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INCORPORATING PEDESTRIAN INDEX INTO GOOGLEMAPS

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Abstract

The trend for new urbanism which encourages public transportation usage has increasingly focused on pedestrian facilities. Pedestrian facilities can be defined as facilities that continuously provide pedestrians with safe access to land uses. Unfortunately, roadway design prioritizes the needs of motorists while putting pedestrians at risk. A number of studies have developed methods to determine pedestrian Level of Service (LOS). However, none have considered the road hierarchy which has a different design standard, level of road usage, access management and scope of pedestrian needs. This paper develops a pedestrian index (P-Index) which incorporates selected indicators according to road hierarchy in evaluating pedestrian facilities. The index is an analytical tool to rate pedestrian facilities using 5 star rating formats whereby the higher the number of stars, the better quality of facilities of a particular pedestrian segment. The method focuses on four indicators namely Facility, Mobility, Safety and Accessibility. Using Taman Bukit Indah, Johor Bahru as the study area, it was revealed that the overall quality of pedestrian facilities achieved three stars, which are interpreted as walkable. The rating scores of pedestrian facility are next incorporated into Google Maps to enable the public to visualise the rating score of pedestrian facilities. The index can also serve as an evaluation tool by the authorities for auditing purposes in the provision and monitoring of pedestrian facilities.

Keywords: pedestrian index, pedestrian facilities, level of service, road hierarchy, evaluation tool, visualization

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INTRODUCTION

As population and vehicle miles traveled continue to grow, transportation planners, engineers and policy makers are looking to non-motorized transportation, often in combination with transit, to relieve some of the pressure of the traditional transportation system. Transport planners are increasingly focusing on pedestrian facilities in order to enhance public transportation usage as a measure to achieve the objectives of sustainable urban development.

The functionality of a roadway should be balanced with the needs of pedestrians. Pedestrian facilities can be defined as facilities that continuously provide pedestrians with safe access to land uses. Unfortunately, roadway design prioritizes the needs of motorists while putting pedestrians at risk. Pedestrians would be well accommodated if they received the same design considerations as motorists. To accomplish this task, roadway designers must understand how road design impact pedestrians and prioritize accessibility. Despite becoming a key policy requirement, no tool is yet available to measure the quality of pedestrian facilities in relation to different road hierarchy.

This paper presents a pedestrian index method that measures and relates pedestrian facilities to different road hierarchy. Pedestrian facilities can be defined as facilities that continuously provide pedestrians with safe access to land uses. This study focuses on four indicators to evaluate pedestrian facilities namely, facility - promote ease of usage; mobility - continuously available; safety - physically and spatially separated; and accessibility - closeness to land uses.

This paper will next review the current risk facing pedestrians, followed by the discussion on the method of assessment on the quality of pedestrian facilities. The next section shows the derivation of the pedestrian index (P-Index) and the computation of the P-index for the study area. The final section demonstrates the application of the P-index in the Google Maps.

PEDESTRIANS AT RISK

Based on statistics road accidents were the third highest cause of death among Malaysian whereby it was reported that 25 of every 100,000 Malaysian died in year 2003 alone (Royal Malaysian Police 2004). The increasing trends in car ownership further heightened the number of conflict between pedestrians and vehicles. The Malaysian Motorcycles Safety Program launched by the Malaysian Government in 1996 involving black spot treatments, overtaking lanes, motorcycle lanes, junction improvement and curve improvement have been successful in controlling the problems involving motorcyclists. However, pedestrians as road users have not been given attention although they are categorized as a vulnerable group. In Malaysia, most of the people killed by road accidents are pedestrians, cyclists and motorcyclists (Royal Malaysian Police 2008). Although the main reasons that attributed to the high numbers of pedestrians accidents is due to careless crossing (Goh et.al. 2012), the lack of good quality pedestrian facilities is an equally important factor.

Generally, pedestrian safety has not been given recognition. At present, not all roads are provided with pedestrian facilities (Public Works Department 1995). The existing pedestrian walkways are either badly built or poorly maintained. Many footpaths are obstructed by holes, garbage, tables and chairs and even vehicles. The vulnerability of pedestrians is further increased when they have to negotiate among moving traffic while crossing. Noise, fumes, obstructions and dangers from speeding vehicles also increased roads hostility, which makes it unpleasant to walk.

