Proceedings of TRANSED2004: The 10th International Conference
on Mobility and Transport for Elderly and Disabled People
Hamamatsu, Japan, May 23-26, 2004

STUDY OF INTENSITY OF ILLUMINANCE REQUIRED BY PEDESTRIAN LIGHTING

Kazuhiko Ando*, Nozomu Mori**,Kentaro Hayashi ***

*Senior Researcher, Advanced Road Design and Safety Division

Road Department, National Institute for Land and Infrastructure Management

Ministry of Land, Infrastructure and Transport, Japan

**Head, Advanced Road Design and Safety Division

Road Department, National Institute for Land and Infrastructure Management

Ministry of Land, Infrastructure and Transport, Japan

***Development and Technical Service Division, Industrial Equipment Dept.,

Seiwa Electric MFG. CO. LTD, Japan

SUMMARY

This paper reports the results of a study on the influence of illuminance levels on visibility and ease of walking (or riding) for various categories of pedestrian (elderly persons, non-elderly persons, cyclists, and wheelchair users). Five illuminance levels were employed in the study: 1,5, 3, 5, 10, and 20 lx. It was found that at low illuminance levels (1,5 and 3 lx), pedestrians were able to identify obstacles and other pedestrians in their path but were not able to see the road surface properly or identify details such as faces, and some difficulty was experienced in walking. At 5 lx, wheelchair users were still unable to identify the faces of other pedestrians approaching from the opposite direction. It was concluded that 5 lx represents the minimum illuminance level required in order to enable pedestrians to identify salient visual information at night. If wheelchair users are taken into consideration, then the minimum illuminance level is 10 lx, which ensures the safety of all pedestrian categories.

Keywords: illuminance, pedestrian, bicycle, elderly person, wheelchair

1. INTRODUCTION

The population of Japan is aging much more rapidly than in other countries. Japan has the highest rate of population aging in the world. It is important to ensure that elderly people, wheelchair users, and those with visual or other physical impairments are able to lead independent and autonomous lives by providing appropriate support and encouraging participation in wider society. To this end, areas of pedestrian traffic should be designed to minimize, as far as possible, the physical and mental burden on these categories of pedestrians.

In this study, we considered the issue of pedestrian lighting from the perspective of ensuring the safety of pedestrians, particularly elderly and physically disabled pedestrians, at night. We investigated the level of illuminance at the road surface required in order to ensure the safety and security of pedestrian traffic.

2. OBJECTIVES

The level of illuminance required in areas of pedestrian traffic at night varies depending on the individual physical characteristics of each elderly or disabled pedestrian. A visibility evaluation experiment was used to determine the level of illuminance required to ensure the safety and security of all such pedestrians.

3. OUTLINE OF EXPERIMENT

In the experiment, the test subjects were asked to rate visibility while proceeding along a test course lighted to a given level of average road surface illuminance. The test subjects consisted of 10 elderly persons aged 65 years or over, 10 non-elderly persons,

