ITS ON EXPRESSWAY FOR BETTER USER SERVICE

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1. Introduction

Approximately 6,851 kilometers of inter-urban expressway network were already in service at the end of 2000. This length is equivalent to about 60 % of 11,520 km of whole planning of expressway network. The traffic volumes on expressways are increasing every year due to the extensive network effect, and now reaches about 4 million a day.

In Japan, during winter, we have considerable snow in the district along the Sea of Japan. Expressways passing through the snowy region (the average maximum depth of snow in 10 years is more than 30 cm) is equivalent to about 50 % of the whole network (Figure-1). During the winter, various traffic problems occur, such as traffic accidents, and road closures due to low-visibility by blizzard or snowfall. As most of expressways passing through the snowy area, these problems will be getting serious. Nowadays, expressways are indispensable for our daily life. Therefore the solution of these traffic problems during the winter becomes urgently.

In order to solve these problems in the winter and aim for improving the service level for users, we are implementing researches and developing utilization of ITS. The technical innovation of ITS is remarkable these days. In this paper, some of the examples of ITS researches and development we have carried out are introduced.

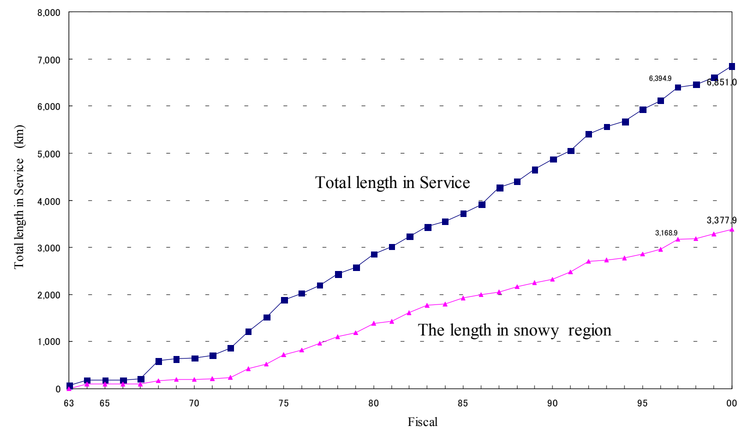

Figure-1 The length passing through snowy regions

2.The examples of ITS research and development

2.1 Case1 : The information service of the snow removal vehicle position

2.1.1 The outline of the system

As snow removal vehicles move over the long distance at low speed on Expressway, many cars are obliged to drive very slowly. This system provides the information of the traffic congestion and the information of the snow removal vehicle position by the various media. The information is collected by " the snow removal vehicle management system " which is already introduced into the partial area. This system can mitigate the irritation of the driver, and help to choose the alternative route and adjust the departure time for user.

2.1.2 Drivers' needs

Last year, we implemented the questionnaire about the snow removal, at some rest areas of expressways. According to the result, almost 80 % of the respondents had experienced the low speed driving which seems to be caused by the snow removal vehicle. As for the time, about 60 % answered 30 minutes, but about 20 % answered more than 1 hour (Figure-2). More than 80 % have a desire to be provided the snow removal vehicle information such as working position. Getting the information beforehand, they do not feel irritated and use the time for meal at rest area and so on.

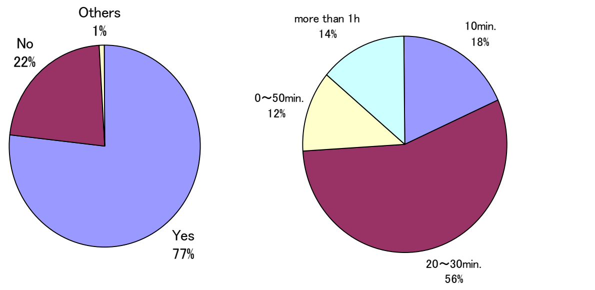

Figure-2 Experience of slow driving and duration time

2.1.3 The provision of the position information using snow removal vehicle management system

" The snow removal vehicle management system " is the system applying the technique of GPS car navigation (Figure-3). First of all, the system collects the snow removal vehicle position using GPS, at the station for snow operation. Secondly, the system indicates the snow removal vehicle position, the operation time, destination and direction of snow removal vehicle, on the computer display. Using correct and real time information of snow removal vehicle, we can indicate operations to snow removal vehicle adequately and automate the operation record.

