THE DEVELOPMENT AND FIELD TRIAL OF DANGEROUS ZONE AVOIDANCE CONTROL SYSTEM IN UTMS

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SUMMARY

UTMS'21 (Next Generation Traffic Management Systems) has infrared beacon as the key infrastructure and is designed to provide drivers with traffic information through two-way communication between individual vehicles and to realize safe, comfortable and environment-friendly traffic society. The system consists of some subsystems, and one of them is DSSS (Driving Safety Support Systems), which coordinates the traffic control infrastructure advancing function and the car intellectualizing function to improve safety in car traffic and to reduce accident.
The Dangerous Zone Avoidance Control System was considered to be realized earlier and most effective to avoid head-on collisions and rear-end collisions among these systems under examination and was selected as the field trial system for introduction in this year.

INTRODUCTION

DSSS (Driving Safety Support Systems) coordinates the traffic control infrastructure advancing function and the car intellectualizing function to improve safety in car traffic and to reduce accident.
The following systems have been examined or developed to which DSSS can be introduced as soon as possible:
1) Pedestrian Support System
Informs drivers of existence of pedestrian at intersections, where pedestrians are going to cross a car running road to the other side, to draw their attention to the pedestrians.
2) Head-on Collision Prevention System
Detects approaching vehicles at non-signalized intersections and provides the approaching vehicle information to vehicles going to pass through on the crossing roads to draw their attention to the approaching vehicles.
3) Right-turn Accident Prevention System
Detects approaching vehicles going to pass straight on the opposing lane and provides the information to vehicles going to turn right at the intersection to draw their attention to the oncoming vehicles.
4) Dangerous Zone Avoidance Control System
Provides drivers with signal change information in advance so that they need not hurriedly pass through intersections or reduce their speeds abruptly when green signals turn yellow.

The Dangerous Zone Avoidance Control System was considered to be realized earlier and most effective to avoid head-on collisions and rear-end collisions among these systems under examination and was selected as the field trial system for introduction in this year.
This paper outlines the functions and describes the field trial of the Dangerous Zone Avoidance Control System.

THE DANGEROUS ZONE AVOIDANCE CONTROL SYSTEM

A dilemma zone is an area where drivers cannot stop their vehicles normally or pass them through normally upon seeing traffic signal change to yellow. Vehicles in dilemma zones are highly possible to cause traffic accidents because they are suddenly decelerated to stop or pass the stop lines after the traffic signal turned to red.
The Dangerous Zone Avoidance Control System controls vehicles in the dilemma zone according to such information as vehicle accessing times to the intersection and vehicle model.
We examined the function development process of this system in three levels taking into account the development situation of the element technology.
1) Phase 1
When detecting a four-wheeled vehicle in the dilemma zone, the system will control the green signal and extend the green time (this signal control called dilemma control). At present, the dilemma control has been introduced and is very effective to lower accident rate. For this signal control, however, the extendable green time is limited, and when a vehicle enters the dilemma zone beyond the limit, the green time cannot be adjusted.
When the green time reaches the extension limit and the green signal turns yellow, the Dangerous Zone Avoidance System will provide a deceleration request message to the vehicle by using the road-vehicle communication from the infrared beacon and the in-vehicle unit. Also, the system provides the message to vehicles without in-vehicle unit by using a roadside traffic information board. This system can be used for providing information only.
2) Phase 2
This system applies to motorcycles in addition to Phase 1.
3) Phase 3
All vehicles are mounted with in-vehicle unit and will receive deceleration request information through the road-vehicle communication for deceleration assist control when they enter the dilemma zone.
The system for Phase 1 has been under development for early introduction and the field trial