Table 1 shows the road fatality statistics for all categories. It can be seen from that the number of death involving pedestrian is the third highest after car passenger/drivers and motorcycle pillion/rider. If the number of road fatalities involving pedestrians is combined with bicycle pillion/riders, which in most cases share the same space, the total is higher than any other categories which are 27%.

Table 1: Road Fatality Statistics from July 2008 and 2009

Consumer Categories	2008	2009	Difference	Percentage (%)
Passenger/Driver Car	102	127	25	24.5
Motorcycle Pillion/Rider	300	374	74	24.7
Pedestrian	47	53	6	12.8
Pillion/Rider Bicycle	21	24	3	14.3
Bus Passenger/Driver	1	1	0	0
Driver/Lorry Attendant	14	16	2	14.3
Driver/Attendant Van	12	9	-3	-25
Driver/Attendant Race 4 Wheel	11	8	-3	-27.3
Others Vehicle	1	6	5	500
Total	509	618	109	21.4

Source: Royal Malaysian Police (2008-2009)

Table 2: Pedestrian Accidents Injury Type (2005-2010)

Injury Type	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Fatal	601 (17%)	595 (21%)	636 (23%)	598 (25%)	593 (25%)	626 (29%)
Serious Injury	747	711	672	617	613	516
Light injury	2175	1493	1430	1184	1171	1019
Total	3523	2799	2738	2399	2377	2161
Total Registered Vehicles & Total Population as at 31 December 2010						
Total Registered Vehicle *	14,816,407	15,790,732	16,825,150	17,733,084	19,020,000	20,006,953
Population **	26,130,000	26,640,000	27,173,600	27,728,700	28,310,000	29,845,448
Pedestrian Deaths Rate						
Death / 10,000 vehicles	0.40	0.38	0.37	0.33	0.31	0.31
Death / 100,000 people	2.30	2.23	2.34	2.16	2.09	2.10

*Source: ** Statistical Department; *Transport Department, Ministry of Transport (MOT) & Royal Malaysian Police (2005-2010)*

Although pedestrian death rates per 10,000 vehicles and per 100,000 peoples have reduced from 0.40 in 2005 to 0.31 in 2010, the number of pedestrian fatalities has remained constantly high at an average of 608 deaths per year with the highest number of 636 in 2007. By implication, efforts to improve pedestrian safety have been minimal since there is negligible difference between the yearly death rates.

THE RELATIONSHIP OF ROAD HIERARCHY AND PEDESTRIAN FACILITIES

The road network system is based on a simple hierarchy which is a means of defining each roadway in terms of its function such that appropriate objectives for that roadway can be set, and appropriate design criteria can be implemented. Most trips originate on local roads, before going through collector roads and ultimately to arterial road, which are intended to carry a large volume of vehicle at relatively higher speeds. This system is based on the assumption that most trips occur by motor vehicle, so most of the facilities are designed primarily for motor vehicle travel (FHWA 2009). The system results in road designs that do not serve pedestrians well for several reasons as follows:

- Some collector and arterial streets are built with inadequate or no sidewalks or walkways, discouraging or limiting safe pedestrian movement along streets.

- Since arterial roads are designed to facilitate smooth and efficient motor vehicle flow, they often have multiple lanes in each direction to accommodate high motor vehicle traffic volumes. It has a direct effect on the complexity of road crossing, thus increasing risk to pedestrians.

- Wide streets encourage and allow higher vehicle speeds, which relate directly to more severe injuries to pedestrians when an accident occurs.

- Typically, wide arterial streets have intersections that are even wider due to the addition of multiple turn lanes. This requires pedestrians to cross longer distances and watch for more cars in more lanes.

- Wide intersections and those with multiple turn lanes create a long wait for pedestrians. If a crosswalk is closed, the pedestrian is left with three choices: cross illegally with no signal protection, walk a long distance around the intersection, or walk to another location to cross.

Until transport planners integrate the needs of pedestrian facilities for all types of road, the transport system will not work in totality. For example, for arterial road which accommodate high volume of vehicles running at relatively high speed, traffic signal should be provided to facilitate pedestrian crossing. On the other hand, the volume and speed of vehicles for local road is significantly low, so it is not necessary to provide zebra crossing. Therefore, it is important to consider the characteristics and requirements of different road hierarchy in designing facilities for pedestrians.