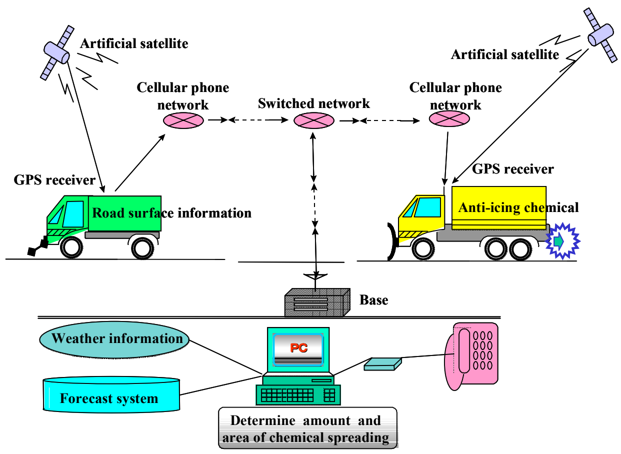

Figure-3 Concept of " The snow and ice control vehicle management system"

This system has already been operated in some area, and is improving user service by providing information as well as utilizing for the arrangement of snow removal vehicle position by road administrators.

2.1.4 The service media

At first, we are planning to install a display for this particular use, which isn't influenced by the information priority originally set, in rest areas experimentally. After confirming user needs, we'll provide the information by various media.

2.2 Case2 : Protection System of Maintenance Vehicle Against Collision (P-MAC)

2.2.1. Background

From 1994 to 1999 there were 132 traffic accidents related to maintenance vehicles working at slow speed. Snow removal and spraying of unti-freezing materials is included this kind of maintenance works. These works are sometimes dangerous and stressful for the driver of the vehicles. Although there is a distance warning system for trucks in the market, almost all trucks don't have such an advanced system. Therefore, all maintenance sign vehicles of JH have on board VMS and huge Bumper to protect them (Figure-4). The maintenance vehicle is colorful and easy to recognize, but there are collision with maintenance vehicles. The authors of this paper plan to add new collision avoidance system for maintenance sign vehicle utilizing ITS technology.

Figure-4 Rear view of the maintenance vehicle

2.2.2. Scenario of Collision Avoidance

Normally, many drivers can find maintenance vehicles easily. Then, they move to the next lane of the maintenance vehicle and pass it or slow down. However, some of them who is absent minded or almost a sleep, cannot find the maintenance vehicle till not to have the enough distance to pass safety. We divided the following vehicle's possibility of collision into four. Those are "Safe", "Danger", "Peril" and "Collision". We defined the meaning of them as follows.

Safe: Drivers can change the lane or stop to avoid collision.

Danger: Drivers can avoid the collision by steering, but it is difficult to avoid the collision by only breaking.

Peril: It is difficult to avoid the collision neither by steering nor breaking.

Collision: It is impossible to avoid collision by no means.

P-MAC gives warning sign of collision. P-MAC indicates suggestions whether to move to the next lane or slow down. If the following vehicle comes close to P-MAC, P-MAC changes more eye-catching sign to make the following vehicle move to the next lane or break to avoid collision. In order to make practical the system, we considered how to obtain precise data, how to judge the status of collision or not, and how to indicate on the on-board VMS.

(1) System Outline of P-MAC

P-MAC installs sensors at the tail of the vehicle to supervise following vehicles. These sensors measure distance to the following vehicle, and speed and position of the vehicle. Then each separate processing unit evaluate the data whether the status is collide or not and send those data and evaluation to the central processing unit. Finally, the central processing unit evaluate possibilities of "collision" and orders to indicate some caution on the on-board VMS (Figure-5).

