Analysis of Streetlight Illuminance in Residential Areas in Kuala Lumpur

Abdul Azeez Kadar Hamsa*1, Masao Miura2, Osamu Sakurai1 and Sohei Seki4

1Associate Professor, Department of Urban and Regional Planning, International Islamic University Malaysia, Malaysia
2Professor, Department of Architecture and Environment Systems, Shibaura Institute of Technology, Japan
3Hoosiers Corporation, Japan
4Tostem, Japan

Abstract
Safety in residential areas, especially at night is essential as the economy and population rises. Streetlight enhances the safety level in residential areas. The purpose of this paper is to examine the actual measurement of streetlight illuminance at night and perceptions of residents on aspects related to streetlight illuminance by a questionnaire survey. Three residential areas were selected namely Taman Dato' Keramat (TK) (comprising mainly old detached houses), Kampung Pasir (KP) (mainly traditional village houses) and Petaling Jaya (PJ) (modern detached houses). The average streetlight illuminance at all measurement points in the TK area was 7.0lx, the KP area 15.9lx and the PJ area 6.9lx. Consideration regarding the layout of trees and streetlights is also addressed in this paper. It was found that residents' perceptions concerning the brightness of streetlights corresponded with the measurement results in the KP area, whereas, it did not in the TK and PJ areas because of the high frequency of low illuminance points. Obviously, the number of low illuminance points should be reduced so that residents will feel safe. At least two-thirds of the respondents who expressed "very bright" or "bright" about the streetlight illuminance felt that their residential areas are "very safe" or "safe".

Keywords: illuminance; streetlight; field measurement; questionnaire survey; residential area

1. Introduction
The population has been increasing in Kuala Lumpur and other major cities in Malaysia due to rapid economic growth and development (Malaysia Plan 2006-2010). As a result, crimes such as house break-in, snatching and street robbery are increasing in residential areas. Additional security measures such as tall gates with secure locks are often practiced by residents. The functions of streetlights are very crucial to enhance security in residential areas. Incidents of crime, disorder, and fear of physical attack were markedly reduced in selected streets in London following street lighting improvements, Painter, K (1996). Thus, it is highly important to measure the actual brightness of streetlights at night and evaluate residents' perceptions concerning street lighting and its impact on the issue of crime incidences in residential areas.

The authors previous study has provided a platform to gauge some of the variables of the existing living environment including street lights and residents' perceptions in residential neighborhoods in Kuala Lumpur, Kadar et al. (2006) and Japan Miura et al. (2007). This paper examines the actual measurement of streetlight illuminance at night and perceptions of residents on aspects related to streetlight illuminance by a questionnaire survey. The objectives of this paper are: 1) to examine the existing level of brightness of streetlights contributing to a safer living environment for residents 2) to evaluate the perceptions of residents concerning the level of safety of their residential areas in association with the provision of streetlights and 3) to formulate measures for the improvement of streetlights and security of the residential areas.

2. Description of Selected Residential Areas
Three residential areas in Kuala Lumpur namely Taman Dato 'Keramat Tambahan (TK area), Kampung Pasir (KP area) and the Petaling Jaya Section 17 (PJ area) were selected as case study areas following discussions with students of the International Islamic University Malaysia (IIUM). Taman Dato Keramat and Kampung Pasir are old residential areas whereas Petaling Jaya is a relatively new residential area.

The TK area consists of 296 households of detached...
houses. This area is located at a distance of 10 minutes walk from a nearby LRT (Light Rail Transit) station. The residents of this area belong to the middle-income class category according to the Malaysian standard. A majority of residents living in this area are ethnic Malays (more than 75%). This area faces major roads carrying high traffic volume. The KP area consists of 180 households of detached houses. There is no LRT station or railroad in this area but it is located very close to a major highway (Middle Ring Road 2). 'Kampung' means village and physical infrastructures are limited in terms of narrow streets in this area. Ethnic Malays (more than 85%) are the predominant community living in this residential area and belong to the low-income class category.