METHODS OF ASSESSMENT FOR THE QUALITY OF PEDESTRIAN FACILITIES

Evaluation of pedestrian facilities is important to determine how well a facility is fulfilling its intended objectives. However, there are various factors which need to be considered when assessing the quality of pedestrian facilities since it varies according to the needs of pedestrians.

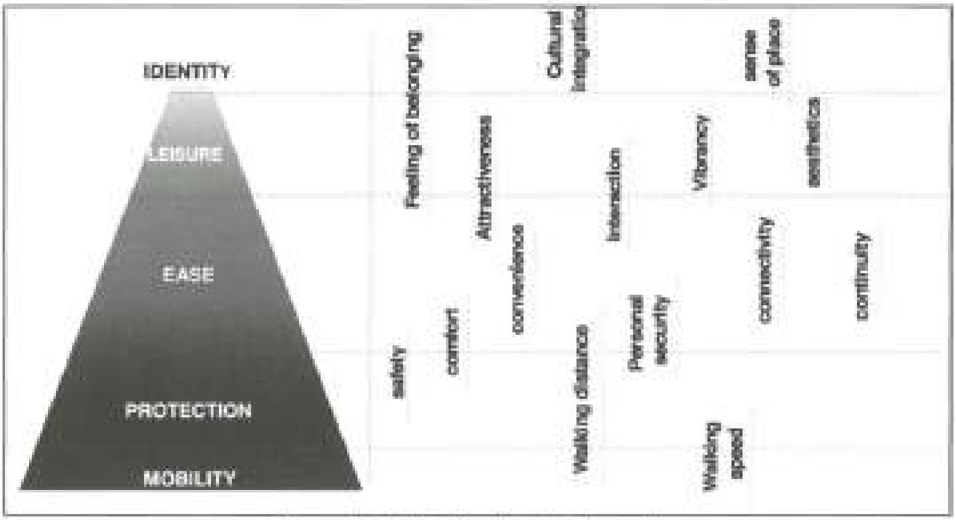

Figure 1: Pedestrian Needs Hierarchy

Source: Babiano 2003

Figure 1 shows the pedestrian needs hierarchy proposed by Babiano (2003). The diagram has been adopted based from the human needs concept by Maslow (1968) and Max-Neef (1992). The attributes indicated on the right side of the figure corresponds to the factors that would directly fulfill the particular need on the left. There are factors that could satisfy two or three needs at the same time. It is hypothesized that the basic need of pedestrians is to move. Fulfilling the needs hierarchy would provide a corresponding increase in the satisfaction level of pedestrians.

At the lowest level, pedestrians need to move from an origin to a destination point. Given that the need for movement has been satisfied, the next level of need for pedestrians is to feel protected, meaning to feel safe along walking paths. In the next level, after the need for protection is satisfied, pedestrians would want to feel at ease while walking. This refers to more secure, comfortable and convenient walking paths. On a higher level, if pedestrians would feel at ease, he would want to enjoy his walking experience. This level is dependent on various factors such as location of pedestrian facility and level of hierarchy of roads. On the highest level is the need for identity which refers to the concept of being able to identify with the surroundings.

Review of existing pedestrian facilities is important as part of an overall strategy to ensure that walking facilities provide acceptable levels of connectivity and demonstrate design consistency. Because of the various levels of needs, different methods have been applied to assess pedestrian facilities.

The level of service (LOS) concept was first developed for vehicular capacity studies connected with street and highway design, and it was later adopted for pedestrian facilities. This section reviews selected methods to evaluate pedestrian facilities according to different variables from previous studies (Sarkar 1993; Khisty 1994; HCM 2000; Landis 2001).

Sarkar (1993) proposed a qualitative method to compute pedestrian LOS based on six factors, which are safety, security, convenience and comfort, continuity, system coherence and attractiveness. She described qualitative attributes of pedestrian environments as opposed to their quantity, thus, the measurement of each factor cannot be easily calibrated.