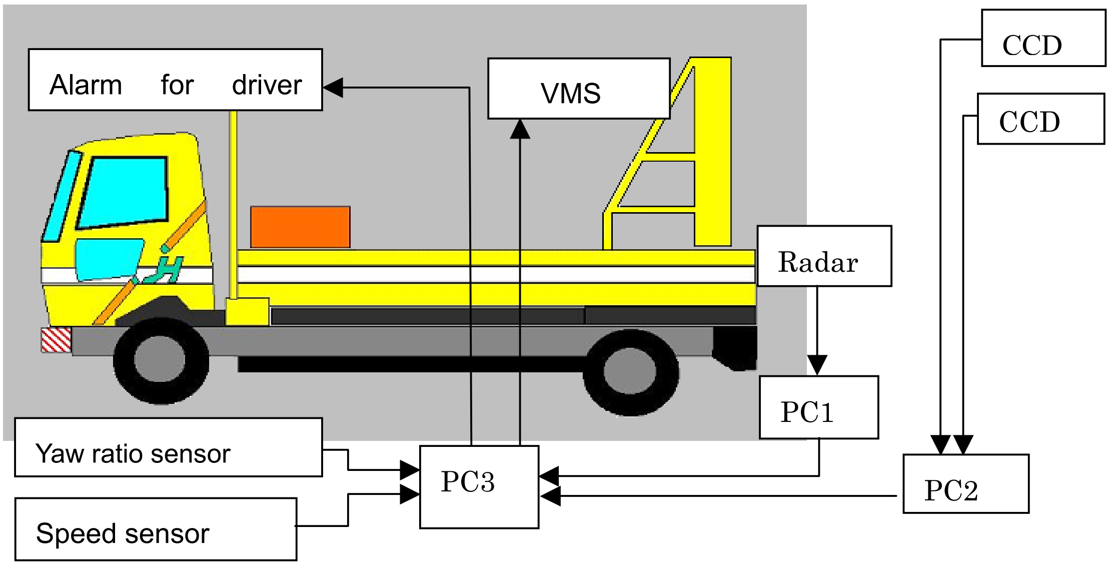

Figure-5 System outline of P-MAC

(2) What kind sensors are suitable for P-MAC?

P-MAC measures the following vehicles' speed and distance to them to judge the possibilities of collision. We considered that the sensors need the following capability.

1) In case that the relative speed between the maintenance vehicle and the following vehicle is more than 80km/h, the following vehicle driver should find at least 100m behind of the maintenance vehicle. Therefore, sensors should defect vehicles in the 100m away or more.
2) There are a few reflectors attached in front of vehicles.
3) It may be used in case of bad weather such as snow, rain, and fog.
4) As the final judgment of collision is relatively high, it is necessary to measure not only longitudinal distance but also transverse distance to make the judgement more accurate.

Therefore, we chose sensors as the millimeter wave radar (MR) and the stereo CCD cameras utilizing image processing (CCD-IP). The MR can detect the vehicle 120m away from P-MAC, it dose not require reflector on the target vehicle and it is able to work under snow, fog or rain situation. On the other hand, the stereo CCD-IP is good at measuring relative position of the maintenance vehicle to the following vehicle and detecting lane mark.

(3) On-Board variable message sign (VMS)

P-MAC gives attention by on-board VMS. Messages and images on VMS change depending on likeliness of collision. We planed to make 3 patterns of design. When following vehicle is in "Safe" area, P-MAC indicates a noticeable sign but not to give too strong impact on the VMS. If the vehicle enters the area "Danger" and "Peril", P-MAC suggests changing the next lane or applying the brakes to avoid collision. Unfortunately, the vehicle enters the "collision" area, P-MAC orders to apply the brakes to reduce the damage of collision. We will decide designs from field tests.

(4) Future development

It was confirmed that we could make the collision avoidance system, because the capabilities of the sensors and computers are good enough to cover our scenario of collision avoidance. We will confirm algorithm of collision judgment for many situations, and we will find the suitable design for on-board VMS. To realize P-MAC, it is expected that casualties of traffic accidents related with maintenance works on the highway will be reduced and the burden of operators of the maintenance vehicle will also be decreased.

2.3 Case3 : ITS-based traffic operation strategy in poor visibility

2.3.1 Background

The objective of this chapter is to develop an ITS-based traffic operation strategy to reduce road closures in the low visibility condition due to snowfall or dense fog. Figure-6 illustrates causes of the road closures. It shows that a weather condition is a dominant cause of road closures and 65% of closures occurred in this environment. Further breakdown of this weather indicates that a slippery road surface condition by snow or icing occupies 25% and a low visibility by snow falling or fog conditions occupies 51 % (right one). So far, various measures such as highway lighting, leading lights, and fog prevention nets have been installed along expressways to cope with poor visibility. However, sufficient effects have not been obtained.

