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도로교통방재

Implementing FDWS(Fog Detect & Warning System) with LED Module Structure : Estimation of Safety Effects

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Abstract

Although drivers use various sensory channels to control and navigate their vehicles, they acquire most of all driving-related information visually. In fog, no matter what visual acuity is, the visual channel is useless due to the induced poor visibility. Drivers react differently to the adverse weather, resulting in high speed variation. That is why it has the high fatal rate during foggy conditions. Then, it is imperative to provide drivers positive guidance in fog. In this study, the Fog Detect and Warning System (FDWS), being called as the fog lighthouse, was conceived to inform drivers of safety speeds and distances between each vehicle. FDWS includes visibility meters, light bars, and vehicle detectors. The visibility meters calculate sight distances when fog occurs and the estimated sight distances inform drivers through the light bars which are installed at every 30m intervals. The light bars which display red warning lights inform a following vehicle of the position of the leading vehicle to keep the safety distance between the two vehicles. Since the main lights with the high-bright LED (Light Emitting Diode) have high visibilities, drivers can easily recognize far away. Also microwave sensors together with the light bars are installed to detect the presence of vehicles at every 30m intervals. The aim of this paper was to evaluate the effectiveness of the fog system on driver behavior and consciousness. As a pilot study, FDWS was implemented on a 1km section of National Highway No. 37 with a divided four-lane, rural highway. The analysis of the driver behavior was based on mean speed with standard deviation, and a questionnaire survey was conducted to estimate the driver consciousness. The results indicates that FDWS significantly led to an about 3kph (for daytime) and 10kph (for nighttime) reduction in mean speed compared to the system turned off. Also the consciousness survey shows that FDWS was useful helping drivers guide safely in fog.

Key words : FDWS(Fog Detect & Warning System), Visibility meter, Light bar, Mean speed, Driver behavior

요 지

도로상의 운전자는 눈을 통하여 90% 이상의 정보를 취득한다. 하지만 안개로 인하여 전방 시야가 제약될 경우 운전자에게 치명적인 결과를 초래한다. 안개는 시간적, 공간적으로 빠르게 변화하는 특성이 있어 1~2개소에서 측정된 시정거리로 대다수의 구간을 예측하는 것에는 무리가 있다. 이러한 안개에 대한 대책으로 개별차량의 주행속도와 차두거리를 인식하고 대응할 여건을 제공, 안개시 사고발생 가능성을 줄여주는 안개도로 안전운전 지원시스템을 개발하였다. 본 시스템은 차량검지기, 시정계, 안개등, 메인컨트롤러 등 4가지로 구성되어 있다. 시정계는 안개 발생시 가시거리를 측정하고 안개등은 30 m 간격으로 설치되어 시정거리별 적정 휘도를 LED에 표출시킨다. 본 논문은 국도 37호선(파주-적성 1 km 구간)에 설치된 안개도로 안전운전 지원시스템에 대한 운전자 행태 및 효과 평가를 실시하였다. 운전자 행태 측정의 척도는 평균주행속도, 서면설문을 이용하였다. 결과적으로 시스템 설치 후 주간에는 3 km/h, 야간에는 10 km/h의 평균 감속도를 보였다.

핵심용어 : 안개도로 안전운전 지원시스템, 시정계, 안개등, 평균주행속도, 운전자 행태

1. Introduction

In general, fog occurs due to differences in the temperature between day and night at the earth's surface. Fog has a negative effect on driving due to poor forward sight distances. Although drivers use various sensory channels to control and navigate their vehicles, they acquire most of all driving-related information visually. In fog, no matter what visual acuity is, the visual channel is useless due to the induced poor visibility. Drivers react differently to the adverse weather, resulting in high speed variation. That is why it has the high fatal rate during foggy conditions. Then, it is imperative to provide drivers positive guidance in fog.

According to the statistics on collisions in 2008 by the

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Road Traffic Authority in South Korea, although fog-related collisions account for the lowest collision frequency as 0.21% of the total collisions, the fatal rate for fog-related collisions is 13.41%, which is the highest of other environmental conditions. Also, it shows that it is the high possibility of multiple-vehicle collisions in fog.

In spite the highway policy makers or engineers have always recognized safety problems during foggy conditions, fog-related safety appurtenances which help drivers to safely guide under restricted visibility are nonexistent in South Korea. Existing road signs and intelligent transportation systems (for example, variable message system) might be insufficient as countermeasures to guide vehicles or alert them of danger or the prevailing conditions.