A methodology which results in a LOS of the facility as perceived by its users was developed by Khisty (1994). He identified six criteria namely; attractiveness, as a pleasant and interesting walking experience; comfort, which refers to adequate space to enable ones to walk at their own pace; convenience, which is good connections and services; safety, which refers to conflicts with cars and with other pedestrians; security, such as good lighting and police presence and lastly system coherence, which means clear orientation and easy navigation. Although Khisty's method provides a quantitative measure of pedestrian LOS on a point scale, the results from this scale is not easy to interpret. A fundamental question remains as whether these scaling systems really address the pedestrian facilities and do pedestrians agree with these scaling systems.

The Highway Capacity Manual (HCM 2000) defines six ranges of LOS (from A to F). However, pedestrian facilities are given equal treatment with the other motor vehicles. A mathematical model was proposed by Landis et. al (2001) based on five variables: lateral separation of pedestrians from motor vehicle traffic, presence of physical barriers and buffers, outside lane traffic volume, motor vehicle speed, and vehicle mix. The Landis's model has been developed for roadway segments only, but intersections have not been considered.

Table 3 summarizes the limitation of various models in assessing the pedestrian LOS. It can be concluded that different variables and evaluation criteria were considered, and as a consequence, there is no definite method to assess pedestrian LOS. However, none of the methods considers the need of pedestrian facilities according to road hierarchy. Thus, this research fills the gap by incorporating selected criteria of pedestrian LOS, as well as road hierarchy into the P-Index computation.

Table 3: Limitation of Various Models in Assessing the Pedestrian LOS

MODEL	PEDESTRIAN LOS EVALUATION CRITERION / VARIABLES	LIMITATION / SHORTCOMING OF MODEL
Sarkar (1993)	Safety, Security, Convenience and Comfort, Continuity, System Coherence and Attractiveness	Qualitative attributes of pedestrian environments are described, but not quantified.
Khisty (1994)	Attractiveness, Comfort, Convenience, Safety, Security, System Coherence and Continuity	Although Khisty's method provides a quantitative measure of pedestrian LOS on a point scale, the results from this scale is not easy to interpret.
Dixon (1996)	Provision of Basic Facilities, Conflicts, Amenities, Motor Vehicles LOS, Maintenance, Travel Demand Management, Multimodal Provisions	The method is simple and easy to apply but criteria points are randomly chosen.
Highway Capacity Manual (2000)	Space available per pedestrian, Flow Rates, Speeds	HCM 2000 focuses on ease of movement which bias to motor vehicles
Landis (2001)	Lateral separation of pedestrians from motor vehicle traffic, Presence of physical barriers and buffers, Outside lane traffic volume, Motor vehicle speed and Vehicle mix	The model has been developed for roadway segments only. Intersections have not been considered.
Gallin (2001)	Design factors, Location factors and User factors	This model is based on physical description of pedestrian facility and their weightage in Pedestrian Level Of Service score. Pedestrians' perception is not included in the calculation.

STUDY AREA

This research was conducted in Taman Bukit Indah, Johor Bahru, Johor. A township located in the heart of Nusajaya, Iskandar Malaysia, Johor. The township launched in 1997, has a population of over 60,000 with over 10,000 houses. Bukit Indah is designed based on the award winning "Australian Green-Street Concept" characterized by extensively landscape environment and meticulously designed houses with wide access ways. The township recognized as one of the better design development has won an array of landscaping awards including the Johor State Landscape Award 2001, National Landscape Competition 2001 and Best of the Best National Landscape Award 2005.

The neighborhood was selected as the study area because it is the hub for human activity. Walking is the most convenient mode of movement due to the proximity to the different type of land uses. However, there are several hypermarkets and facilities located within the town center of Taman Bukit Indah which generate high volume of motorized traffic. Hence, there is a need to assess whether the facilities are pedestrians friendly.

The study of pedestrian facilities was conducted on various road segments covering different types of road hierarchy including the Arterial, Collector and Local roads (Table 4).