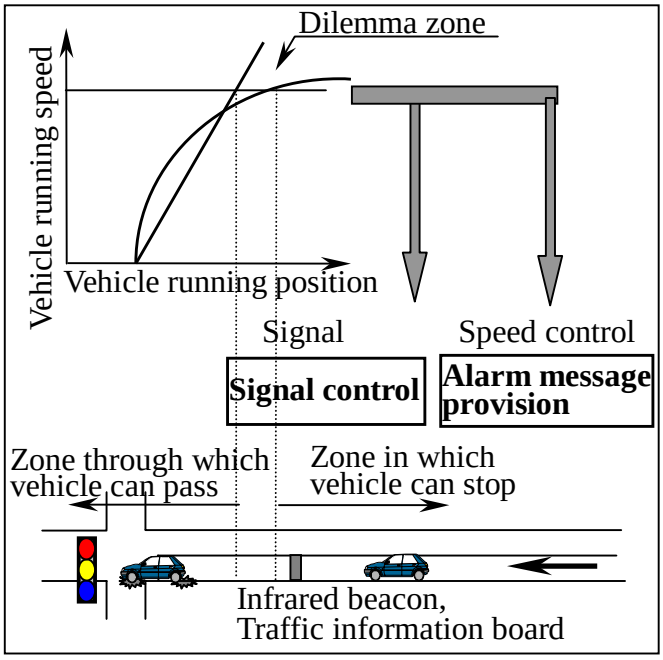

Figure 1. System Concept

was conducted in this year.
Figure 1 shows the conceptual drawing of the system.

Functions

1) Speed Measurement of Accessing Vehicle
A speed detector or an infrared beacon is installed 150 ~ 200m ahead of a signal control intersection to measure speeds of vehicles accessing the intersection.
2) Dilemma Zone and Calculation of Existing Time in Zone
When detecting a running vehicle on an approach to an intersection, the system will calculate the range of the dilemma zone and its existing time in the dilemma zone as follows.
3) Signal Control
The system executes the dilemma control. When detecting even a vehicle in the dilemma zone during the actuated range in the green time, the system will continue lighting the green signal. When no vehicle exists in the dilemma zone, the system will change the signal from green to yellow.
It is desirable to use the dilemma control for the traffic, but it can be used only for provision of information.
4) Provision of Information
When the system judges that any vehicle may exist in the dilemma zone in a certain monitoring time right after receipt of signal indication information from a traffic signal controller, a traffic information board or an infrared beacon installed near the intersection will give a message concerning signal indication to the driver.
The system is introduced during light traffic hours. So, the system will automatically judge the necessity of information provision when the measured speed comes to the lower limit value.

Conditions for system introduction

The following items are the conditions for system introduction.
1) The system should be introduced at an intersection with higher probabilities of red signal being ignored by drivers and higher probabilities of traffic accidents.
-An intersection with a signal where vehicles tends to enter at a speed exceeding the speed limit due to the distance or timing with the traffic lights behind and in front of the concerned intersection.
-An intersection judged as highly dangerous from past data regarding traffic rules violations and accidents.
2) It should be a location where a speed detector and a traffic information board can be installed.
3) The installation location for the traffic information board should be a location where there is no visual obstruction by surrounding buildings or trees and drivers should be able to recognize it easily.
In addition, with respect to system operation, we need to consider the following measures of information provision that take into account the display signal at the intersection along with a traffic signal.
- When the front signal shows an arrow indicating a right turn, the information should correspond to the signal.

- If the system is able to detect a right-turning vehicle at the opposite side of the road, the information regarding this should be provided.

VERIFICATION FIELD TRIAL

In order to conduct a survey on the behavior of vehicles before (in cases of dilemma control) and after (in cases where both the dilemma and information provision are jointly used) the introduction of the system, and to verify the establishment of the information providing method and the usefulness of the system, an field trial was conducted at Honishiki Intersection on Kanjyou 7 gou line in Tokyo in March, 1999.
In the field trial system, we took into consideration the following points when providing messages through the traffic information board to vehicles in the dilemma zone.
- The contents of the message should not cause the drivers to accelerate suddenly or make a sudden stop.
- The length of the message should be appropriate; if the sentence was too long, recognition by the drivers take too long and it becomes dangerous.
- The interpretation of the contents should be unambiguous. In the field trial system, there should be no effect due to the character providing order under the condition where five characters were used in the alternating display.

Considering the above conditions, we decided to use information provision by alternating a display of "Soon red signal" or "Caution" in the present field trial.
Figure 2 shows Traffic information board, Figure 3 shows arrangement of terminal equipment in Honishiki intersection.