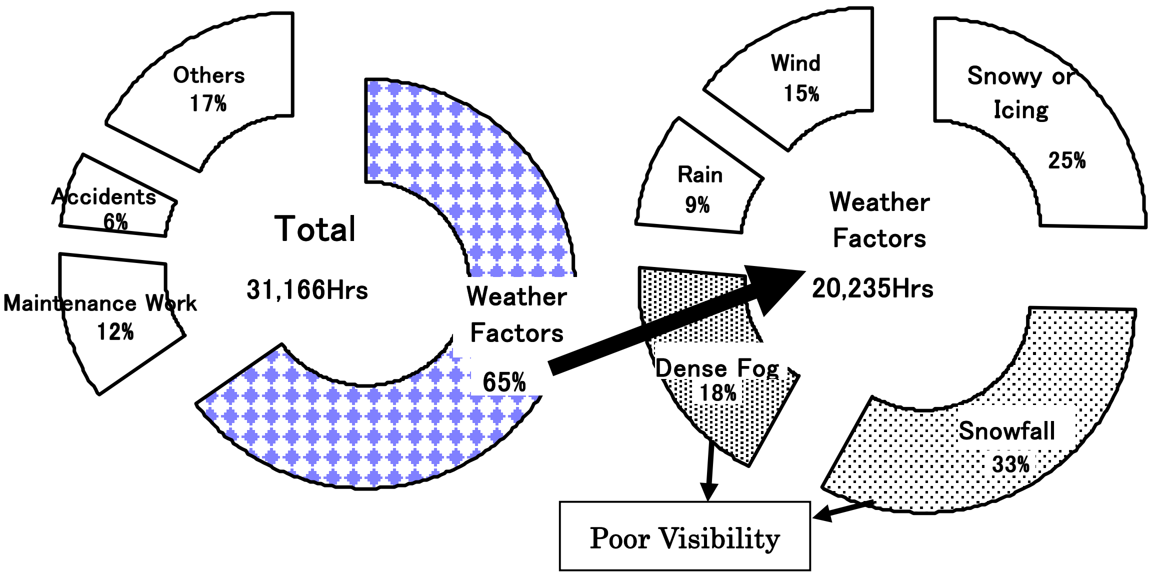

Figure-6 Causes of Road Closure of Inter-urban Expressways (1999)

2.3.2 Traffic operation strategy with ITS technology

A traffic operation vehicle equipped with ITS technology is now under study. In this strategy, a traffic operation vehicle equipped with ITS technology will lead vehicles at a fairly low speed corresponding to the visibility in the fog (Figure-7). The strategy named "Vehicle Guiding Operation" to reduce the road closure will be applied for the expressway where dense fog arises frequently and whose traffic volume is heavy. This kind of operation actually has already been carried out in some snowy regions though, since it was without any ITS technology, the operation has been very stressful for operators. Last year, one of our operation offices in a region with heavy fog installed an infrared camera on an operation vehicle tentatively, but, it was less effective than we expected. Therefore, we have been looking for more effective technology with an ITS equipment for the vehicle guiding operation. This operation strategy is designed to lead traffic under the fog induced visibility where the visibility range is 30 to 50 m, and is expected to reduce the road closure due to dense fog by half to 70 %

