Experimental Verification of Performance Method for Vehicle Headlighting Systems in China

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Abstract—As the number of traffic deaths grows each year, traffic security draws more and more attention according to the WHO global status report on road safety 2013. For the sake of assessing the photometric performance of vehicle headlighting systems with a standardized, accurate and reliable method, the CIE 188 Technical Report specifies the methods to assess the photometric performance of vehicle headlighting systems. In order to verify the rationality of the methods described in this report and the suitableness of the methods if used in China, three subjective rating tasks were conducted. An aided software for this experiment was developed and the validity and accuracy of the software was verified by the calculation with a professional machine. The comparison between the results calculated according to CIE 188 Technical Report and subjective rating scores indicated that it was necessary to conduct further research on the methods described in this report before they were promoted in China.

Keywords-headlighting system; CIE 188 Technical Report; software; subjective rating; verfication

I. INTRODUCTION

As the growing number of traffic deaths, traffic security receives more and more attention [1]. During nighttime driving, proper lighting equipment can contribute to improving visibility and thus reducing traffic accidents and fatalities. Therefore, the photometric performance of headlighting system is of big importance to traffic security [2].

An effective headlighting system design is to find the balance between the need to provide good illumination of the road-scene whilst minimizing the effects of glare toward other road users [3-4]. In China, there are three relevant national standards concerning the performance of headlighting systems. They are GB 4599-2007, GB 21259-2007 and GB 25991-2010 [5-7]. The rationale of these standards is to define the basic illuminance in the safety braking distance. Thus, however, using the requirements in these standards to evaluate the performance of headlighting systems is only qualitative. Research on working out method for quantitative evaluation of headlighting system is necessary [8].

In 2010, CIE TC4-45 "Lighting and Signaling for Transport" prepared a technical report titled "Performance Assessment Method for Vehicle Headlighting Systems" (numbered 188, in this paper this report is called CIE 188 Technical Report for short) [9]. This report specifies the methods to assess the photometric performance of vehicle headlighting systems and thus enable the performance of different headlighting systems to be compared. Measurement and calculation procedures are described in the report in detail.

In simplicity, the method in the report is to calculate the performance scores of a headlight system at a number of critical areas of the road scene taking account of the actual installation parameters. For passing beam, aspects for evaluating include range for lane guidance (both on straight road and on curved road), range for pedestrian detection, width for lane guidance and visibility on curves, width for pedestrian detection at intersections, total luminous flux and opposing glare. For driving beam, the aspects for evaluating include range for pedestrian detection, lane guidance and visibility, width for pedestrian detection at intersections and total flux.

However, this technical report just illustrates the way to measure and calculate the several attributes related to headlighting system photometric performance separately. The reasons such as why those areas and isolux curves are chosen for calculation do not interpreted in the report. What's more, preliminary studies for summarizing these methods did not use many Chinese people as subjects [10]. Therefore, it is necessary to verify the correlation between the scores of calculation and subjective assessment using Chinese subjects before using the methods in China.

Besides, the procedure of calculating is quite complicate, inconvenient and unavailable if all the work for measurement and calculation is carried out by hand. It is necessary to develop an aided software to displace some of such work since there's no such customized software developed for calculating procedure according to the methods described in this report at present.

Therefore, the purpose of this study is to develop an aided software for calculation according to the methods described in CIE 188 Technical Report and to investigate the relationship between the scores of calculation and subjective assessment using Chinese subjects, thus verify the suitableness for the methods in CIE 188 Technical Report in China.

II. Methods

A. Experiment Design

This study had two parts. The first part was the verification of the aided software. The verification of the validity and accuracy of the software was achieved by the comparison of the iluminance calculated by the software and a professional machine (LMT LIMES 2000 software). In the second part, several subjective rating tasks were conducted, in order to verify the correlation between the subjective rating scores and that calculated according to the methods in the CIE 188 Technical Report. In total, there are four different headlighting systems (headlighting system A, B, C and D) being evaluated in the study, as shown in Fig .1.