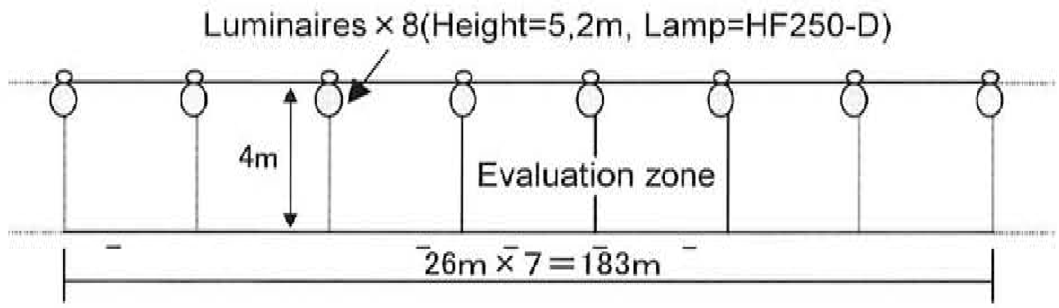

Figure 1. Experimental set-up

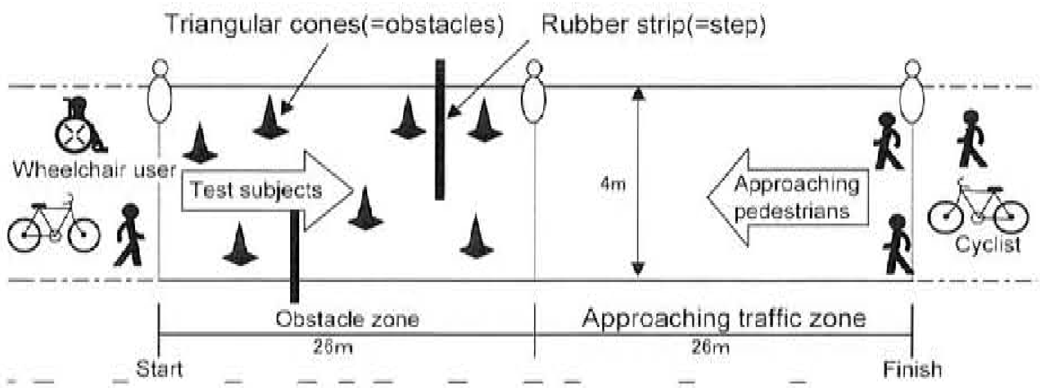

Figure 2. Close-up of evaluation zone

and seven wheelchair users. The non-elderly subjects were asked to perform the visibility ratings both on foot and on bicycle.

3.1 Methodology and conditions

Figures 1 and 2 show the experimental set-up. The test course was 182 m in length, lighted by eight luminaires mounted at a height of 5,2 m and spaced at intervals of 26 m. The evaluation zone was confined to the two middle spans of the test course, a length of 52 m, with a width of 4 m. The first span was designated the obstacle zone, and the second span the approaching traffic zone. The obstacles in the obstacle zone consisted of two black rubber strips measuring 60 mm in height and 180 mm in width laid out across the road surface to resemble steps, and seven blue triangular cones of height 700 mm placed on the road surface to resemble obstacles. The test subjects were asked to pass through both zones in succession. The fluorescent mercury discharge lamps (HF250-D) were used as the source lamps in the luminaries. Road surface brightness was regulated using a combination of optical filters of varying degrees of transmittance attached to the luminaire globes.

Within each span of the test course, the illuminance level was defined as the average of road surface illuminance readings taken at 55 measurement points on a grid created by dividing the span (L 26 m x W 4 m) into 10 sections in the longitudinal direction and four sections in the transverse direction. Five illuminance levels were used in the experiment: the four Recommended Levels of Illuminance (3, 5, 10, and 20 lx) given in Japanese Industrial Standard (JIS) Z 9111[1)], which is used extensively for pedestrian lighting design in Japan, and the minimum illuminance level of 1,5 lx recommended by Publication CIE 115-1995[2)], which is based on pedestrian lighting illuminance standards from around the world. To ensure uniform illuminance across the entire test course, the value derived by dividing the minimum road surface illuminance by the average road surface illuminance was kept to a target of 0,2[3)].

3.3 Evaluation method

The test subjects were asked to pass through the obstacle zone and negotiating approaching traffic (both pedestrians and bicycles) in the approaching traffic zone, then answer yes or no to the six-point checklist shown in Table 1. This procedure was repeated at each of the five illuminance levels.

Table 1. Evaluation items

1	Can see steps and obstacles
2	Can see road surface and proceed without difficulty
3	Can see faces of approaching pedestrians
4	Feel no danger from approaching pedestrians
5	Feel no glare by lighting
6	Lighting is uniform at road surface

Positive response rates were tabulated in each pedestrian category; thus, for instance, if seven out of ten elderly subjects said that they could see the road surface and proceed without difficulty, this translates into a 70% response rate for that item. Response rates of 50% or more were deemed "high" and response rates of less than 50% were deemed "low."

