Development Strategy for Driver’s Night-time Visibility Assessment Solution

1 Young Rok Kim, 2 Chunjoo Yoon*, 3 Minho Park
1 Senior Researcher, Korea Institute of Civil Engineering and Building Technology, Korea
Professor, University of Science & Technology, Korea
2 Researcher, Korea Institute of Civil Engineering and Building Technology, Korea (* Corresponding Author)
Ph.D. Student, Department of Transportation Engineering, University of Seoul, Korea
3 Senior Researcher, Korea Institute of Civil Engineering and Building Technology, Korea

1 cjyoon@kict.re.kr, 2 busbay@kict.re.kr, 3 minhopark@kict.re.kr

ABSTRACT

This paper is aimed to introduce the system (Driver’s Night-time Visibility Assessment System) in progress in Korea, and explain the details for the various comments to build the highly-advanced system. The outcome accomplished to date includes establishing the evaluation method, separately from roadside lighting criteria, for evaluating the driver’s visibility at night as well as evaluating the indispensable elements thereof. In this study, image data were collected to evaluate the driver’s visibility level at night and selected Y value as outcome scale which represents chromaticity value (RGB) of image in luminance value. For measuring driver’s visibility at night, measuring point was set at driver’s eye level and driver’s eyesight was 0.7m or higher. Length of measurement zone was set 160m ahead and image data collection interval was set as 4 seconds. Two evaluation methods were considered; the evaluation depending on luminance on road and relative luminance on road. To that end, continuous measurement technology for measuring and evaluating the visibility is the most important remaining processes. This technology, when developed, would possibly help provide objective judgment guideline for road safety diagnosis which is underway in Korea.

Keywords: Nighttime, visibility, evaluation, road

1. INTRODUCTION

Generally, evaluation of driver’s visibility at nighttime is based on road illumination at the zone where lighting system is installed according to CIE’s roadway lighting criteria, and appropriateness of roadway lighting criteria shall be evaluated by using stationary luminance measuring instrument, which however takes time because it measures up to 10 times at same point as well as requires traffic constraint because it measures at the center of the road, causing difficult to cover a wide area [1].

Roadway luminance is measured by using stationary luminance measuring instrument throughout the world for evaluation of driver’s visibility at night and for other facilities including pavement markings, lightings and delineator, performance evaluation and improvement measures by individually system have been sought, focusing on improvement in material. Carlson and Gibbons et al. studied on improvement of visibility and evaluation in rain at night, focusing on characteristics of the material for pavement marking [2, 3].

Visibility evaluation by individual facility is very unfavorable in terms of reliability, duration and manpower & cost required because of using a mean value by segment measured by the instrument at the zone as representative value. Particularly among others, replacing the whole at certain interval (3 years) instead of replacing based on performance evaluation, securing homogeneity over the sections and shortage of manpower and stationary luminance measuring instrument are critical issues to be resolved.

2. DEVELOPMENT PRINCIPLE

2.1 Technology for Commercialization

1) Changes to Luminance Measurement Method

Point luminance meter is simple to use and accurate but difficult to measure whole luminance while plane luminance meter is able to measure whole luminance but costly and unhandy to carry about and thus the approach using CCD or DSLR camera has been under development [4, 5].

2) Automation of Measurement

Instead of manual measurement, technology to measure the luminance and illumination level of the road using vehicle measurement system which measures automatically the luminance and illumination level at many locations was developed [6]

3) Road Video and Image Photograph System

The system developed in road safety investigation system (RoSAS, ARASEO etc) is used to collect the image ahead on road [7, 8]. The equipment collecting the images at 360° to link with Internet portal map service has been used and video luminance meter (Japan) which is able to measure the luminance ahead on road has also been used in part. This system mounted on vehicle is able to measure the road luminance using CCD camera-based video luminance meter (ELF system) and included in the measurement are average road luminance, overall and lane illumination uniformity ratio.

4) Investigation Using Mobile System

When it comes to Korea, mobile systems are mostly for linear safety diagnosis of the road and...
Pavement Management System but mobile mapping system (MMS) for driver’s visibility has yet to be developed. Table 1 shows and compares the South Korea technologies.