The PJ area consists of 270 households of detached houses. Unlike the other two residential areas, this area predominately houses an ethnic Chinese community comprising about 70%. The houses in this area are larger than those in the other two residential areas, and the residents belong to the high-income class category.
3. Field Measurement

3.1 Background on the Provision of Streetlights

Background information on the provision of streetlights at three selected residential areas was collected from the local government (authority in-charge for provision of streetlights) in November 2005. According to the standard and guidelines on streetlights, the average horizontal plane illuminance of streetlights at road level should be 10lx; the height of streetlights should be 10m from the road level; and a Halogen lamp of 150W is normally used. Moreover, streetlights are subjected to repair, as and when required, according to a working chart prepared by the local governments.

3.2 Field Survey on Horizontal Plane Illuminance of Streetlights at Night

A field survey to measure the horizontal plane illuminance of streetlights at the road level at selected residential areas was administered. The reason was to identify dispersion of illuminance in terms of bright and dark spots between streetlights. Measurement on streetlight illuminance was recorded at about 901 points in the TK area on November 8th, at 344 points in the KP area on November 10th and at 696 points in the PJ area on November 11th 2005. The streetlight illuminance at 5m intervals horizontally (normally the interval in residential areas as stated by Simons, R. H. et al., 2001) at the road level in the selected three residential areas was measured by using a digital illuminance meter (MINOLTA T-IM). The reason for selecting 5m intervals was to cover as many points as possible within the interval of streetlights to determine the coverage area of illuminance emanating from the streetlights. Measurements were taken from 20:00 to 22:30 intermittently because of light drizzle on the day of the measurement.

Measurements of streetlight illuminance were recorded jointly by the students of the Shibaura Institute of Technology (SIT), Japan (4 students) and the International Islamic University Malaysia (IIUM) (4 students). A briefing session was arranged to explain the details of the measurement approach, use of the hand-held illuminance meter, including instructions regarding the operators’ shadow while measuring the reading, to the IIUM students before the field survey. Four groups were formed with an IIUM and SIT student in each group.

4. Results of Field Measurement

4.1 The TK Area

Fig.1. shows the distribution of streetlight illuminance at night along each road in the TK area based on measured data during the field survey. Table 1.(1) shows the average illuminance (in lx), the number of points and average interval of streetlights along each road in the TK area. Fig.4.(1) shows the average streetlight illuminance along each road in the TK area. A wide difference in the average illuminance between each road was noted. It was also noted that the average illuminance along 13 out of 20 roads (65 percent) did not reach the average standard illuminance of 10lx. The average interval of streetlights in the TK area was 42m, which was the shortest interval among the three selected residential areas. The illuminance at the measurement point at the road level vertically below the streetlight located at a height of 10 m from the road level was above 5lx, but generally low. The average
illuminance at all measurement points was 7.0 lx.
From the analysis, it was noted that the illuminance even directly below the streetlights at the road level at many points was less than 3 lx. This is illustrated in Fig.1. The reasons identified were that the electric bulbs of the streetlights were either fused or blocked by nearby trees. Increasing frequency of maintenance of streetlights to replace fused bulbs is highly recommended.

The analysis also showed that light from the streetlights spreads widely along streets ④⑧⑨⑩, as shown in Fig.1., and thus the average illuminance was approximately 10 lx. On the other hand, the coverage area from streetlights along streets ⑬⑮⑯ was found to be very narrow, as shown in Fig.1., and thus the average illuminance was approximately 5 lx. This showed that the effectiveness of streetlights varies between one street and another.

Fig.5.(1) shows the position of streetlights along street ⑥ in the TK area. It should be noted that trees are not aligned along the same side with that of streetlights. Therefore, the average illuminance of the streetlights along this street was very high. It is important to carefully consider the existing location of trees when installing streetlights to improve illuminance.

4.2 The KP Area

Fig.2. shows the spatial distribution of streetlight illuminance at night along each street in the KP area based on measured data during the field survey. Table 1.(2) shows the average illuminance, the number of points and average interval of streetlights along each street in the KP area. Fig.4.(2) shows the average illuminance along each street in the KP area. The analysis showed small differences in the average streetlight illuminance between streets. The average illuminance at all streets in the KP area was found to exceed the standard average illuminance of 10 lx.

The average illuminance along street ③ was 15.1 lx though the average interval of streetlights is wide.

