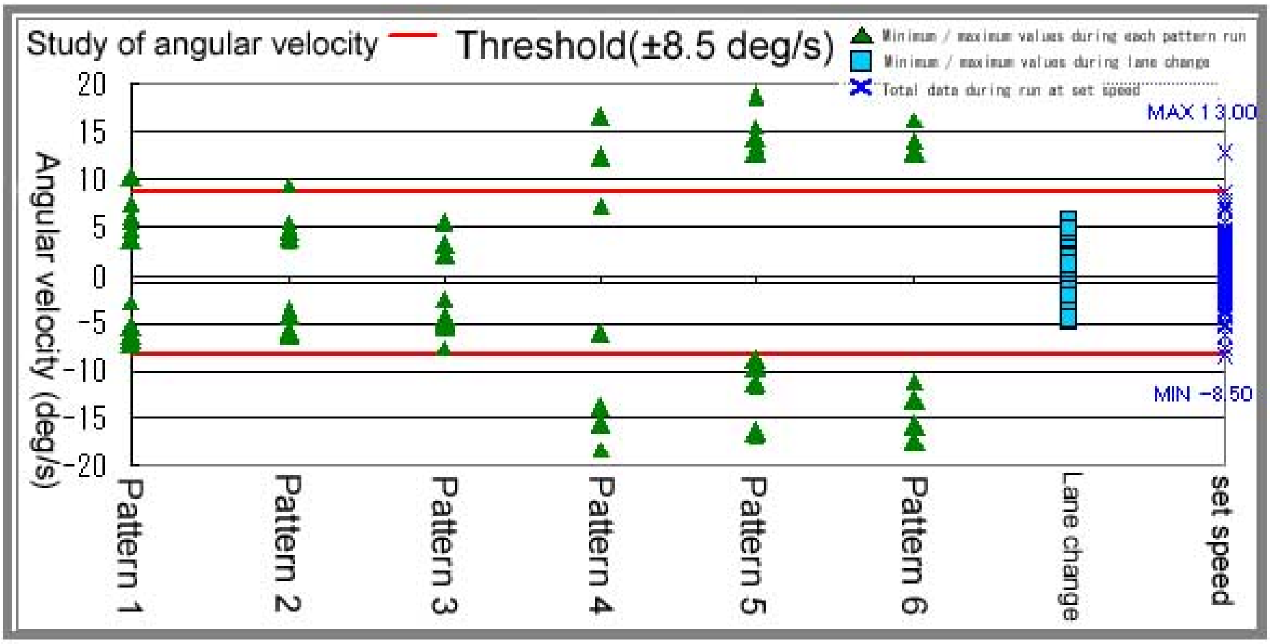



Fig.8-Distribution of angular velocity

### 4.3 Lateral acceleration

Lateral acceleration indicates the vehicle's sideways movement, and is measured using the accelerometer built into the DSRC vehicle-mounted unit. Fig.9 shows the simulation run data. In Patterns 4 to 6, in which the brakes were applied and the steering wheel turned, with a threshold value of ±0.25G it was detected in 14 runs out of 18 (78%), which cannot be said to be sufficiently accurate. When the threshold value was changed to ±0.15G, it was possible to detect lateral acceleration in 18 out of 18 simulation runs (100%). The possibility of detecting lane changes during patrol runs, or behaviour during a run at the set speed, is extremely low.

