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# ANALYSIS OF THE EFFECT OF RAINFALL ON ADAS SENSOR

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**Abstract**

ADAS including LDWS which is designed to support the driver for safe driving has been generalized and used more widely. Such system is intended to supplement driver's carelessness so as to create safe road environment, and viewing from such standpoint, it shall be able to help the driver run safety even at the inclement weather condition such as torrential rain, heavy snow or foggy condition.

But at real rainy weather condition, ADAS is often not functional correctly, failing to provide the assistance. This study is meaningful that it quantitatively measured the effect of rainfall on ADAS performance.

To that end, while the vehicle runs at 60km/h, 48km/h and 30km/h at 4 stages of rainy condition, the change to view range which corresponds to ADAS visibility was monitored. As a result, when the rainfall exceeded 20mm, ADAS sensor became not functional.

The experiment indicated that ADAS failed to function properly at inclement weather condition when the driver was really in need of help by ADAS. Such experiment result indicated the need of technical development which is able to maintain ADAS function at the least at the inclement weather.

**Keywords:** ADAS, performance, rainfall, effect, view range.

## Introduction

Lane departure warning system (hereinafter called, LDWS) is the mechanism to give a driver warning when the vehicle running on the road deviates from its lane. This system was designed to minimize the cause of accident such as careless driving, confusion or drowsy driving and in 2009, U.S. National Highway Traffic Safety Administration(NHTSA) began reviewing to make LDWS and forward collision warning system mandatory [1][2]

In Korea, LDWS became available as part of Advanced Driver Assistance System (ADAS) for the luxury vehicle and in an effort to reduce the increasingly growing accident by heavy-duty vehicle on highway, LDWS became mandatory to bus and truck, beginning in July 2017.

Then the performance of LDWS which has become mandatory for the safety of the driver and people is usually measured at ideal situation such as fine day time when the visibility is granted, but in terms of safety, it's more necessary at unusual weather than usual climatic condition.

This study is intended to review the performance evaluation methodology for LDWS to check the limit as well as test the performance at rainy weather when the performance of LDWS is not

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in normal condition for analysis. Based on the outcome, it's intended to claim that the performance evaluation method of LDWS needs to be changed.

**Review of LDWS evaluation standard**

**SAE Information Report J2808**

This is the test method for OEM and aftermarket LDWS system for light-duty vehicles. It's designed to conduct the test on relatively straight road with curve radius 500m at good weather and the vehicle speed for LDWS operation was set at 44.74mph(72.00205km/h)

**NHTSA-2006-26555-0135**

LDWS specification for light-duty vehicle with GVWR 10,000. It stipulates that when the vehicle runs on test track marked in white line at constant speed 45mph(72.42km/h) for 200feet(60.96m), LDW shall be generated before the vehicle deviated 1.0ft(0.3m) from the lane. The test shall be conducted in two directions (left, right) and repeated 5 times on three types of lane mark (continuous white lines, discontinuous yellow lines, and discontinuous botts dot raised pavement markers) and LDW, to become acceptable, shall satisfy the requirements of 3 tests among 5 and 20 cases of 30 cases shall pass the tests. The requirements for these tests are also based on good weather condition as well.

**Korean standards**

Three types of LDWS-related standards are available in Korea. The standards defining the equipment performance test method include 'Performance test of LDWS for light-duty vehicle - definition of road and environment requirements and test method (KS R 1172)' and the regulation on automobile safety evaluation test (MOLIT Notice No 2019-70, 2018.1.25.)' The regulation on performance and standard of automobile and automobile parts (MOLIT No 534, 2018. 7.11, partly revised) is the guideline which defines the equipment performance requirements.

The requirements for the test vehicle test speed, road and environment conditions, lane subject to recognition and performance requirement are all different as seen in Table 1 and except KS R 1172, all is subject to the test at good weather condition (fine weather, dry road surface, lane painted in good condition) Among them, "Enforcement Regulation of Traffic Safety Act which was established in 2017, requiring bus and truck to have LWDS mandatorily, suggests the regulation on automobile safety evaluation test and the performance standard of automobile and automobile parts. Thus it means that ADAS (LDWS) according to the Enforcement Regulation of the Traffic Safety Act may not properly function in inclement weather.