In this study, the Fog Detect and Warning System (FDWS), being called as the fog lighthouse, which informs drivers of safety speeds and distances was conceived to reduce fog-related collisions. The system was implemented on a pilot road to evaluate the effectiveness of the system on driver behavior and consciousness. In addition to collecting observation regarding speed, this study carried out a survey of preferences for the system targeting local drivers near the pilot road. Then, this paper is to provide insights on the potential to implement FDWS as a promising solution to the problem of what speed and distance to choose in foggy conditions. This paper are organized as follows; the second section is a brief review of related literatures; the third section is a review of FDWS; the fourth section describes the methodology of how to estimate the effectiveness of safety and preference; the fifth section provides a summary of the performance of FDWS; and the last section provides the conclusions.

2. Literature Review

Ali S. Al-Ghamdi (2004) examined the safety effectiveness of fog detection and warning system on driver behavior regarding speed and headway. The system which consists of a visibility sensor and a variable message sign (VMS) informs drivers an advisory speed when fog occurs. The study showed that the system decreased speeds by about 6.5 kph.

The Utah Traffic Lab (UTL) and the Utah Department of Transportation by Martin and Perrin (2000) conducted to quantify the effects of the Adverse Visibility Information System Evaluation (ADVISE) on speed variation during foggy conditions. ADVISE with a fog sensor, loop detectors, and a VMS measures visibility and displays the safe speed based on the measured fog density. The study indicated that the system was contributed to decrease in speed variation by 22% during poor visibility conditions.

Braham et al. (2000) developed a far infrared vision-support system which helps drivers detect vehicles and objects in a road in poor visibility. The system is based on heads down virtual image display. They estimated the effectiveness of the vision system on drive behavior through a driving simulator. The human factors evaluation indicates that the system led to increase consistently headways among subjects.

Cooper and Sawyer (1993) conducted to estimate the effectiveness of an automatic fog warning system on driver behavior in terms of changes in speeds. The system which was employed on a freeway in London detects fog formation by a fog sensor and informs drivers of a warning message on dynamic message signs (DMS) upstream of the detector. The study showed that there was a statistically significant reduction in mean speeds of about 1.8 mph.

In 1990, the Tennessee Department of Transportation employed a low visibility warning system on a fog-prone interstate freeway after multi-vehicle collisions occurred in fog. The system is comprised of environmental sensors, forward-scatter visibility sensors, and vehicle detectors. The system detects low visibility conditions and warns drivers of the prevailing conditions. The study showed that the warning system improved significantly safety.

As a result of reviewing the relevant literatures, some fog-related systems inform drivers an advisory speed, while others alert drivers of the presence of fog ahead. The authors expect that in addition to the alerting function, a fog system with the function of tracing the location of preceding vehicles like lighthouse could be more beneficial to road safety in fog, and then FDWS was developed to operate simultaneously the two functions.

3. Fog Detect and Warning System (FDWS)

FDWS consists of a main controller, a visibility meter, a light bar, and a vehicle detector. The main controller includes various memories and CPU to receive and store data from the other devices.

As shown in Fig. 1, the visibility meter detects fog formation and calculates visibility according to fog density. Also, it is equipped with a heater to prevent dew condensation below zero temperatures.

Fig. 2 shows the light bar with a microwave sensor which is installed at every 30 m intervals according to the criteria of delineation in Highway Safety Facilities Design and Management Guideline by Ministry of Land Transportation and Maritime Affairs. The sensor is to detect the presence of vehicles. The light bar displays a red warning light to inform a following vehicle of the position of the leading vehicle in fog. Whenever vehicles pass at the detection zone, the light bar is switched on. Then, the light leads to encourage drivers to keep safety distances between each

Fig. 1. Visibility meter

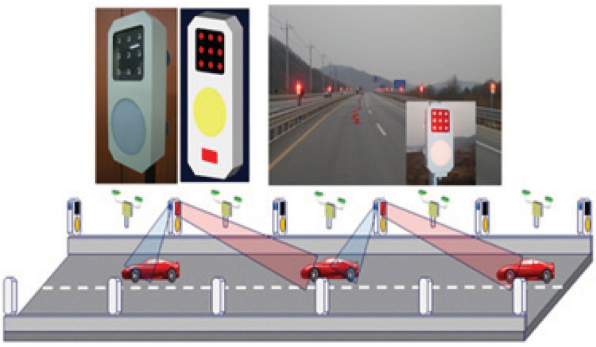

Fig. 2. Light Bar

vehicle. Since the main light with the high-brightness LED has a high visibility, drivers can easily recognize far away in foggy weather.