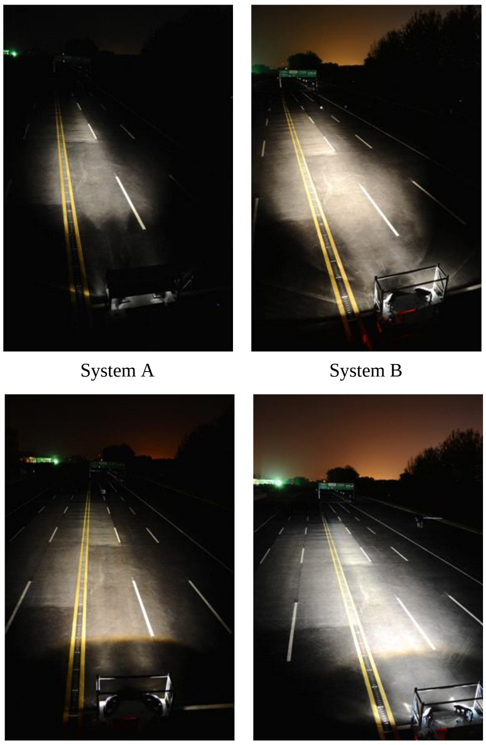


Figure 1. Plan view of the headlighting systems in the study

B. The Aided Software for Calculation

The original data of a headlamp we can get is the vertical illuminance of a vertical plane perpendicular to the road surface at the distance of 25m from the headlight. The scan resolution is shown in Fig .2. In order to accomplish the calculation, using the 111185 illuminance value, the software mainly needs to do the following works:

- Calculate and merge the origin illuminance data of a headlight into the data of two headlamps from the same vehicle, since the origin data we can get is illuminance illuminated by one of the headlamps of a vehicle.
- Calculate and transfer the illuminance of two headlamps of a vertical plane perpendicular to the road surface at the distance of 25m into the vertical illuminance both at the road surface and at a horizontal plane located above the road surface of an optional height.
- Calculate and find the isolux curves of 1lx, 3lx and 5lx.
- Based on the above results, calculate the performance scores according to the methods described in CIE 188 Technical Report.

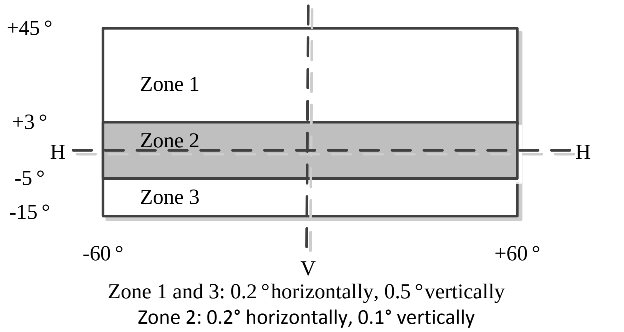


Figure 2. Zones of test point matrices

C. Experiment scene

The subjective rating tasks were carried out on a wide field on in the open air, from 19:00 to about 1:00 of the next day. All the controllable lamps around the field were turned off, in order to guarantee that the ambient illumiance is less than 0.1lx. The experimental field was a simulative road with 6 lanes (also there's some more space on both sides of the road). The width of the lane is 3m while the length is about 200m. The experimental field is shown in Fig .3.

Figure 3. The experimantal field in this study

(the left one was taken at 14:00, the right one was taken at 20:00)

D. Experimental tasks

For the length limitation of the experimental field, this study was only confined to passing beam. Three subjective rating tasks were carried out in this study.

1) Task 1: Evaluation of passing beam range

As shown in Fig .4, the task for evaluating passing beam is to detective the dark grey square target in front of the headlamp. The reflectance of each target is 5% and the dimension is 400mm. The occurring places of the target are all on the right edge or center of the longitude lines of the lane, from the distance of 100m as shown in Fig .4. The target would be moved 10m closer if the observer could not see it. Observers were asked to observe through a screen located behind the headlamps with a distance of 0.5m. The viewing screen is shown in Fig .5.