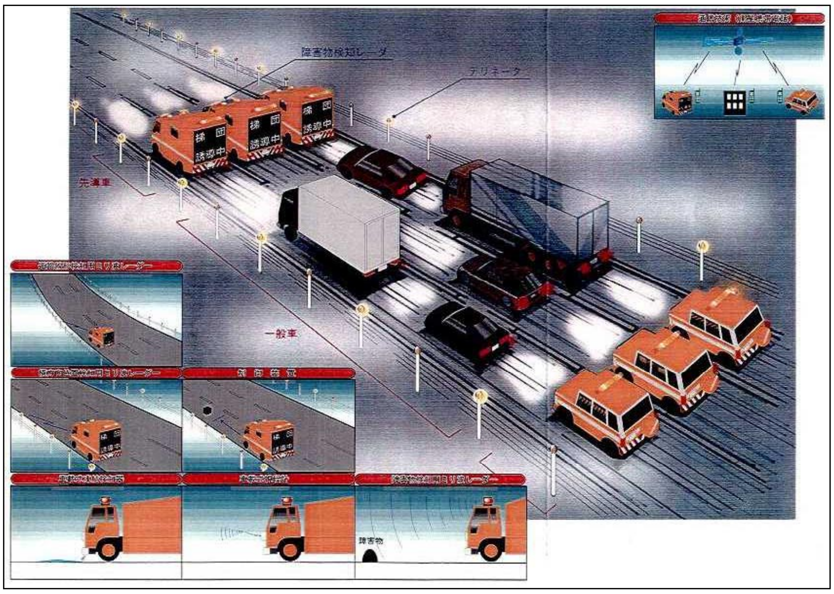

Figure-7 Traffic Operation Strategy with ITS Technology in Fog Weather

2.3.3 Obstacle detection sensor

As the result of some study, a millimeter wave radar (MR) was expected to be effective as the obstacle detection sensor. Therefore, we checked the performance of the MR by conducting a field experiment with prototype sensor. As a result, the prototype sensor could detect a box object (cubic; 375mm * 375mm * 375mm) or larger at a distance of 110 meters under both good and poor visibility conditions (Table-1). Our target for the obstacle detection is to detect at least stopped compact vehicle, and the MR is found to be more efficient than we expected.

Table 1 Results of the Field Test

Under Good Visibility Condition

Obstacles / Distance	50m	70m	90m	110m
Tire	N/A	N/A	N/A	N/A
Rubber Cone	○	○	N/A	N/A
Board Case (300@400@290)	○	○	○	N/A
Board Case (375@475@375)	○	○	○	○
Compact Car	○	○	○	○

Under Poor Visibility Condition

Obstacles / Distance	50m	70m	90m	110m
Board Case (375@475@375)	○	○	○	○

2.3.4 Magnetic lane marker

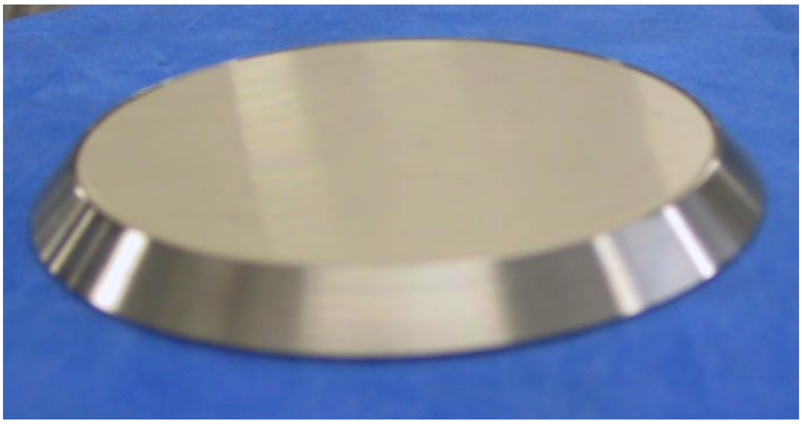

Figure-8 Magnetic Lane Marker Pilot Model

Magnetic Lane Markers for preventing vehicles from lane departure are also expected to be effective for road operation under poor visibility. This facility has been developed for Advanced Cruise Assist Highway System. After almost five-year research and experiment by Ministry of Land Infrastructure and Transport, we took over the research, and finally established a pilot model (Figure-8). In spring, the first segment with ITS equipments including magnetic lane markers is in effect. We are also thinking to apply the vehicle guiding operation to the markers.

2.3.5 Benefit and Cost Analysis

A rough benefit and cost analysis was conducted for two specific locations of expressways where dense fog appears so frequently, and road closure is unavoidable. One is Kan-etsu Expressway (Shibukawaikaho - Numata : 22.4km) with 200-hour annual road closure cased by dense fog, and the other is Oita Expressway (Yuhuin - Oita, and Hayami – Hiji JCT : 42km) with 270-hour annual road closure. The analysis for the period of 10 years justified this operation plan when traffic is heavy, so that the plan would be made possible when ITS safety technology is further developed in near future. In this analysis, cost of on-board equipment, employment cost, and cost for infrastructure on road are counted as the initial cost (Table-2).