Even though the average interval of streetlights in this residential area is almost similar to the interval at other selected areas, the average illuminance at all points was 15.9 lx and measured the highest among the selected residential areas. This is mainly due to use of sodium lamps in this residential area as it is an old area and it was also observed that illuminance was not obstructed by trees.

Fig.5.(2) shows the position of streetlights along street ① in the KP area. It should be noted that coverage area of illuminance from the streetlight at the road level was wide despite many trees along the road.

4.3 The PJ Area

Fig.3. shows the spatial distribution of streetlight illuminance at night along each street in the PJ area based on measured data during the field survey. Table 1.(3) shows the average illuminance, the number of points and average interval of streetlights along each street in the PJ area. Fig.4.(3) shows the average illuminance along each street in the PJ area.

The illuminance of streetlights in this residential district was blocked by the presence of many trees.
The analysis showed that the average illuminance was more than 10lx along only one street but generally the average illuminance along each street was low. Moreover, the average interval of streetlights is comparatively wide. As a result, the average illuminance at all points in this residential area was 6.9lx.

Fig.5.(3) shows the interception of streetlights by a tree in street ① thus affecting the function of the streetlight. Illuminance varies between points close to streetlights and points away from streetlights along street ②③④⑦.

4.4 Frequency Distribution of Streetlight Illuminance

Fig.6. shows the frequency distribution of streetlight illuminance at all points in the study areas. Because of high average illuminance in the KP area, the frequency of illuminance less than 10lx was low in KP area compared to other residential areas. The frequency distribution of illuminance in the PJ area was relatively different than that of the TK area even though the average illuminance at each area was almost equal. The frequency of 0 - 3lx was 58% in the PJ area but only 44% in the TK area. Even though the average illuminance at all points in the TK and PJ areas were approximately equal, the frequency of low illuminance points was high in the PJ area.

5. Residents' Perceptions on Streetlight Illuminance

5.1 Method of Survey

A questionnaire survey involving all households at three residential areas was administered from November 12-14, 2005 to ascertain perceptions of residents concerning safe living conditions in association with the provision of streetlights.

Four Japanese students and fourteen (four male and ten female) IIUM students participated in the survey. Briefing on administration of the questionnaire survey was given to IIUM students accordingly. An interview was carried out at each household in the three residential areas Sato et.al. (2006). Fig.7. shows an interviewer interviewing a resident in one of the residential areas. The response rate was generally higher involving female students than their male counterparts. The response rate was 48% (number of respondents = 141) in the TK area, 62% (number of respondents = 112) in the KP area, and 40% (number of respondents = 109), the lowest, in the PJ area.

5.2 Questionnaire

The questionnaire consisted of nine close-ended questions covering security aspects, streetlight illuminance, crime prevention, socio-economic characteristics of the respondents and household characteristics. The languages used in the questionnaire include both English and Bahasa Melayu (the official language).

5.3 Basic Attributes of Respondents

The number of male and female residents was almost the same in the TK area (number of respondents=141) and the KP area (number of respondents=112), but the ratio of female residents was slightly higher (about 60%) in the PJ area (number of respondents=109). The average age of the respondents was about 38 in all three residential areas. Regarding the ethnicity of the respondents, ethnic Malays were predominant in the TK and KP areas but Chinese constituted two-thirds in the PJ area. The average tenure of residence in the present house was 18 years in the TK area, 17 years in the KP area and 13 years in the PJ area. The average household size was six persons in the TK and KP areas but five in the PJ area.
5.4 Perceptions Concerning Streetlight Illuminance

Fig. 8 shows residents' perceptions concerning the streetlight illuminance in the three residential areas. About 69% of the residents in the TK area expressed "very bright" or "bright", 78% in the KP area but only 39% in the PJ area. On the other hand, about 14% of the residents in the TK area expressed "very dark" or "dark", 7% in the KP area and 42% in the PJ area.

Thus, the percentage of respondents in the TK and KP areas who expressed "very bright" and "bright" was higher than those who expressed "very dark" and "dark". While on the contrary, the percentage of respondents in the PJ area who expressed "very dark" and "dark" was higher than those who expressed "very bright" and "bright".