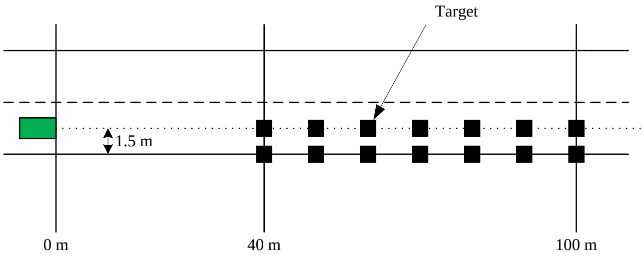


Figure 4. Passing beam range evaluation

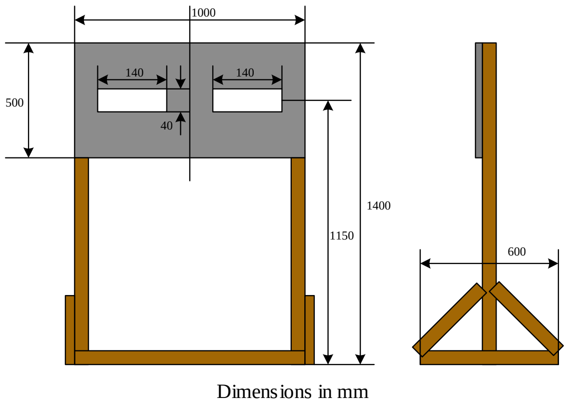


Figure 5. View screen arrangement used for range and width evaluation

2) Task 2: Evaluation of passing beam width

As shown in Fig .6, a series of targets were arranged. Observers were asked to count the number of visible targets for distances of 10m, 20m, 30m, 40m and 50m through a viewing screen located behind the headlamps with a distance of 0.5m. The targets and the viewing scree were the same as those used in Task 1.

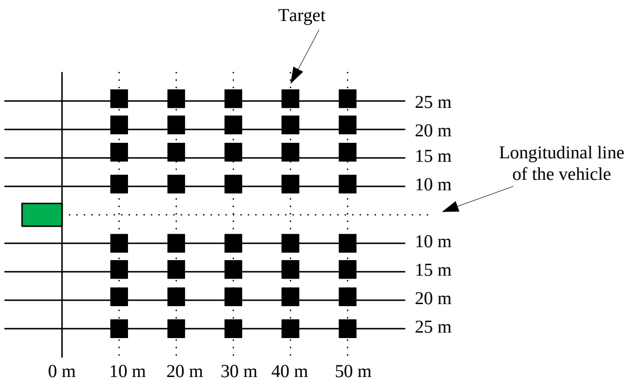


Figure 6. Passing beam width evaluation

3) Task 3: Evaluation of passing beam opposing glare

The opposing glare was assessed by observers located at the center of the left lane and with a distance of 50m from the headlamps. They were asked to assess the discomfort glare level using De Bore's 9-point scale (as shown in Table 1) whilst concentrating on a target located as shown in Fig .7. Observations were recorded for eye heights of 950mm, 1150mm and 1500mm using the viewing screen shown in Fig .8.