Based on previous studies, FDWS categorizes into fog-free, light fog, and dense fog. Fog-free is the visibility distance of 200 m and above, light fog the range of 100 to 200 m, and dense fog the visibility distance of below 100 m, respectively. Depending on the visibility distance classifications, FDWS operates differently. For the fog-free condition, the system does not activate in the daytime but the light is turned on to help guide drivers safely at night. For the light fog, the system becomes operational and the illuminance of the main light is adjusted to minimize glare. In the dense fog, the main light displays with the most intense illuminance.

4. Estimating Effectiveness

In addition to developing the innovation fog lighthouse, this study was to evaluate the performance of FDWS on site and to estimate the effectiveness of the system on driver behavior and consciousness.

In general, previous studies show that collision rates increase as mean speed increase, and then it could be concluded that reducing speeds is contributed to lower collisions rates. This study selected mean speed and standard deviation as the measure of effectiveness of FDWS on driver behavior. In addition to the speed analysis, this study carried out the other analysis based on driver consciousness, this analysis is to estimate whether drivers consider FDWS as the positive guidance which helps safely travel in poor visibility due to fog.

As a pilot study, FDWS was implemented on a section of National Highway No. 37 with a divided four-lane, rural highway, where signalized intersections are spaced by a distance of above 3 km. The section is the section 1 km long with the speed limit of 80km/h and is one of fog-prone locations. Fog occurs most often between 4 a.m. and 8 a.m. with the low visibility of about 40 m on average. The test section carried out the ADT of about 3,200 vehicles per hour with the free-flow speed of about 100km/h, so traffic volume is always low. Fig. 3 shows the schematic study section which installed FDWS.

In order to assess the effect of FDWS on driver behavior, instead of selecting control sections, this experiment was only performed on the test section with controlling the two conditions (the system turned on and off). The experiment was conducted for day and night and foggy periods and clear periods. Speed data was collected by the portable detectors, NC-97, and fog-related information was measured by the visibility meter. As shown in Fig. 3, four devices were installed at the beginning, the middle, and the ending of the test section by each lane and direction. The data were obtained from January first to August 30 th in 2011. The measurements were aggregated and analyzed over each point.

Table 1 shows that a total of 175,540 speed observations were collected during the experiment periods. The sample size of the system turned off condition for foggy periods is relative small compared to the other conditions because of the limited times of collecting the data. In addition, the dense fog data were pooled with the light fog data to provide the best chance to say something meaningful about the effects of FDWS on driver behavior, since not enough the dense fog data had occurred to make any meaningful conclusions. Then, the foggy periods belongs to the visibility

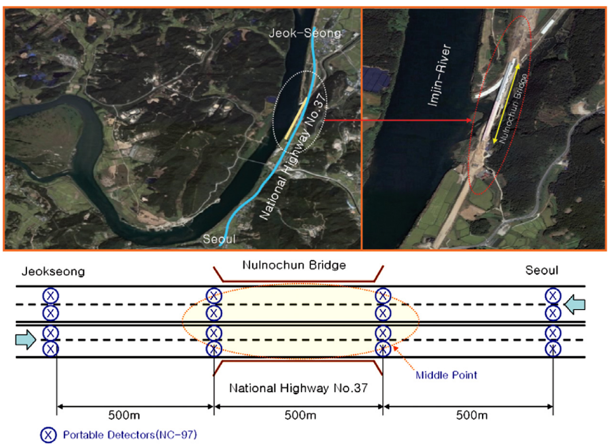

Fig. 3. Schematic study section

Table 1. Sample Size (Speed Observations)

Condition		System On	System Off	Total
Foggy periods	Day	2,392	172	2,564
	Night	398	123	521
	Sub-total	2,790	295	3,085
Clear periods	Day	45,055	84,906	129,961
	Night	18,551	23,943	42,494
	Sub-total	63,606	108,849	172,455

distance of below 200 m.

In addition to the speed analyses, this study carried out a survey of preferences for the system targeting local drivers near the pilot road. The purpose of this survey was to collect qualitative information related to the topic of FDWS; whether drivers consider FDWS as the positive guidance which helps safely travel in poor visibility due to fog. The survey consists of four sections with multipart questions. The first section inquires about driver behavior in fog. The second section is whether the subjects recognize the innovative and unique fog system or not. The third section focuses on the satisfaction of the criteria of implementing FDWS. The fourth section inquires about the preferences of the subjects in the view of psychology and morality.

This study surveyed fifty drivers who had experience in travelling on the test-bed for the study period. This study randomly selected the subjects among drivers experienced in the test-bed. The survey was conducted through individual interviews. All but a few of questions has Lickertis scale with the score of 7 (Extremely Agree, Fairly Agree, Agree, N/A, Fairly Disagree, Extremely Disagree). Lickertis scale, as a psychometric scale, is the most commonly used approach to scale responses in survey research. The scale was converted to the score of 100, and then the preference for the fog system was estimated.