Table-2 Initial Cost of System

		Kan-etsu Expressway Shibukawaikaho - Numata	Oita Expressway Yufuin – Oita Hayami – Hiji JCT
Cost of On-Board Equipment	Patrol Vehicle	100 (2 vehicles)	150 (3 vehicles)
	Leading Vehicle	800 (16 vehicles)	900 (18 vehicles)
Employment Cost		1,370 (83 people)	1,730 (93 people)
Infrastructure On Road	Lane Markers	2,690	4,040
	Communication	3,700	6,200
Initial Cost		8,700	13,000

(1,000 U.S dollars)

Also, value of time loss and running cost for drivers on both expressway and alternative route in case of expressway closure are counted as cost of damages (Table-3).

Table-3 Cost of Damage

		Kan-etsu Expressway Shibukawaikaho - Numata	Oita Expressway Yufuin – Oita Hayami – Hiji JCT
Expressway Users	Time Loss	5,010	4,680
	Running Cost	230	230
Total : Expressway Users		5,240 (67%)	4,910 (48%)
Alternative Users	Time Loss	1,740	4,670
	Running Cost	60	150
Total : Alternative Users		1,800 (23%)	4,820 (47%)
Users Total		7,040	9,730
JH	Total Revenue	780 (10%)	480 (5%)
Total Damages		7,820	10,210

(1,000 U.S. dollars)

As a result of the analysis with 10-year benefit and 10-year cost estimated, the Benefit and Cost ratio without the lane markers at Kan-etsu Expressway is 2.1, and that at Oita Expressway is 2.2. Also, the ratio with the lane markers at Kan-etsu Expressway is 1.7, and that at Oita Expressway is 1.8 (Table-4). Therefore this strategy can be said benefitable.

Table-4 Benefit and Cost Analysis

	Kan-etsu Expressway Shibukawaikaho - Numata	Oita Expressway Yufuin – Oita Hayami – Hiji JCT
Benefit from System (/ year)	5	7
B : Benefit of Present Value (/ 10years)	36	53
Initial Cost for System with Lane Markers	9	13
C' : Cost of Present Value (/ 10years)	21	29
Cost – Benefit Ratio with Lane Markers (B/C')	1.7	1.8
Initial Cost for System without Lane Markers	6	9
C : Cost of Present Value (/ 10years)	17	24
Cost – Benefit Ratio without Lane Markers (B/C)	2.1	2.2

(million U.S. dollars)

2.3.6 Pilot model Operation Vehicle

In order to achieve the "Vehicle Guiding Operation" and apply it to the sites with poor visibility problem, a pilot model operation vehicle is developed. This vehicle is equipped with an on-board detection sensor mentioned above, CCD camera, and a system distinguishing obstacles from road facilities along the expressway (Figure-9,10). This Pilot model was just established in this spring, and the first field experiment was conducted. As the result of the field experiment, the on-board detection sensor could detect some obstacles such as a compact vehicle, a cardboard case at least 50 or 70m in front, etc, and distinguish them from road facilities such as road signs and guardrails. At present, this pilot model is planned to be introduced to Oita Expressway. Moreover another field test under the problem condition is supposed to be conducted. We also think to apply this operation system into regions with heavy snow. Now we are planning another field experiment to see if the system is effective under the heavy snow conditions as well as dense fog.

Figure-9 Pilot model Operation Vehicle

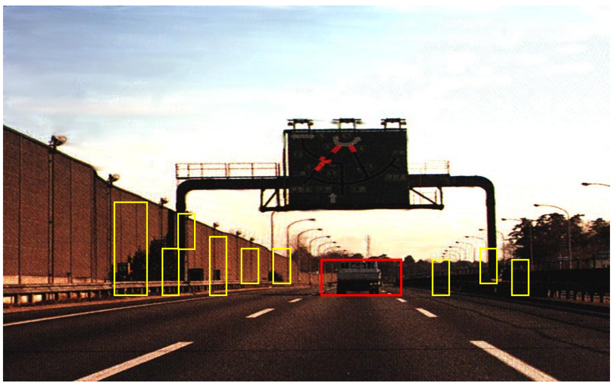

Figure-10 Image of Obstacle detection System

3.Conclusion

In the current situation, the role of expressway in Japanese social life is rising more and more, and the mitigation of the traffic problem during the winter can be called a duty for the road administrators. As the trend of ITS promotion has been risen in recent year, we are implementing the examination of countermeasures utilizing ITS technologies for the mitigation of traffic problems. We'll try to improve the convenience of the expressway user and the efficiency of road management, using ITS technologies.