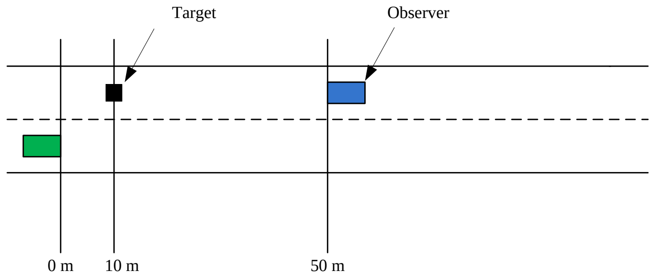


Figure 7. Passing beam opposing glare evaluation

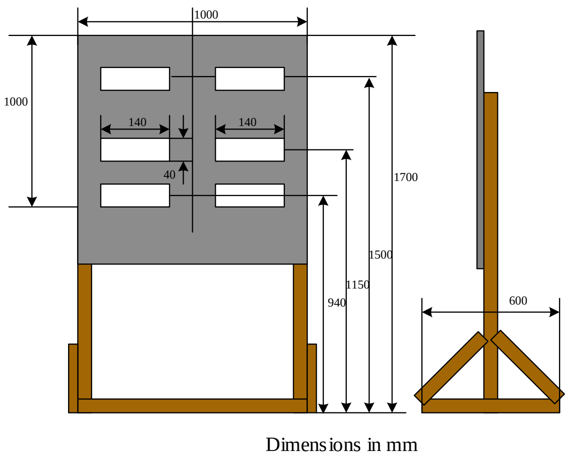


Figure 8. Viewing screen arrangement used for opposing glare evaluation

TABLE I. TABLE 1 DE BORE RATING

No	Description in English
1	Unbearable
2	
3	Disturbing
4	
5	Just permissible
6	
7	Satisfactory
8	
9	Just noticeable

E. Subjects

There were 8 subjects participating in the experiment, aged from 21 to 35. They participated voluntarily. All observers were either with normal or corrected normal visual acuity and no one was colour-blind.

F. Test procedure

Within-subjects design was adopted in the study. For each headlighting system, each subject must be informed the whole procedure of the experiment and accomplish all the three tasks described above.

The following preparatory steps were undertaken before performing the actual experiment.

- Measure and record the detailed lamp and installation data of the four headlighting systems in Table 2.
- Measure the vertical illuminance at a vertical plane perpendicular to the road surface at the distance of 25m from the headlamps using LMT goniophotometers. The scan resolution was that shown in Fig .2.
- Set up headlighting system A to the test stand corresponding to the values in Table 2.
- Turn off other controllable lamps around the field.
- Turn on the headlamps and preheat for a while.

TABLE II. LAMP AND INSTALLATION DATA(PASSING BEAM)

No	Light Source	Voltage (V)	Height (mm)	Separation (mm)	Initial Aim
A	H7	13.2	730	1280	1.00%
B	H7	13.2	760	1400	1.00%
C	D3S	13.2	760	1400	1.00%
D	D1S	13.2	730	1400	1.00%

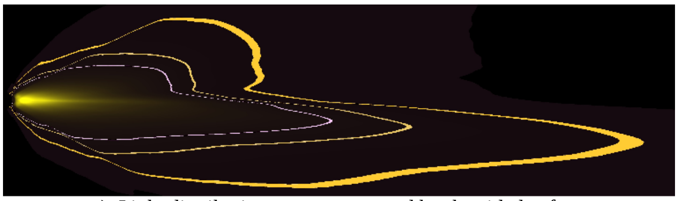
After finishing these steps, the three tasks were carried out for headlighting system A. The same steps were undertaken for headlighting system B, C and D as well.

III. RESULTS

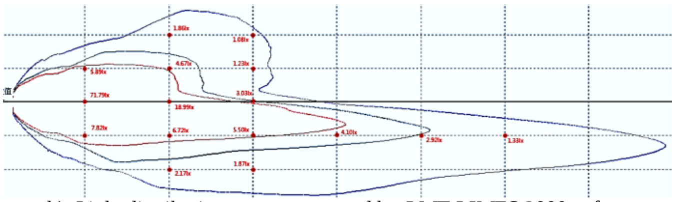
A. Verification of the software

1)Comparion of the light distrubution curves

LMT LIMES 2000 software is the bundled software of the LMT goniophotometers. It can output the light distributions of the headlighting system. Fig .9 shows the light distributions of headlighting system A outputted by the aided software and LMT LIMES 2000 software.



a) Light distribution curves outputted by the aided software



b) Light distribution curves outputted by LMT LIMES 2000 software

Figure 9. Light distribution curves of headlighting system A outputted by the aided software and LMT LIMES 2000 software

It can be seen from Fig .9 that these two light distributions were almost the same with human eye.

2) Comparison with the data measured by hands

Further, 13 random chosen vertical illuminance on the same points outputted by these two kinds of software were recorded. The results were listed in Fig .10. The differences between the illuminance outputted by these two kinds of software were almost all less than 1lx and the average rate of difference was about 6%.