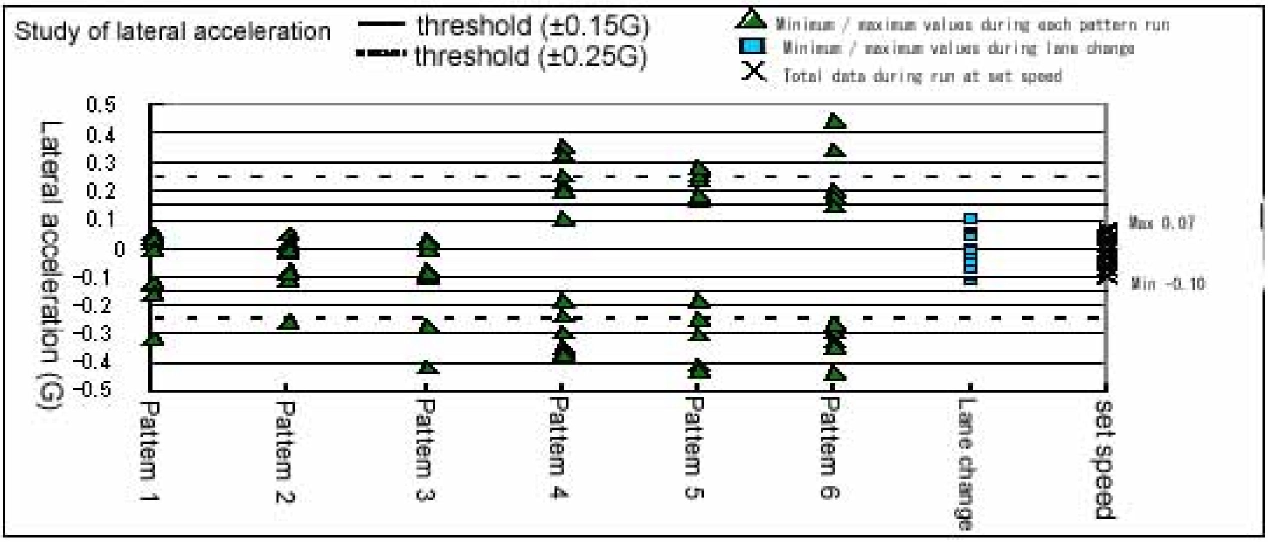



Fig.9-Distribution of lateral acceleration

4.4 Longitudinal acceleration

Longitudinal acceleration indicates the state of acceleration of the vehicle, and is measured using the accelerometer built into the DSRC vehicle-mounted unit. Fig.10 shows the simulation run data. In Patterns 1 to 6, in which the brakes were applied, the status of the vehicle was detected, but it was ascertained that normal application of the brakes or accelerator from the set speed is not recorded.

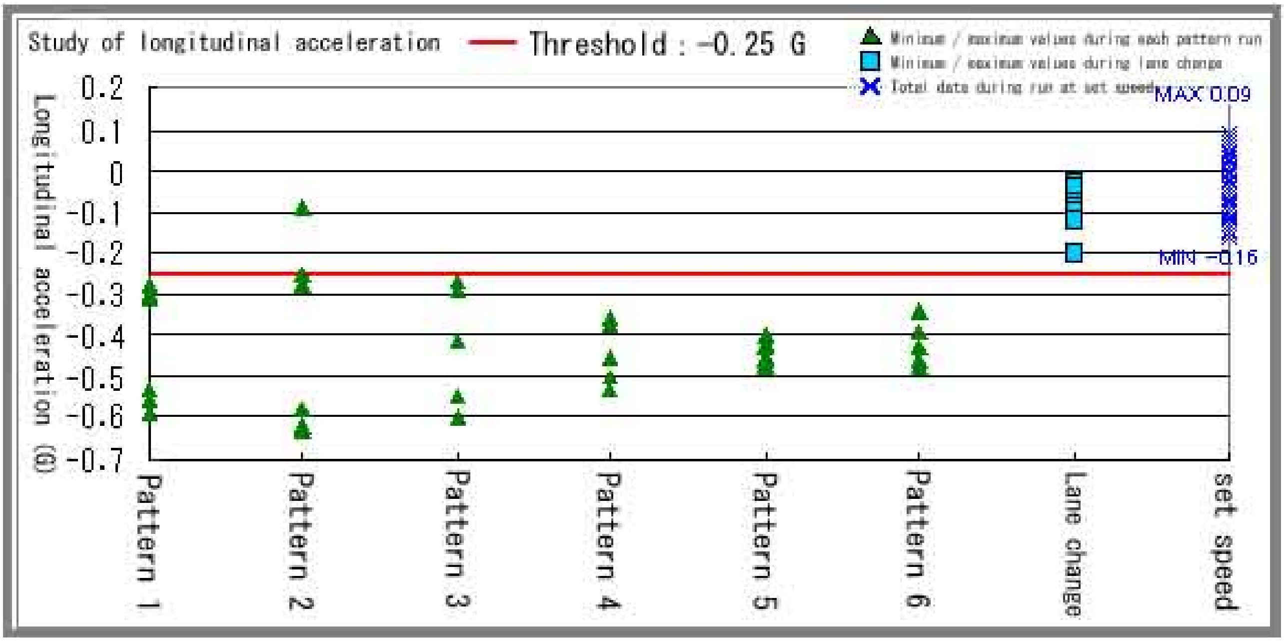



Fig.10-Distribution of longitudinal acceleration

4.5 Verification of GPS accuracy

As the location where the experiment was carried out is a valley area of a mountainous zone, tests were carried out to verify whether positional data obtained from the GPS used in road administration were accurate enough to enable lanes to be distinguished and lane changes detected. When the positional data from 8 runs obtained without map matching are plotted, the run history describes a standardised line, but when the individual runs are compared disparities in their relative positions are produced.