Figure 2. Traffic information board

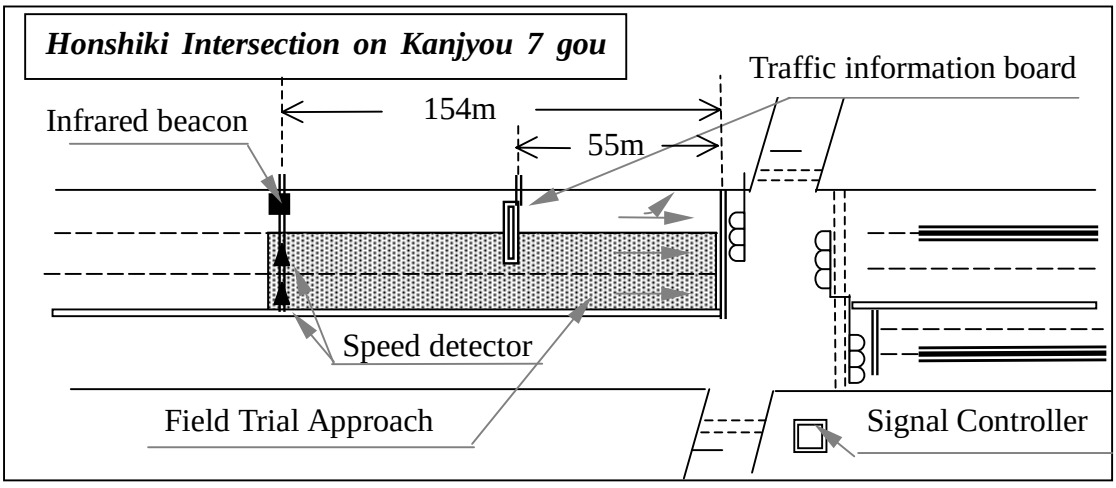

Figure 3. Arrangement of terminal equipment

Field Trial Evaluation Method

1) Influence on the behavior of vehicles by information provision
We took a video tape recording of vehicles' behavior at the upper stream of the intersection's approach and the condition of a signal lamp before and after the introduction of the system.
We then carried out data sampling from the recorded images with respect to the following items for each traffic lane. The data sampling was targeted on the last passing vehicle and the first stopping vehicle on each cycle and a lane whose stops and passages were clearly discernible, and vehicles that received information provision from the traffic information board through the decision of dilemma (hereafter referred to as the information supplied vehicle).
- The last passing vehicle and the stopping vehicle on each cycle, running position and speed of the vehicle at the start of yellow and red signal.
- The approaching speed of the last passing vehicle at the intersection (a speed measured by the speed sensor) and the outflow speed (a passage speed at the stop line).
- Running position, the intersection approaching speed, whether or not the vehicle stopped, vehicle speed at the traffic information board and the outflow speed (when the vehicle passed) of the information supplied vehicle at the start of the yellow and red signal.

We analyzed the sampled data with respect to the following items.
a) The running position and speed of vehicles at the start of a yellow signal.
Make a comparison between vehicles before and after in the dilemma zone using the running position and speed of the last passing vehicle, leading vehicles of the stopping vehicles and the information supplied vehicle at the start of a yellow signal during the survey hours.
b) Vehicle speed distribution.
Make a comparison of vehicles' acceleration tendencies from the intersection approaching speed and the position of the traffic information board of the information supplied vehicle, vehicle speed distribution at the stopping position, the distribution of the intersection approaching speed, the outflow speed of the last passing vehicle, and the deceleration distribution of the first stopping vehicle.
A decision is made that the system's side effects are too strong if there is a strong tendency towards sudden acceleration and deceleration. If the condition is stable, a decision is made that the system is effective.
2) Verification of information provision function for the in-vehicle units.
Measurement is taken of the infrared beacon processing time from the reception of the speed sensor pulse data to the transmission of information, and the processing time of the in-vehicle unit from the reception of the information to the character display.
It verifies basic functions in transmission of information to the in-vehicle unit on the vehicle through the infrared beacon.