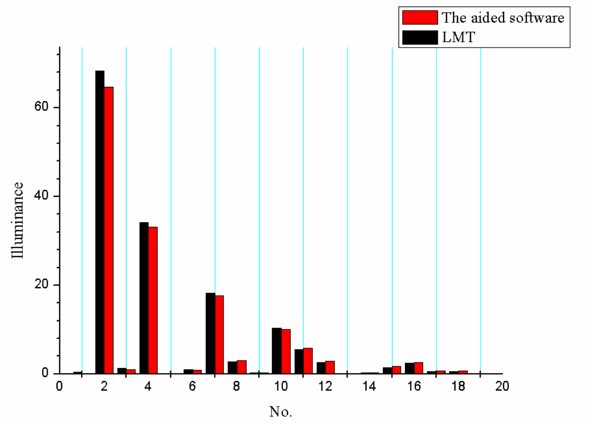


Figure 10. Vertical illuminance outputted by the aided software and LMT LIMES 2000 software

B. Results of the three headlighting systems calculated according to the CIE 188 methods by the aided software

Table 3 lists the results of the four headlighting systems calculated according to the methods described in the CIE 188 Technical Report with the help of the aided software. Higher score means better performance, except for those of opposing glare evaluation.

TABLE III. RESULTS OF PHOTOMETRIC PERFORMANCE CALCULATED BY THE SOFTWARE

Parameters		Headlighting systems			
		A	*B*	*C*	*D*
Range (m)	Straight road	81.90	77.00	102.80	100.00
	Curved road	90.90	88.10	91.50	88.90
	Pedestrian visibility	57.20	53.90	61.80	62.00
Width (m)	Visibility at intersections	11.75	11.25	17.25	16.80
	Visibility on curves	14.80	13.33	27.67	24.27
Opposing glare (lm)		0.70	0.80	0.30	0.30
Total Luminous Flux (lm)		945.80	905.10	1103.60	989.00

Friedman test of the scores of range, width and total luminous flux was used to compare the results of the four headlighting systems (except for glare). The results indicated there were significant differences among the four headlighting systems (p=0.002) and the rank of the scores was C>D>A>B. It means that the scores of range and width of the headlamps with halogen light source is higher than those of HID headlamps.

C. Results of the subjective rating scores

Table 4 lists the results of the subjective rating scores of the four headlighting systems. The results of Friedman test of the scores of range and width of the four headlighting systems indicated that there were significant differences among them ($p=0.013$) and the rank was C>D>A>B. However, the results of Friedman test of the scores of glare rating of the four systems indicated that there was not significant difference among them ($p=0.183$). The results of repeated test showed there were significant differences among the glare rating scores at the three height ($p=0.008$).

TABLE IV. SUBJECTIVE RATING SCORES

Parameters		**Headlighting systems**			
		A	***B***	***C***	***D***
Range (m)	**On the center of the lane**	63.75	47.5	82.5	70
	On the right edge of the lane	61.25	51.25	76.25	66.25
Width (m)	**10m**	10.625	16.25	14.375	18.125
	20m	16.25	20	26.875	21.875
	30m	18.75	15.625	35.625	25
	40m	15	13.75	32.5	28.125
	50m	13.125	13.125	33.125	22.5
Glare	**950mm**	6.625	5.875	6.25	6.375
	1150mm	6.75	6.25	6.875	6.625
	1500mm	6.75	6.75	6.875	6.75

D. The correlation between the calculation results and subjective rating scores

Fig .11-Fig .13 showed the scores calculated by the software and by subjective rating. It can be seen that for range and width, these two kinds of scores has similar trend. However, the results of correlation analysis (pearman) indicated that there was only significant correlation between the calculation results and subjective rating scores of the width on curved road ($p=0.019$).