**Table 1Performance standard of LDWS in Korea**

| Item | Performance test standard | | Performance requirements |
|---|---|---|---|
| | KS R 1172 | Automobile safety evaluation test | Performance requirements of |

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| | | | |
|---|---|---|---|
| | | | **automobile & parts** |
| Vehicle | ·Type is not specified<br>·Less than 150kg including a driver with test device or maximum weight test (5-person loaded vehicle according to agreement between the parties) | ·Passenger car<br>·VAN 4.5ton or less or small truck | ·VAN(excluding compact car))<br>·Truck or special vehicle 3.5ton or less |
| Test speed | 100km/h or more on highway 60km/h on national/local road | 65km/h±3km/h | 60km/h |
| Road condition | ·Curvature: ≥500m, ≥250m<br>·Road: Highway, national/local road<br>·Weather: Good(4 types), Rain (4), snow (4), fog(2)<br>·Others: Tunnel, day/night (with street lamp) | ·Flat and dry asphalt or concrete road surface<br>·Clearly visible lane | - |
| Lane subject to recognition | - | ·Yellow double line (center) white dotted line and solid line (lane) blue solid line (exclusive)<br><br>cf) <LKAS><br>·White solid line | - |
| Performance | - | 90% or more of the total | - |
| Note | | Excluding inclement weather conditions | Warning light when weather is worsened (possibly no lane information) |
| | | **Domestic requirements to be satisfied to participate in the bid for the order (subsidy project) issued due to mandatory LDWS according to MOLIT's Enforcement Regulation of Traffic Safety Act** | |

**Existing standard review result**

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As a result of reviewing existing standard, all standards except 'KS R 1172' which is one of the Korean performance test methods stipulate that the result obtained at the normal climatic condition shall be applied to equipment performance test which may lead to failure of support in inclement weather (torrential rain, heavy snow, fog) to the driver who is in need of such support. As the warning to deviation from the lane to the driver is the only factor that determines the performance, irrespective of information obtained or reliability of information, verification of detail data cannot be made. That is, type of data detected by LDWS, accuracy of data and evaluation standard to determine the reliability are not available in any domestic or foreign standards and thus, as long as the requirements for lane departure warning are satisfied, the equipment is considered acceptable for supply and use, irrespective of the reliability or accuracy of the data. This study was intended to review the data obtained and check how the data was obtained in rainy weather.

## Performance test methodology for lane departure warning system

### Performance test equipment

The equipment used for performance test of LDWS was Mobil eye's 'Mobil eye 630' (Figure 1) which is the equipment used widely throughout the world for its high reliability. Detail information was obtained through Mobil eye 630 and CAN communication and the photo of the equipment and information obtained are as Table 2.


**Figure 1 Mobil eye 630 Camera unit**

**Table 2 List of Mobil eye 630 data for LDWS operation**

| Data collected | |
|---|---|
| · Time<br>· Latitude<br>· Longitude<br>· Model degree<br>· Quality | · Curvature Parameter C2<br>· Curvature derivative Parameter C3<br>· Width left marking<br>· Heading angle<br>· View range |

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| | |
|---|---|
| · Lane type<br>· Position Parameter C0 | · View range availability |

**Characteristics of the data obtained**

As a result of analyzing the lane-related information and the data influenced by inclement weather (rain) among the data obtained through LDWS test and detected by Mobil eye 630 by means of test run, total 4 data were obtained. The type of data and characteristics (definition) which are influenced by inclement weather (rain) on Mobil eye data protocol are as follows. Among major parameters relating to 4 lanes, the parameter relating to visibility is View Range and remaining 3 parameters are related to the accuracy of lane information, because View Range information is the distance to the farthest lane which ADAS (LDWS) recognizes and thus it's considered the visibility to the driver.

1) Quality
   - · 0~3 range representing the quality of lane information
   - · 0,1 – low quality, not give an LDW in that situation/ 2,3 – high quality
   - · Lane information can be obtained even in the situation of quality 0 or 1 and LDWS alarm is provided using the information obtained.

2) Lane Type
   - · Total 6 types
   - · 0 – dashed, 1 – solid, 2 – undecided, 3 – road edge, 4 – double lane mark (including dashed on one side), 5 – Botts' dots, 6 – invalid)

3) View Range
   - · Farthest distance from ADAS (LDWS) on vehicle which is the range of visibility of ADAS (LDWS) in each situation and view point
   - · Value within in range of 0 ~ 127.996m (Actually Range: 0~80 according to test run)

4) Width left (right) marking
   - · Thickness of lane on left (right) of the vehicle (m)

**Detected data analysis method and Test methodology**

Using the parameters (Lane Tape, Width left(right) marking, Quality) that can determine the data accuracy, data filtering was implemented first (deleting error data) Using view range data based on filtering data, LDWS data variation by rain was analyzed.

To check the performance change depending on rainfall, variation of view range obtained from ADAS was analyzed while changing the rainfall to 0mm, 10mm, 20mm and 30mm. Vehicle speed was set at 48km/h and 30km/h from 60km/h for the test in consideration of reduction range during rain.

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Above test was conducted at the Center for Road weather Proving Ground at Yeoncheon. Fig 2 shows the real test situation while simulating the rainy condition at the Center for Road weather Proving Ground.

**Figure 2 View of test environment while simulating the rainy condition**

**Analysis of LDWS data characteristics during rain**

**ADAS data variation depending on rainfall**

When the vehicle speed is constant, View Range which is the visibility parameter in rainfall 10mm and 20mm was reduced in similar pattern. In rainfall 30mm when vehicle speed was 30km/h, View Range reduction was insignificant (decrease in 10m) but at 48 and 60km/h, View Range reached 0 and ADAS (LDWS) was not working.