Table 4: The Detail Information of Selected Road Segments

Road Segment	Road Hierarchy (Width in feet)	Road Name	Road Length (km)
1	Arterial Road (66)	Persiaran Indah	3.16
2	Arterial Road (66)	Jalan Indah Utama	1.90
3	Collector Road (50)	Jalan Changkat Indah	1.83
4	Collector Road (50)	Jalan Indah 15/2	0.71
5	Local Road (40)	Jalan Indah 17/5	0.26
6	Local Road (40)	Jalan Indah 18/4	0.44
7	Local Road (40)	Jalan Indah 10/4	0.52
8	Local Road (40)	Jalan Indah 10/3	0.41
		Total	9.23

THE PEDESTRIAN INDEX METHOD

The P-Index utilizes the 5 star rating formats where the better quality of facilities of a particular pedestrian segment, the higher the number of stars. Mathematically, the P-index (P) is a function of three criteria - Index of Pedestrian Facilities at Arterial Road (P_{AR}); Index of Pedestrian Facilities at Collector Road (P_{CR}) and Index of Pedestrian Facilities at Local Road (P_{LR}). The functional relationship between P-index (P) and the criteria is given in Eq. (1) below:

$$P = f\left(P_{AR}, P_{CR}, P_{LR}\right) \qquad \text{(Eq. 1)}$$

F_{CR} = facility indicator for collector road
F_{LR} = facility indicator for local road
B_i = bollard facility
R_i = ramp facility
Z_i = zebra crossing facility
TS_i = pedestrian traffic signal facility
RI_i = pedestrian refuge island facility
WS_i = pedestrian warning signage facility

$B_i, RI_i, TS_i, WS_i =$ 2, if available on both sides
1, if available on one side
0, if not available

$Z_i, R_i =$ 1, if available
0, if not available

Mobility (M) Indicator

The Mobility (M) indicator describes the provision of a paved, continuous pathway relative to the total length of roadways for the pedestrians. The formula for the Mobility (M) indicator is as in Equation 7 below;

$$M = \left(\frac{0.5D_c}{D}\right) \times 100 \qquad \text{(Eq.7)}$$

Where:

Dc = total length of paved pedestrian pathway, calculated on both sides of the roads (km)

D = total length of roadway, calculated one-way (km)

Safety (S) Indicator

The Safety (S) indicator describes how safe the pathway is for the pedestrians. For this purpose, a safe pathway is defined as pathways that provide both spatial and physical separations between the pedestrians and the motorized vehicles. The formula for the Safety (S) indicator is as in Equation 8 below;

$$S = \left(\frac{0.5D_{SP}}{D}\right) \times 100, \quad 0 \le D_{SP} \le D_c \qquad \text{(Eq. 8)}$$

Where:

D_{SP} = total length of spatially and physically separated paved pedestrian pathway, calculated on both sides of the roads (km)

D_C = total length of paved pedestrian pathway, calculated on both sides of the roads (km)

D = total length of roadway, calculated one-way (km)

Accessibility (A) Indicator

Finally, the Accessibility (A) indicator measures the closeness of houses to selected land uses. The formula for the Accessibility (A) indicator is as in Equation 9 below:

$$A = \frac{\sum_{j=1}^{k} L_j}{k} \times 100 \qquad \text{(Eq. 9)}$$

Where:

L_j = percent (%) of houses within walking distance to land uses j, $j = 1, 2, \ldots, k$

COMPUTATION OF P-INDEX FOR TAMAN BUKIT INDAH

The calculation of P-Index for the various road segments i.e. P_{ARi}, P_{CRi} and P_{LRi} is shown in Table 6. Meaning that all the indicators, Facility (F), Mobility (M), Safety (S) and Accessibility (A) were added and then divide by four, which means all the indicators have the same weightage. Then, the next step is to calculate the value of P_{AR}, P_{CR} and P_{LR}. The value of arterial road (P_{AR}) was obtained by dividing the total score of (P_{ARi}) with the number of each road type, n. The same steps go to collector road (P_{CR}) and local road (P_{LR}) as shown in the Table 7.

Table 6: Calculation of Facility (F), Mobility (M), Safety (S) and Accessibility (A)

Road Segment	F	M	S	A	(F+M+S+A) /4	Rating
1	20.83	55.54	87.34	31.81	48.88	3 stars
2	20.83	96.05	192.11	31.81	85.20	5 stars
3	10	0	0	31.81	10.45	1 star
4	40	91.55	0	31.81	40.84	3 stars
5	0	0	0	31.81	7.95	1 star
6	0	0	0	31.81	7.95	1 star
7	0	0	0	31.81	7.95	1 star
8	0	0	0	31.81	7.95	1 star

Table 7: The Calculation of P_{AR}, PCR, PLR

Road Type	Total Score	The value of P_{AR}, P_{CR}, P_{LR}
P_{AR}	(48.88+85.20)/2	67.04
P_{CR}	(10.45+40.84)/2	25.65
P_{LR}	(7.95+7.95+7.95+7.95)/4	7.95

The next step is to calculate the coefficient b_1, b_2, b_3. The coefficients were obtained by dividing the road length (km) for each road hierarchy with the total road length (km). Table 8 shows the calculation of the coefficients (b_1, b_2, b_3).