RESULTS OF VERIFICATION FIELD TRIAL

1) Assessment of influence on vehicles' behavior by information provision
a) Vehicles' running position and speed at the start of a yellow signal
Table 1 shows the number of vehicles inside the option zone and inside the dilemma zone calculated from the relationship between the running position and speed at the star

of a yellow signal before and after the installation of the system. Table 2 shows the number of information supplied vehicles for general vehicles and large-sized vehicles.
Comparing the relationship between the running position and speed at the start of a yellow signal, there was no noticeable difference between the running position and speed distributions for the last passing vehicle and the first stopping vehicle, nor between congested situations of the last passing vehicle and the first stopping vehicle.
There was almost no difference between the proportions of vehicles inside the dilemma zone and those inside the option zone.
Looking at the number of vehicles inside the dilemma zone and option zone by vehicle types such as general vehicles and large-sized vehicles, among the information supplied vehicle, the proportion of large-sized vehicles inside the dilemma zone is found to be greater than general vehicles. With respect to the stopping probability (the number of stopping vehicles among the information supplied vehicles /the number of the information supplied vehicles * 100 [%]), the stopping probability of general vehicles is 40%, and that of large-sized vehicles is 8%. This result shows a very low stopping probability for large-sized vehicles.

Table 1. Number of vehicles inside option zone and that inside dilemma zone (before and after)

	Number of samples		Number of vehicles inside dilemma zone			Number of vehicles inside option zone		
	Last passing vehicle	First stopping vehicle	Last passing vehicle	First stopping vehicle	Total	Last passing vehicle	First stopping vehicle	Total
Before [veh] [%]	372	369	7 (1.8)	4 (1.1)	11 (1.5)	9 (2.4)	5 (1.3)	14 (1.8)
After [veh] [%]	326	314	6 (1.8)	3 (0.9)	9 (1.4)	11 (3.3)	5 (1.6)	16 (2.5)

Table 2. Number of vehicles inside option zone and that inside dilemma zone among the information supplied vehicles (General vehicles, large-sized vehicles, total)

	Number of samples		Number of vehicles inside dilemma zone			Number of vehicles inside option zone		
	Passing vehicle	Stopping vehicle	Passing vehicle	Stopping vehicle	Total	Passing vehicle	Stopping vehicle	Total
General [veh] [%]	9	6	1 (11.1)	0 (0)	1 (6.7)	2 (22.2)	0 (0)	2 (13.3)
Large [veh] [%]	11	1	3 (27.3)	0 (0)	3 (25.0)	2 (18.2)	0 (0)	2 (16.7)
Total [veh] [%]	20	7	4 (20.0)	0 (0)	4 (14.8)	4 (20.0)	0 (0)	4 (14.8)

b) Vehicle speed distribution

There was no noticeable difference between the intersection approaching speed (speed measured at the speed detector position) of neither the last passing vehicle nor that between the speed distribution conditions of the intersection outflow speed (a speed at the time of passing the stop line).

The distribution of the intersection approaching speed and that of the intersection outflow speed has approximately the same distribution, showing that stable running is maintained before and after the introduction of the system.

These speed distributions show approximately the same results for passing vehicles among the information supplied vehicles.

According to the data, we can make a judgment that there was no tendency of the incident of a sudden acceleration due to the information presented on the traffic information board in the present field trial, showing that there was no sign of the system's side effect that disrupts the stable running of vehicles due to the introduction of the system.

2) Verification of information provision function by the in-vehicle units

A test was conducted on the communication between the infrared beacon and a test vehicle to measure the time between the reception of information by the receiver in-vehicle unit a vehicle and the display of a message at the display unit. In the actual information provision, however, the time taken for the infrared beacon processing from speed measurement to the information transmission and the processing time required by the in-vehicle unit should be taken into account. In the present field trial, however, we only verified the functions starting from the information provision by the infrared beacon ending at the display of a message. Since there is a delay in the driver's recognition of the display of a message, it is considered desirable in the future to use jointly the display of a message and voice information provision by the in-vehicle units.

Summary

The summary of the results of the field trial assessment is described below.