5. Results

This section is to estimate the effects of FDWS on driver behavior in terms of changes in speeds and driver consciousness in terms of the preferences for the system targeting the local drivers. To analyze the speed data, the study team used a t-statistic to test a hypothesis about the difference in mean speed between each condition.

Fig. 4 through 7 present mean speeds and standard deviations versus the measurement points by the experiment conditions (i.e., fog and clear and day and night). The results indicate that for fog and daytime, FDWS turned on appeared to have statistically significant reduction in mean speed of about 3km/h compared to the system turned off. In addition, for fog and nighttime, the system turned on exhibited a reduction in mean speed of about 10 km/h compared

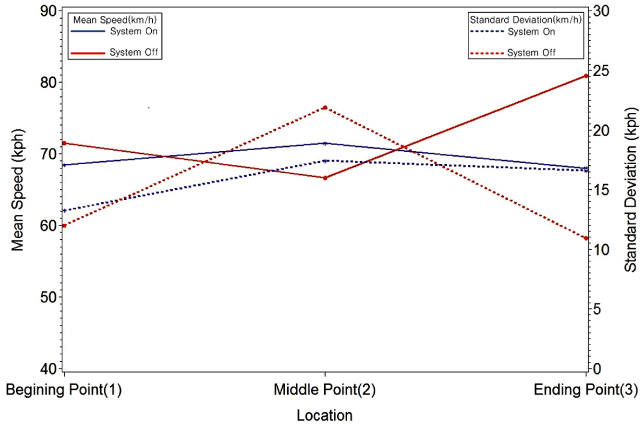

Fig. 4. Mean speeds and S.D. at each measurement point by System On/Off (Fog, Daytime)

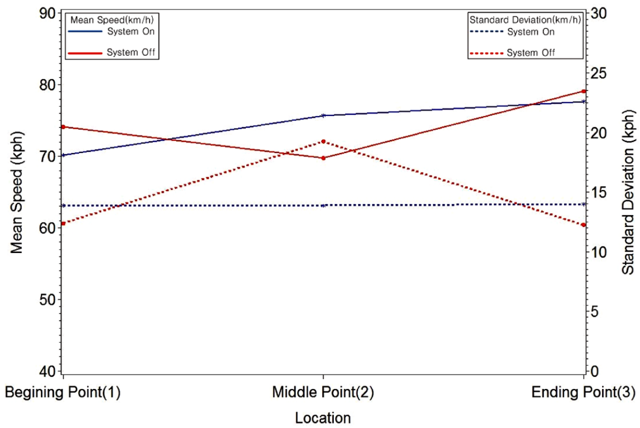

Fig. 5. Mean speeds and S.D. at each measurement point by System On/Off (Clear, Daytime)

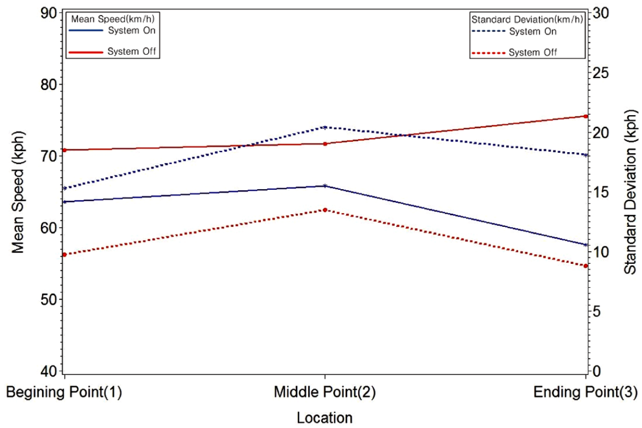

Fig. 6. Mean speeds and S.D. at each measurement point by System On/Off (Fog, Nighttime)

to the otherwise. Looking at the variance of speed among the measurement points, it can note that a difference in the speed variability for the system turned on appears negligible compared to the system turned off. While a reduction in mean speed for nighttime was exhibited from the system turned on, there was no significant difference in mean speeds between the system turned on and off for clear peri-