Table 8: The coefficient b_1, b_2, b_3

Road Hierarchy	Road Length (km)	Coefficients (b_1, b_2, b_3)
Arterial Road	5.06	$b_1 = \frac{5.06}{9.23} \times 100 = 0.5482$
Collector Road	2.54	$b_2 = \frac{2.54}{9.23} \times 100 = 0.2752$
Local Road	1.63	$b_3 = \frac{1.63}{9.23} \times 100 = 0.1766$
Total	9.23	100%

From Table 8, $b_1 = 0.5482$, $b_2 = 0.2752$ and $b_3 = 0.1766$, so that the final step is to calculate P, which is the overall rate of pedestrian facilities using the improved method as shown below:

$$\begin{aligned} P &= b_1 (P_{AR}) + b_2 (P_{CR}) + b_3 (P_{LR}) \\ &= 0.548\ P_{AR} + 0.275\ P_{CR} + 0.177\ P_{LR} \\ &= 0.548\ (67.04) + 0.275\ (25.65) + 0.177\ (7.95) \\ &= 45.1993 \text{ (3 stars)} \end{aligned}$$

According to the P-Index method, the three stars rating for pedestrian facility in Taman Bukit Indah can be interpreted as walkable (Refer to Table 9). This means in relation to the actual facilities, the new improved method is correctly and truly describe the quality of the facility because it considers the different purposes of pedestrian needs according to different road hierarchy.

Table 9: P-Index, Star Rating and Associated Colour Codes

Colour Codes	P-Index value	Star Rating	Description
	0 - 20	★	Dangerous for pedestrians
	21 - 40	★★	Unfavourable to pedestrians
	41 - 60	★★★	Walkable
	61 - 80	★★★★	Supportive towards pedestrians
	81 - 100	★★★★★	Very pedestrian friendly

Source: Zaly and Nelson 2008

Finally, the results are mapped according to the star rating. Figure 2 shows the visual star rating of pedestrian facilities for the road segment in the study area which is Taman Bukit Indah. The three star ratings can be interpreted as walkable according to Table 9.

Figure 2: Ratings of Pedestrian Facilities in the Study Area

GEOCODING RATING OF PEDESTRIAN FACILITY IN GOOGLEMAPS

P-index can be translated visually so that the value of ratings can be more meaningful. This simple concept is presented here through the use of Google Maps that would dynamically display pedestrian walkway's rating information. Using Google Maps has many advantages. It is free, highly accessible and ubiquitous. A life example of these ratings in action can be viewed online at a purpose built website www.lokasee.com./maps/pedestrian.php. A snapshot of this webpage is shown in Figure 3. On this particular webpage, visitors can view the quality of pedestrian facilities. Clicking on any of the markers will open an info box with the name of the roadway it represents and an image of the pedestrian walkway (Zaly and Nelson 2008).

Colour Codes	P-Index value	Rating	Qualitative Meaning
	0	-	Extremely unsafe for walking
	1 - 20	*	Hostile towards pedestrians
	21 - 40	**	Unfavourable to pedestrians
	41 - 60	***	Walkable
	61 - 80	****	Supportive towards pedestrians
	81 - 100	*****	Very Pedestrian Friendly

Figure 3: Colour-coded Lines Representing Different Ratings of Pedestrian Facility using Google Map

Source: Zaly and Nelson 2008

CONCLUSION

The P-index is an analytical tool developed to increase the visibility of pedestrian needs in urban planning policy applications. It encourages urban planners, city agencies, developers and community groups to use the index and its concepts for transportation and land use planning and as an evaluation tool. It give benefits to the local authority include standard guideline to measure pedestrian facilities and as a tool for Town and Country Planning Department (JPBD) requirement as well as auditing purposes. For the developer, the benefits such as marketing tool and improve the quality of property of the area. Lastly, for the community, it will benefits them in terms of create a walkable and healthier communities.

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