- No difference was found in the number of vehicles inside the dilemma zone before□after the introduction of the system.
- Among the information supplied vehicles, 40% of general vehicles stopped while only 8% of large-sized vehicles stopped. The proportion of general vehicles staying in the dilemma zone is 7% while that of large-sized vehicles is 25%, showing that the effect of introducing the system differs between different types of vehicles. While the system was found to be useful for general vehicles, it was not for large-sized vehicles.
- There was no difference in vehicle speed distribution before and after the introduction of the system, showing stable running in both cases. No side effects of information provision, such as sudden acceleration or deceleration, was found in the behavior of information supplied vehicles.
- Of vehicles passing the dilemma zone after the introduction of the system, 67% of them were information supplied vehicles. Since these vehicles could have avoided the dilemma zone if they had made a deceleration maneuver, the improving effect of the system is considered to be great. We could at least verify the system's realization in terms of functional aspects in that appropriate information was provided through the judgment of the dilemma.

As described above, we were able to verify the validity of the timing of information provision, or in other words, the likelihood of its materialization as a system. Looking only at the results of general vehicles, we were able to confirm the usefulness of the system.

If all of the information supplied vehicles had decelerated, the improvement effect could have been greater. Considering the fact that only 25% of the information supplied vehicles decelerated and the fact that our analysis did not go so far as to pinpoint the cause of stopping maneuvers as coming from information provision, the probability of a stopping maneuver due to information provision is reduced even further.

We consider that the following factors influenced this result:

1) Visibility of a traffic information board.

We conjecture that the traffic information board installed in the upper stream of the traffic information board reduces the visibility of a traffic information board. Since the probability of the stopping of large-sized vehicles receiving information provision is lower than that of general vehicles, we suspect that the probability of the stopping of large-sized vehicles was greatly influenced by information provision.

2) Acceptability of provided messages

The messages used in the verification field trial were sent to provide the condition of the traffic signal. It all depends on the individual driver's judgment if he/she decides to decelerate or not. It is conjectured that many of the drivers did not interpret the content of the messages as suggesting the necessity of deceleration.

Comparing the numbers of vehicles in the dilemma zone before and after introducing the system, there was no difference between them, suggesting that the effect of the system was not present. We can expect the effect of the system to be seen by solving the problems presented by the above factors.

CONCLUSION

Our future tasks can be listed as follows.

1) Timing of information provision by a traffic information board

When providing information through a traffic information board in the Dangerous Zone Avoidance Control System, there is a high probability that regular running vehicles other than information supplied vehicles may see the message, which may cause problems. When the vehicles in front of the information supplied vehicles are at the entrance part of a multiple-lane road, the concerned vehicles are those running on the other lanes. Since the vehicles on the other lanes do not have to decelerate, it is highly possible that the information displayed is inappropriate.

It is necessary that the timing of information provision that takes into consideration preceding vehicles, the speed of vehicles running in the other lanes, and the distance between the rear of the preceding vehicle and the front of the trailing vehicle, etc.

2) Acceptability of messages in information provision

In order for the driver who has received the message to appropriately decide to decelerate the vehicle, an investigation of message content in information provision, including psychological aspects such as driver's responses, etc. should be carried out.

3) Information provision that takes weather conditions, etc. into consideration

In the present field trial, the weather condition adopted was a clear day only. Since brake-distance, visibility of the traffic information board, etc. can change depending on the weather (clear day/rainy day), information provision that takes into account the

environmental conditions is necessary in order to enhance the system's effect for realizing the actual system.

4) Timing of information provision by the in-vehicle units

The current in-vehicle units are compatible with VICS and each type has a different delay time for providing information.

Considering the materialization of the present accident prevention system, the variance in delay times for providing information should be eliminated. The standardization of the warning timing of in-vehicle units such as delivering the concerned message to other system (VICS information, car navigation information) with a higher priority will be required.

5) Application of the system to motorcycles

Unlike the case of vehicles where their drivers can be protected by the vehicle's body, the basic measures for motorcycles are preventive measures. The present system put to use in the practice is considered to be useful for reducing the number of accidents caused by motorcycles. In order to create also a system for motorcycles, we consider the development of motorcycle detection techniques an important task that lies ahead of us.

Of the several systems planned by DSSS of UTMS'21, with the purpose of preventing traffic accidents, we investigated and conducted a verification field trial on the danger zone avoidance control system that provides information about a change in the signal to the driver beforehand. We are determined to continue our efforts to make investigations to develop the traffic control system and to facilitate the process of its introduction.

REFERENCE

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