Table 1: Comparison of MMS systems in Korea

<table>
<thead>
<tr>
<th>Model</th>
<th>MIDAS</th>
<th>KRISS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFR</td>
<td>Road Korea</td>
<td>Road Tech</td>
</tr>
<tr>
<td>Equipment</td>
<td>GPS, DMI, Road profiler laser</td>
<td>GPS, AHRS, DMI, Road profiler laser, 360°camera</td>
</tr>
<tr>
<td>Limit</td>
<td>Difficult to analyze road stability with pavement-specialized equipment</td>
<td>Pavement-specialized equipment depending on manual operation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>RoSSAV</th>
<th>ARASEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFR</td>
<td>KICT</td>
<td>KICT</td>
</tr>
<tr>
<td>Equipment</td>
<td>GPS/IMU, Front/side camera, roadside camera, DMI, rotary laser, road profiler laser</td>
<td>GPS/IMU, Front/side camera, DMI, rotary laser, surface water sensor (laser, infrared), road surface texture / temperature sensor (laser)</td>
</tr>
<tr>
<td>Limit</td>
<td>No automatic mapping function for road alignment and road safety diagnosis function</td>
<td>Need for reducing H/W weight for portability (study for improving accuracy &amp; usability is underway)</td>
</tr>
<tr>
<td>Features</td>
<td>Road geometric information collection &amp; analysis function</td>
<td>Road geometric information collection &amp; linear analysis function (facility, linear risk) linear mapping function</td>
</tr>
</tbody>
</table>

2.2 Determination of Development Principle
Currently video luminance meter (Hi-Land Korea) and portable illuminance and luminance meter (Kangwon University) which are designed to collect and analyze the luminance value based on roadway lighting as well as to evaluate the luminance value according to roadway lighting criteria. Then it’s difficult to collect accurate data with mobile instrument depending on observation environment while it’s easy to collect the data with video instrument but the data on distance from the driver to the analysis zone is not accurate which causes reliability problem and extended time for analysis.

To cope with such constraints, investigation while moving, convenience and incorporation of what the driver feels shall be granted, thereby reducing the efforts and time and securing the driving safety at night based on user-focused logical judgment. This study thus adopted the principle to develop the technology that provides mobility. Simplicity and driver’s visibility and road condition as well as continuous investigation and lower cost than existing systems.

3. DETERMINATION OF BASIC ITEMS FOR INVESTIGATION

3.1 Definition of Driver’s Visibility at Night
Wikipedia defines the visibility as “In meteorology, visibility is a measure of the distance at which an object or light can be clearly discerned. It is reported within surface weather observations and METAR code either in meters or statute miles, depending upon the country. Visibility affects all forms of traffic: roads, sailing and aviation. Meteorological visibility refers to transparency of air: in dark, meteorological visibility is still the same as in daylight for the same air”.

According to the study for improving road marking visibility to reduce traffic accident by Yeo, visibility is defined as the distance in which the driver clearly recognizes the object [9]. Visibility from lexical meaning is defined conceptually and in related studies, it’s defined as clearly visible at certain distance. To define the characteristics of visibility, it’s rather difficult to describe other way than conceptual meaning. Viewing the definition of visibility, there are such terms as certain distance or object and it would be possible to define the visibility, should the meaning of them be clearly established. Thus, in defining the visibility at night in this study, MSSD was set as the concept of certain distance and the road and road safety facility including traffic marking was set as the object and road visibility was determined by the road brightness to the stopping distance and linear guidance visibility by the brightness on lane up to stopping distance at least and surrounding safety devices.

![Figure 1: Example of measuring sight at mean road luminance (source: KSA 3701, 2007)](image)

3.2 Driver’s Eye Level and Eyesight
It’s necessary to set up the driver’s eye level to determine the installation height of camera, and according to road facility standard, driver’s eye level is set as 1.0m
and according to roadway lighting standard, instrument shall be placed at 1.5m height.

The equipment to be developed in this study may be simply installed at driver’s eye level (irrespective of vehicle) because road brightness (including luminance) from driver’s view is accurate, but the visibility evaluation equipment to be used by road manager would be desirable to be at 1.0m which provides the worst visibility. When it comes to visual acuity, minimum corrected acuity shall be 0.7m (based on category 2 passenger cars) according to Korea’s Road Traffic Act and standard driver’s acuity was set as 0.7m accordingly.

3.3 Length of Measurement Zone Considering Minimum Stopping Sight Distance (MSSD)

CIE and Korea’s roadway lighting standards require measurement zone at 60m ~ 160m from measuring point as indicated in Figure 1 and necessary MSSD by design speed according to explanation on Korea’s road facility standard is indicated in Table 2 which will serve the base in determining the zone length for measuring the driver’s visibility at night [10, 11].

3.4 Camera Location for Visibility Measurement

Camera installation height was set at driver’s eye level but review of horizontal location is needed. Generally, it’s convenient to place it at black box position (at the middle between driver and fellow rider) but calibration is needed because the brightness depends on angle and thus the images taken from driver’s eye level and black box position will be compared through site investigation.