Table 2. Driving Behavior and Consciousness Surveys

Performance Assessment	Question	Grade
Psychology	If FDWS are not implemented, increasing anxiety when driving in fog	72.3
	After implementing FDWS, having a psychological space when driving in fog	69.7
	After implementing FDWS, feeling at ease when driving in fog	71.3
Behavior	After implementing FDWS, driving safely much more than before	71.0
	After implementing FDWS, affording to look around when driving in fog	68.0
	After implementing FDWS, turning on hazard lights when driving in fog	79.0
	After implementing FDWS, slowing down speed during foggy periods	81.3
Reliability	The location information of the lead vehicle provided by FDWS will help to prevent collisions	74.0
	FDWS provides exactly the location information of the lead vehicle	65.0
	If FDWS notifies to be near the lead vehicle, increasing headway distance	76.7
Preference	Being in favor of installing FDWS	80.0
	FDWS should be installed on roads where fog occurs most often	80.7

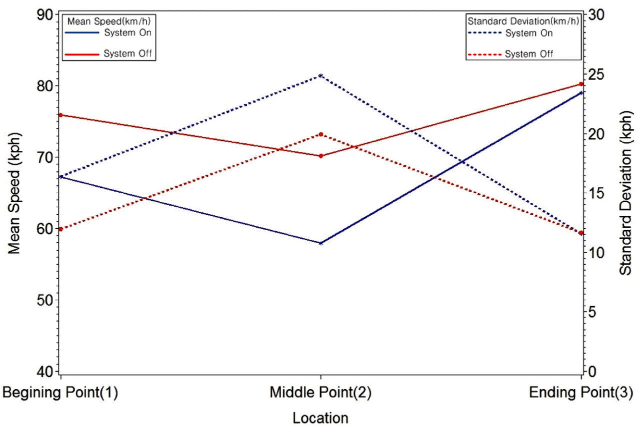

Fig. 7. Mean speeds and S.D. at each measurement point by System On/Off (Clear, Nighttime)

ods and daytime.

Table 2 summarizes the results of the questionnaire survey in terms of psychology, behavior, reliability, and preference. The score of the psychology estimation showed that drivers felt their psychological stability while driving in fog after implementing FDWS. The score of the behavior indicated that the system caused drivers slow down and encourage to increase headway distances. The score of the reliability estimation confirmed that notifying drivers of the location of the lead vehicle would help to prevent collisions. As being expressed a high preference for the system, the high score of the preference showed that FDWS is likely to be popular with drivers if well operated. In summary, it provides evidence that the system as the fog lighthouse on roads is useful helping drivers guide safely in fog.

6. Conclusions

Automatic fog warning systems are promising countermeasures that have been implemented in a few countries where fog-related safety problems on roads recur. The previous study showed that the systems are contributed to reduce speeds and collisions.

The main efforts of this study developed FDWS to provide drivers positive guidance in fog much better than existing fog systems and were to estimate the capability and applicability of FDWS as the fog lighthouse on roads.

The developed FDWS consists of a visibility meter, a light bar, and a microwave sensor. The visibility meter calculates visibility distance according to fog density, and then the estimated visibility distance is transmitted to the light bar installed at every 30m intervals. The light bar which displays a red warning light informs the following vehicle of the position of the preceding vehicle in fog in order to encourage to keep a safety distance between the two vehicles. Since the main light with the high-brightness LED has a high visibility, drivers can easily recognize far away. The microwave sensor together with the light bar is installed to detect the presence of vehicles. The fog management system is automatically activated with one of the three operation modes (i.e., fog-free, light fog, and dense fog condition) depending on fog density during certain foggy periods.

This study installed FDWS on a section of National Highway No. 37 in South Korea to evaluate the performance of FDWS on site and to estimate the effectiveness of the system on driver behavior and consciousness. Estimating the effects of the system on driver behavior was based on changes in mean speed and speed variability. The t-statistic analysis used speed data from the experiment periods (day and night, fog and clear weather). Findings indicate that the system turned on appeared to have the mean speed lower than the system turned off for both daytime and nighttime in fog. In addition, there were no large differences in the variance of speed among the measurement points for the system switched on during foggy periods, compared to the otherwise.

The questionnaire survey conducted for estimating driver consciousness showed that drivers expressed a high preference for FDWS, and then it seems to provide evidence that the system is the positive guidance in low visibility.

On the basis of the findings, it confirms that FDWS could be more beneficial to road safety in fog. The team highly recommends that FDWS is sufficient as countermeasures to guide vehicles or warn them of the presence of the leading vehicle under the prevailing condition.

Another area for future research on FDWS is to estimate the safety- and cost-benefit of the new fog system as it compare to other existing positive guide devices. This study pertained to FDWS. Although the safety estimation indicated that there was a reduction in mean speed from the system, the data for this study were limited to low traffic volumes. Then, a follow-up research is needed to show the effects of FDWS on safety under high traffic volumes in fog.

Acknowledgement

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