The findings between the questionnaire survey and field measurement showed that residents' perceptions were almost identical with that of the measurement results in the KP area, which recorded the highest average streetlight illuminance at all points. Even though, the average illuminance at all points was equal in the TK and PJ areas, the residents' perceptions were different. The high frequency of low illuminance points in the PJ area compared to the TK area was among the reasons (Fig. 6.) Koyasu et al. (2006). It is highly essential to reduce the number of low illuminance points so that residents feel that streetlights are bright, but more importantly, to feel safer.

5.5 Perceptions Concerning the Level of Safety

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5.5 Perceptions Concerning the Level of Safety

Fig. 9 shows residents' response to the question:
"How safe do you feel in your residential area?" (the area within and immediately surrounding the residential neighborhood). About 56% of the respondents in the TK area expressed "very safe" or "safe", 67% in the KP area and only 48% in the PJ area. On the other hand, about 18% of the respondents in the TK area expressed "very unsafe" or "unsafe", 8% in the KP area but 32% in the PJ area. The residents of the KP area felt that they are staying in a "very safe" and "safe" residential neighborhood but residents of the PJ area felt "very unsafe" and "unsafe". This trend is almost identical with that of perceptions on streetlight illuminance (Fig.8.). Thus, there exists a close relationship between perceptions regarding streetlight illuminance and perceptions on the level of safety in the residential area.

The number of robberies and snatch thefts in Kuala Lumpur recently was about 110 cases and 52 cases respectively according to Malaysia Crime Watch, an independent news and discussion site Malaysia Crime Watch (2009). Street crime made up 17% of the overall crime index in 2008 with 72% of such cases happening in major states including Kuala Lumpur Sunday Star (2009). However although there are no reported actual statistics on street robberies, house break-ins and snatch thefts in the selected residential areas, incidences regarding the occurrence of such crimes have been reported in the local dailies.

5.6 Perceptions on Community Relationship in the Residential Area

The residents' community relationship is also very important in promoting their safe living conditions. Fig.10. shows the residents' response to the question: "How do you feel about the community relationship in your residential area?". About 83% of respondents in the TK area expressed "very good" or "good", 80% in the KP area but only 59% in the PJ area. On the other hand, respondents who expressed "very bad" or "bad" were 24% in the PJ area, only 1% in the TK area and none in the KP area. A very low community relationship especially in the PJ area was noted. It should also be noted that a high percentage of residents (about 32%) in the PJ area expressed "very unsafe" and "unsafe" concerning the level of safety. The residents in the PJ area were predominately (about 70%) ethnic Chinese and their income level is generally higher than the residents in the other two residential areas. It can be concluded that the residents' perceptions regarding the community relationship influences their perceptions concerning safe living conditions in the residential area.

5.7 Relationship Between Streetlight Illuminance and Level of Safety

Fig.11. shows the relationship between streetlight illuminance and level of safety in the three residential areas. Generally speaking, it was found that as residents' perceptions toward brightness of streetlights change from "very dark" to "dark" to "bright" to "very bright", their views concerning level of safety from "very unsafe" to "unsafe" to "very safe" and "safe" also change. In other words, respondents felt very safe as the streetlight illuminance became brighter. It was found that at least two-thirds of the respondents who expressed "very bright" or "bright" felt that their residential area was "very safe" or "safe". These findings were found to agree with a study stating that improvement in streetlights would provide a safer living environment (more than 80%) in a neighborhood, Painter, K (1996). It is important to ensure that streetlights are brighter so that residents feel that their residential areas are safe.

5.8 Relationship Between Community Participation and Level of Safety

Fig.12. shows the relationship between community relationship and level of safety. Generally, in all three selected residential areas (TK, KP and PJ), as respondents' perceptions toward community relationship vary from "very bad" to "bad" to "good" to "very good", their views on level of safety from "very unsafe" to "unsafe" to "very safe" and "safe" also change. However, in the PJ area, the total percentage of respondents who expressed "very safe" and "safe" regarding the level of safety in their residential areas was only 48%, even when they expressed that their community relationship was "very good" and "good" (59%). There are some limitations for residents in the PJ area in expressing that their residential area is safe even though they have a strong community relationship. It is important to make the community relationship in residential areas better for safe living, however, in some other areas, the residents' view regarding safety level were not high even though they had a strong community relationship.