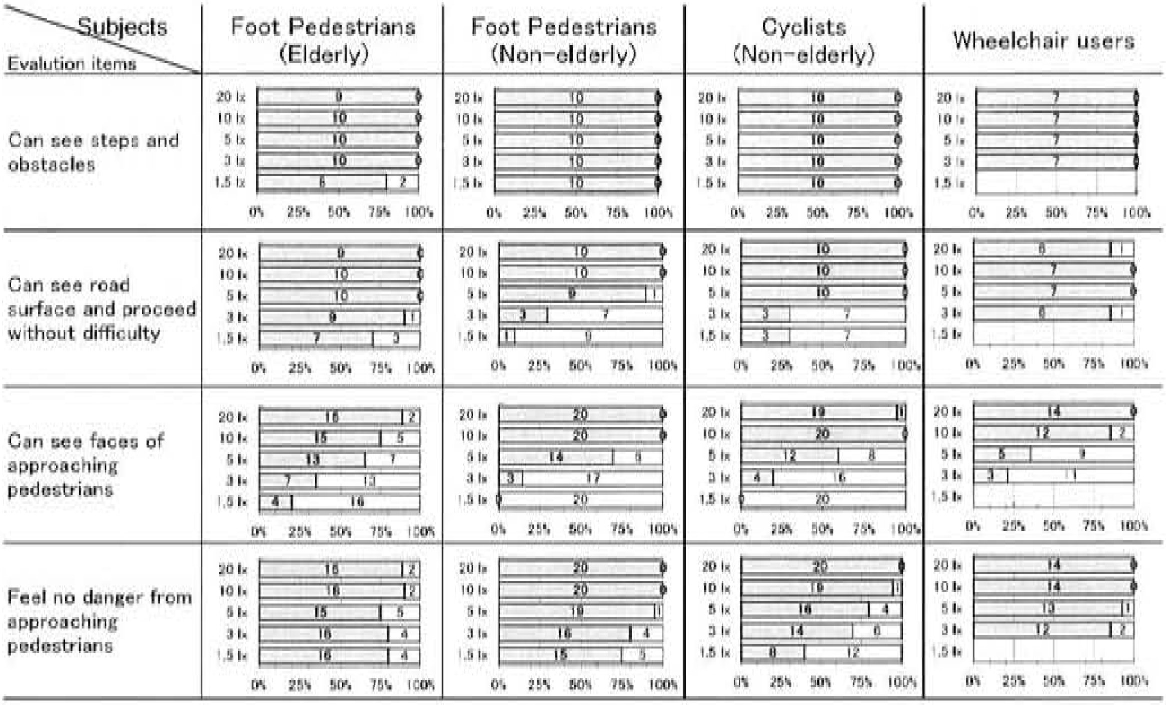

Figure 3. Visibility ratings by subject category
(The X-axis represents the positive response rate. The Y-axis represents the level of illuminance)

4. RESULTS

Figure 3 shows the visibility evaluation results by subject category. On each graph, the Y-axis represents the level of illuminance while the X-axis represents the positive response rate.

It can be seen that the positive response rate to the "can see steps and obstacles" question was high irrespective of the illuminance level. Similarly, high responses were obtained for the "felt no glare by lighting" and "lighting was uniform at road surface" question at all illuminance levels, so these have been omitted from the discussion here.

- Pedestrians (elderly and non-elderly): At 1,5 lx and 3 lx illuminance, both elderly and non-elderly pedestrians had a low response rate in the "can see faces of approaching pedestrians" category. Non-elderly pedestrians also had a low response rate in the "can see road surface and proceed without difficulty" category. Response rates in other categories were high for all illuminance levels.
- Cyclists: At 1,5 lx, cyclists had a low response rate in the "feel no danger from approaching pedestrians" category. Response rates in other categories were similar to those for foot pedestrians.
- Wheelchair users: At illuminance levels of 5 lx and below, wheelchair users had a low response rate in the "can see faces of approaching pedestrians" category. Response rates were high in all other categories irrespective of illuminance level. Wheelchair users were not asked to do the experiment at 1,5 lx.

5. DISCUSSION OF RESULTS

There was a pronounced difference in the response rates of elderly and non-elderly subjects in the "can see road surface and proceed without difficulty" and "can see faces of approaching pedestrians" categories. Whereas 70% of elderly subjects felt that an illuminance level of 1,5 lx was sufficient to see the road surface and proceed without difficulty, only 10% of non-elderly subjects agreed. Thus, elderly people are more likely to be satisfied with a lower level of lighting than non-elderly people in order to see the road surface and proceed without difficulty. The non-elderly subjects were all able to see the faces of approaching pedestrians at a luminance level of 10 lx, whereas some of the elderly subjects were still unable to do so even at 20 lx.