3.5 Data Collection Interval

The instrument collects the image data while running and excessive data may cause the problem with memory capacity which is rather unfavorable to data analysis. Distance of measurement zone based on roadway lighting standard was 160m and time interval considering the time to be taken is as Table 3 and 4. Given the MSSD according to explanation on road facility standard, optimal time interval for image data collection was considered 4 seconds or less.

4. TECHNOLOGY TO EVALUATE DRIVER’S VISIBILITY AT NIGHT

4.1 Data used for Evaluation

1) Determination of Y Value Indicating Brightness among Chromaticity Coordinates

Viewing luminance value, it’s distributed to the wide range from the dark nighttime to the bright daytime and Y value is easily collected from the image and converted by general conversion formula. Given the

\[
\begin{bmatrix}
Y \\
U \\
V
\end{bmatrix} = 
\begin{bmatrix}
0.339 & 0.587 & 0.144 \\
-0.14713 & -0.2766 & 0.436 \\
0.618 & -0.15499 & -0.10001
\end{bmatrix}
\begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\]

Measurement zone according to roadway lighting standard includes MSSD according to explanation on Korea’s road facility standard in case of design speed up to 100kph, thus in this study, measurement zone was set as 160m, taking into account of MSSD (155m) at design speed 100kph and roadway lighting standard.

2) Estimate of Spatial Data in Measurement Zone

The concept that divides the zone based on vertical pixel after calculating vertical pixel and inverse-conversion factor is applied. Measurement zone is divided into 2~25m, 25~60m and 60~160m and central point of the zone is calculated and then the angle between central points is identified and the distance from measuring point to the central point of the object is calculated.

4.2 Determination of Evaluation Method

In this study, road surface ahead was set as the object for evaluating the driver’s visibility at night and mandatory data to be collected included number of pixel (area of the measurement zone) and maximum/minimum mean Y value. Two evaluation methods were considered: mean luminance on road ahead which can be absolutely compared with other zones and relative luminance of surroundings which can be relatively compared by condition.

Figure 2 shows the images collected for evaluating driver’s visibility at night are divided into 4 zones and based on this evaluation; indices are defined as indicated in Table 5. Where, $L_{\text{surface}}$ refers to visibility on road which represents mean luminance in measurement zone and $RL_{\text{surface}}$ refers to relative visibility on road which is calculated by dividing mean luminance on road by mean luminance of surroundings (roadside and celestial area).

<table>
<thead>
<tr>
<th>Index</th>
<th>Definition and formula</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminance</td>
<td>Mean luminance on road</td>
<td>$L_{\text{surface}}$ Absolute comparison with the visibility of other roads</td>
</tr>
<tr>
<td>Relative luminance</td>
<td>Mean luminance on road / Mean luminance of surroundings</td>
<td>$RL_{\text{surface}} = \frac{L_{\text{surface}}}{L_{\text{peripheral}}}$ Relative comparison by condition</td>
</tr>
</tbody>
</table>

5. CONCLUSION AND FURTHER STUDY PLAN

In this study, as the first step, for the various feedbacks to develop the system, image data were collected to evaluate the driver’s visibility at night and selected Y value as outcome scale which represents chromaticity value (RGB) of image in luminance value.

Necessary standard conditions were set for objective evaluation. That is, it’s defined that MSSD for nighttime visibility as the concept of certain distance, road safety facility with linear guidance function for object and visibility on road is represented by luminance on road till MSSD and visibility of linear guidance is represented by luminance of road marking and road safety facility till MSSD at least.

For measuring driver’s visibility at night, measuring point was set at driver’s eye level and driver’s eyesight was 0.7m or higher. Length of measurement zone was set 160m ahead and image data collection interval was set as 4 seconds. Two evaluation methods were considered and the methods include the evaluation depending on luminance on road and relative luminance on road.

The future study to complete the system includes the followings:

- Establish the method to measure driver’s visibility at night.
- Software Development: Investigation program, Evaluation program, Data management program.
- Driver’s visual test.
Propose the criteria to measure driver’s visibility at night: Quantify the feedback from survey into Fuzzy algorithm and conduct statistical verification and propose a 5 to 7-stage criteria to measure driver’s visibility at night.

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REFERENCES


AUTHOR PROFILES

Chunjoo Yoon received his master’s degree in geoinformatics engineering at the Inha University in Korea. Currently, he is a researcher at the Korea Institute of Civil Engineering and Building Technology as well as a PhD student in transportation engineering at the University of Seoul in Korea.

Young Rok Kim has completed PhD degree in the University of Seoul in Korea. Currently, he is working as a senior researcher at the Korea Institute of Civil Engineering and Building Technology as well as a professor at the University of Science & Technology.

Minho Park has completed PhD degree at the Pennsylvania State University in the U.S. Currently; she is working as a senior researcher at the Korea Institute of Civil Engineering and Building Technology.