The results of the verification show that, since the standard error deviation $\sigma$ 3.8, with a reliability of 95% an error of roughly ±8m is produced. Since the traffic lanes are 3.5 m wide, it is not possible to distinguish lanes. This means that from the GPS alone, it is difficult to detect lane changes and skidding caused by speed changes or by the driver steering at different speeds.

4.6 Detection of hazard spots

The on-line data on simulation runs featuring sharp deceleration or abrupt lane changes collected via the DSRC beacons were verified.

The results of the verification confirmed that the behavioural history data at spots where sharp speed reduction or abrupt lane changes were executed in the simulation runs were by and large uplinked, confirming the possibility of detecting evasive action from the online data. There were also some spots excluded from the simulation runs where data were uplinked, which suggests the potential to detect hazard spots where the road bends sharply. In the future, methods of distinguishing these phenomena (spots with a high incidence of swerving and potential accidents, etc) will need to be considered.

4.7 Summary of assessment and verification results

The results obtained from the simulation run data suggest that it is possible to detect the following behaviour in vehicles travelling on a snow-covered road:

- Sharp, brief reduction of speed due to the discovery of a fallen object, etc.
- Gradual lowering of speed, congestion at the tail end of a snow-removal convoy (It is also possible to know the position and length of the congestion, and the time needed to pass through it)
- Sudden evasive action to avoid a breakdown or other obstacle on the road ahead
- Hazard spots where the road bends sharply

In addition, the following threshold values were obtained for the items measured:

| | |
|---|---|
| ・Speed (Sampling interval) | within 80m |
| ・Angular velocity (threshold value) | ± 8.5deg/s or higher |
| ・Longitudinal acceleration (Threshold value) | -0.25G or higher |
| ・Lateral acceleration (Threshold value) | ± 0.15G or higher |

## 5. CONCLUSION

In this experiment the probe data that can be collected by a DSRC vehicle-mounted unit was used to carry out a basic verification regarding the detection of traffic abnormalities caused by obstacles on the road ahead, road conditions, etc; and it was learned that it is possible for these to be detected. As a result, it became clear that effective use of the information obtained from vehicles will make it possible for measures to be taken to prevent accidents or reduce their numbers.

It is hoped that in the future, development of the DSRC vehicle-mounted unit, the accumulation of still more data and the correlation of weather, accident and various other types of statistical data will lead to advances in the provision of information, such as support for safer driving in snowy regions through improvements in the validity and accuracy of the collected data. It is also expected that the data from this experiment will be helpful when the standard specifications for the DSRC vehicle-mounted unit come to be reviewed.

## 6. REFERENCES

[1]Harutoshi Yamada et al., "Development of next-generation road services on SMARTWAY project", 14th World Congress and Exhibition on Intelligent Transport Systems and Services (2007), ITS China

[2] Harutoshi Yamada et al., "Effects of AHS for Safety in Curve Section", 13th World Congress and Exhibition on Intelligent Transport Systems and Services (2006), ERTCO -ITS Europe

[3] Hideto Hatakenaka et al., "Development of AHS for traffic congestion in sag sections", 13th World Congress and Exhibition on Intelligent Transport Systems and Services (2006), ERTCO -ITS Europe

[4] Hideto Hatakenaka et al., "Traffic Safety Measures with Image Processing Sensors And Analysis of Vehicle Behaviors", 13th World Congress and Exhibition on Intelligent Transport Systems and Services (2006), ERTCO -ITS Europe

[5] Setsuo Hirai et al., "Incident detection by probe data", 14th World Congress and Exhibition on Intelligent Transport Systems and Services (2007), ITS China

[6] Setsuo Hirai et al., "A field trial of a highway bus location system utilizing DSRC", 12th World Congress and Exhibition on Intelligent Transport Systems and Services(2005), ITS America