The threshold visibility level needed for pedestrians is influenced significantly by the spatial frequency characteristics of the visual objects. It has been shown[4)] that people can usually walk without difficulty so long as it is possible to discern the general shape of obstacles; this type of visual information is called "low spatial frequency band information." In order to determine a person's gender and recognize a known face, however, it is necessary to identify facial details such as the profile and the eyes and nose; this is called "high spatial frequency band information." Our ability to discern the spatial frequency threshold of an object is governed by factors such as age and surroundings brightness. Mitsui et al[5)] studied the relationship between contrast sensitivity and age for different spatial frequency bands and found that sensitivity in the low spatial frequency band changes little with age, while sensitivity in the high spatial frequency band declines rapidly. The "can see road surface and proceed without difficulty" category in our experiment thus corresponds to the low spatial frequency band, which is why elderly subjects were able to recognize objects and proceed without difficulty even at low luminance levels. Meanwhile, "can see faces of approaching pedestrians" corresponds to the high spatial frequency band, and this is why some of the elderly subjects found it difficult to recognize faces even at high illuminance levels of 10 and 20 lx. However, the link between spatial frequency characteristics and declining contrast sensitivity with age does not adequately explain why elderly subjects had a higher positive response rate than non-elderly subjects in the "can see the road surface and proceed without difficulty" category at low illuminance levels. It may be that concepts such as "can see easily" and "can proceed without difficulty" constitute subjective evaluations of convenience, which are influenced by lifestyle differences and past personal experience that can vary considerably with age. At this stage, we do not know the sorts of factors that govern concepts such as visual comfort and brightness. Further investigation is required in this area.

5.2 Foot pedestrians, cyclists, and wheelchair users

In the experiment, the non-elderly foot pedestrian subjects doubled as the cyclist subjects. They reported that it was harder to discern the faces of approaching pedestrians at low illuminance levels both on foot and on a bicycle. At 1,5 lx, the subjects did not feel any danger when walking but they did feel danger when riding. Riding is faster than walking, which means that a rider has less time than a walker to assess the traffic conditions ahead. In other words, an illuminance level of 1,5 lx is dangerous for cyclists because they are unable to determine whether evasive action is required.

Wheelchair users, who travel more slowly than foot pedestrians, had trouble identifying the faces of approaching pedestrians at illuminance levels of 5 lx and under. This is probably attributable to the fact that their eyes are at a lower level, which means that they can't see as far as foot pedestrians, and also the fact that propelling the wheelchair involves a back and forth movement which means that they have less opportunity (in terms of frequency and period) to look up and assess approaching traffic conditions such as the road lines and the direction in which others are moving. Wheelchair users therefore require higher levels lighting than foot pedestrians in order to provide the same degree of visibility of visual information.

6. SUMMARY BY ILLUMINANCE LEVEL

The findings discussed above can be summarized as follows:

- At 1,5 and 3 lx: Pedestrians can discern the presence of obstacles and approaching pedestrians but experience difficulty seeing the road surface and recognizing details such as facial features and are not able to negotiate their way forward with ease.
- At 5 lx: Pedestrians are able to discern obstacles and see the road surface easily (the basic prerequisites for pedestrian traffic at night), and can also recognize details such as the facial features of approaching pedestrians. Wheelchair users are unable to recognize the facial features of approaching pedestrians.
- At 10 lx and above: Pedestrians of all types are able to proceed safely and securely.

7. CONCLUSIONS AND FUTURE ISSUES

In this study, we evaluated five average road surface illuminance levels with respect to six evaluation items in four pedestrian categories in order to determine the level of the average road surface illuminance required to enable pedestrians of all types to proceed safely and securely in area of pedestrian traffic. Future studies should look at the influence of colour temperature and colour rendering of the source lamp on the perception of visibility in the pedestrian area.

REFERENCES

1) JIS Z 9111-1988, *Roadway Lighting Standard*, Japanese Industrial Standards

2) CIE 115-1995 *Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic*

3) JIEC-006, *Outdoor Public Lighting Standards for Pedestrians*, The illuminating Engineering Institute of Japan, 1994

4) JIER-061, *Preliminary Study of Lighting Visibility Environment Taking into Consideration the Visibility Characteristics of Elderly Persons*, The illuminating Engineering Institute of Japan, 2000, pp. 69 -75

5) MITSUI, T. Older Driver's Visual Ability and Recognition of Road Signs, *Japan: Expressways And Automobiles*, 2001, 44, 11, pp. 37-41