It was also found that there is no clear relationship between household tenure and level of safety and also between household size and level of safety.

6. Discussion

The findings showed that streetlights are very instrumental in improving the living environment of the neighborhood as perceived by the residents. It is generally learned that some crimes normally take place at dark spots because of the absence of visibility and recognition at a distance. Although it can be seen that improved street lighting is not a straightforward solution to eliminating crime altogether and bringing safety to residential areas, however, it is generally agreed among residents that if streets are brighter it will have a positive effect on safety. It includes a greater sense of attachment to the living areas, greater visibility, and increased pedestrian circulation. As Painter, K. (1996) pointed out, improved lighting is an immediate means of cost effectively creating a sense of public safety, enhancing the quality of the built environment and increasing the number of people on the streets after dark. The perceptions of residents concerning streetlights and safety are imperative, as highlighted in the findings of this study, in the sense that it may translate into residents freely walking in residential areas after dark, thereby increasing the number of pedestrians walking in the neighborhood at night to accomplish activities. As stated by Painter, K.
Perceptions concerning safety were found to vary among ethnic groups with respect to actual measurement of streetlight illuminance in the three selected residential areas. A high percentage of residents in PJ, a predominately Chinese community, expressed unsafe living environment (about 32%) as it was found to be related to the high frequency of low illuminance points in that area. It is also noted that residents in the PJ area generally live in bigger houses and belong to the high-income category compared to residents in the other two residential areas.

Studies showed that streetlights also increase natural surveillance of the streets in the neighborhood by increasing pedestrian density and traffic flow Painter, K (1996). This will make the area more vigilant in the sense that people are being watched and may come to the rescue if there is any potential attack. Additionally, streetlights also act as an environmental strategy in providing a positive image in terms of the physical environment of the area. Brightness and visibility will make the area safer for living with the absence of other contributing factors.

7. Conclusions
This paper has provided an insight into the existing streetlight illuminance in the selected residential areas and residents' perceptions concerning their level of safety in relation to the provision of streetlights. Provision of streetlights is very important in ensuring the safety of the residents living in residential areas. It is also equally important to ensure adequate brightness along each road in such areas, as prescribed in the standard and guidelines of streetlights, to promote safety. The measurement of streetlight illuminance in the selected residential areas showed that the average streetlight illuminance at all points was 7.0lx in the TK area, 15.9lx in the KP area, and 6.9lx in the PJ area. In the TK and PJ areas, it was found that the streetlights were blocked by trees, thus, reducing the level of dispersion of light along the road. Even though, the average illuminance at all points in the selected residential areas was approximately equal, the frequency of low illuminance points was high in the PJ area. The recommended measures to achieve the maximum brightness of streetlights include: carefully considering the layout of trees in terms of shape and growth while installing streetlights along the streets, increasing the frequency of maintenance of streetlights to replace fused bulbs, if any, and regular average interval between streetlights. This will, eventually, enhance the feeling of safety and security among the residents.

The residents' perceptions concerning the brightness of streetlights were found to be identical with the measurement of streetlight illuminance in the TK and KP areas. However, the residents' perceptions were different in the PJ area because of the high frequency of low illuminance points. It is highly recommended to reduce the number of low illuminance points so that residents will feel streetlights are brighter and as a result they will also feel safer. It is noted that the residents' perceptions regarding the brightness of the streetlights and community relationship were found to have influenced their views on the level of safety in the selected residential areas.

At least two-thirds of respondents who expressed "very bright" or "bright" concerning the brightness of streetlights felt that their residential areas were "very safe" or "safe". It is important to ensure that streetlights are brighter so that residents feel that their residential areas are safe. Additionally, it is also important to make the community relationship in the residential area better for safe living, but in the PJ area, it was found that there exist some limitations in expressing "safe living" even though the neighborhood has a strong community relationship.

This paper showed that streetlight illuminance plays a very important role in promoting the safety level of the residents. With strong community participation, it provides close social bonds among the community thus ameliorating further safe living for the residents in the residential neighborhood.

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