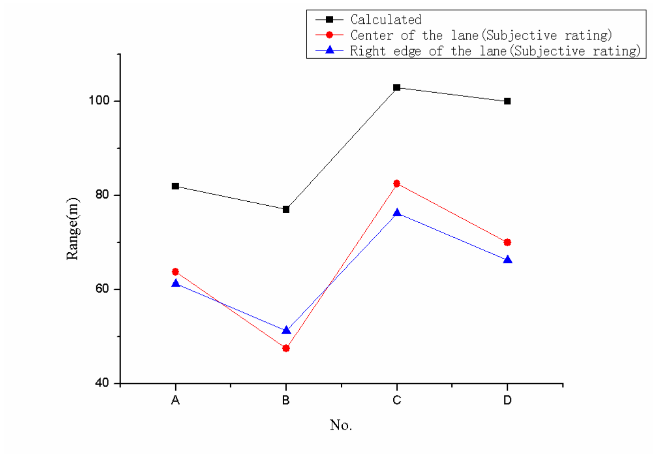


Figure 11. Passing beam range – compassion of calculation and observation results

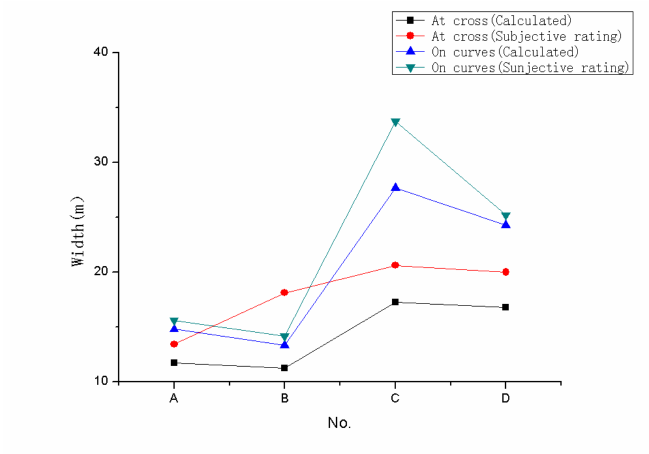


Figure 12. Passing beam width – compassion of calculation and observation results

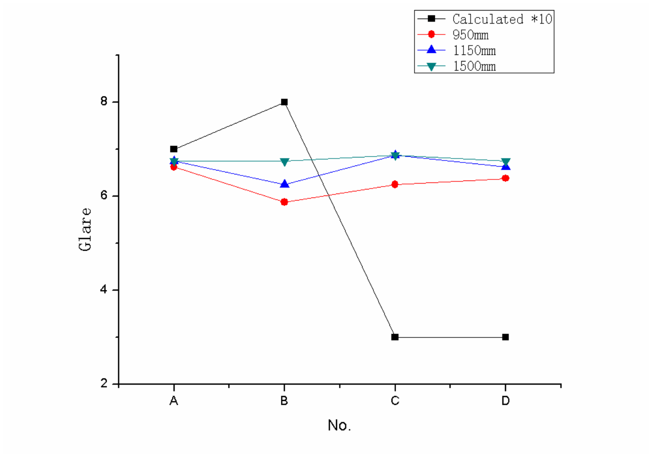


Figure 13. Passing beam opposing glare – compassion of calculation and observation results

IV. DISSCUSSION AND CONCLUSION

A. Verification of the software

In this study, the software was verified by two ways:

- Compare the light distribution curves outputted by the software and a kind of professional software (LMT LIMES 2000).
- Compare the illuminance calculated by the software and a kind of professional software (LMT LIMES 2000).

The results of these comparisons indicated the precision of the software. This verification guaranteed that the software could be used to assist the calculating procedure of headlighting systems' performance scores according to the methods described in CIE 188 Technical Report.

B. Verification of the methods described in CIE 188 Technical Report

In this study, four headlighting systems were calculated the performance according to the methods described in CIE 188 Technical Report and assessed by observers. The results of Friedman test (except for glare) showed the same rank of the four headlighting systems. However, further analysis indicated there were not significant correlations between the calculation results and subjective rating scores. It might be cause by the insufficiency of sample size.

ACKNOWLEDGEMENT

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