Assuming View range 15m at transition section of ADAS (LDWS) is the minimum view range, ADAS (LDWS) was still functional at vehicle speed 60km/h up to rainfall 20mm, but in 30mm, it's necessary to reduce the vehicle speed to 48km/h or less or other technology to enhance the visibility is required. The result obtained from the test is as Fig 3.

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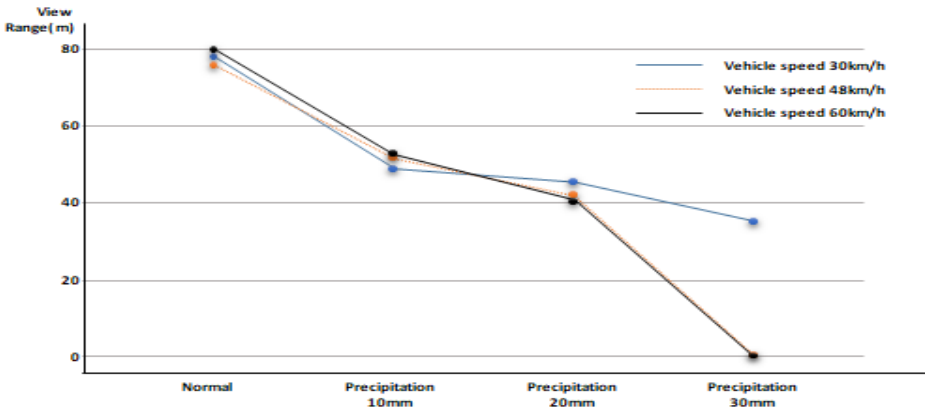


**Figure 3 ADAS data variation depending on rainfall**

**ADAS data variation depending on vehicle speed**

When the rainfall remains unchanged, the faster the vehicle speed he lower the view range which is the visibility parameter of ADAS(LDWS), that is, distribution downward to the right.

Up to rainfall 20mm, 40m view range in average was maintained at vehicle speed 60km/h and in rainfall 20mm, view range 20m or less at vehicle speed 60km/h corresponds to outlier (error)

According to detail review, in rainfall 0mm, view range 80m was maintained irrespective of vehicle speed which is considered ideal environment. But the data at vehicle speed 60km/h needs to be supplemented through the additional data analysis in the Year 2.

As seen from ADAS(LDWS) baseline analysis depending on rainfall, 40m which far exceeds View Range 15m to be obtained was maintained in rainfall up to 0~20mm.

When it comes to rainfall 30mm, view range was 0 from vehicle speed 48km/h, indicating that ADAS (LDWS) was not properly working and the result is as Fig 4.

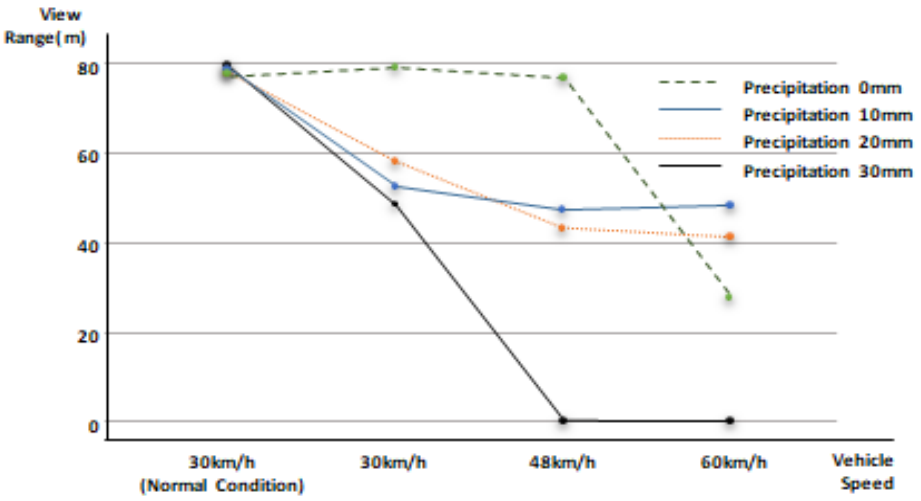


**Figure 4 ADAS data variation depending on vehicle speed**

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## Conclusion

This study shows the empirical verification result on ADAS performance variation depending on rainfall and vehicle speed. The driver is more in need of the system such as ADAS that helps the driver driving in rainy weather. However current ADAS is dependent on image sensor which serves the human's eye and thus ADAS fails to function as long as it's visible to the human. Particularly, the more rainfall the lower the ability to distinguish and recognize the lane information by ADAS as seen from view range analysis.

This means, it's necessary to develop the technology to reduce the decrease in view range even in case of increase in rainfall. Such technology would help the driver (human) secure the view and recognize and determine the situation as well as create the safe environment for driving. The study on autonomous driving and ADAS sensor in the coming days shall include such extreme situation (inclement weather)

## Acknowledgments

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