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A pedestrian level of service method for evaluating and promoting walking facilities on campus streets

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ABSTRACT

Modern universities seek policies to sustain the streets on their campuses by making campus streets pedestrian-friendly. To maintain inclusive streets, campus designers and planners should consider all users. Currently, there are efforts to evaluate street conditions for pedestrians. However, a limited range of pedestrian facilities and abilities make the results of previous studies insufficient to evaluate and promote inclusive walking facilities. This study attempts to create a foundation for evaluating and improving campus streets for pedestrians. This research presents pedestrian design indicators based on different guidelines that consider various pedestrian needs. This paper also introduces the pedestrian level of service (PLOS) for campuses, which is a measure to evaluate campus street facilities and infrastructure for pedestrians. An analytical point system comparing existing pedestrian facilities to a standard is proposed to estimate this PLOS. Although this method can be utilized on campuses around the world, this research uses it to assess streets on the campus of Universiti Teknologi Malaysia (UTM). This method can identify existing street problems for pedestrians and can be used to propose improvements to existing campus streets. Since this study tries to serve all requirements of pedestrians, specifically vulnerable users whether old or disabled, designers have room to implement accessible routes for pedestrians in campus streets.

Introduction

Universities with large numbers of academic staff, students and administrative personnel and a variety of activities (e.g., working, studying, and business) are comparable to small cities (Mat et al., 2009; Norzalwi and Ismail, 2011). Therefore, campus planners must address the mobility and accessibility needs of these large populations. Planners and designers are concerned with walking conditions as a means to solve many problems (e.g., global warming, health problems, energy consumption, air pollution, etc.). Recently, universities have sought to propose strong pedestrian and bicycle plans to support the aims of sustainability. Walking is a green travel mode that is beneficial to the environment and the economy and can promote the health of campus users.

Norzalwi and Ismail (2011) estimated that approximately 18% of people use walking as their travel option at the Universiti Kebangsaan Malaysia (UKM). Walking is the third most frequent (20%) travel mode at Kasetsart University, after private cars and buses (Panitat, 2010). In addition, a survey at North Carolina State University showed that only 2% of employees used walking as a primary mode of transport (North Carolina State University, 2011). These statistics show that a lower proportion of people on these campuses use walking than other travel modes. Ample hidden costs are produced by car-based transportation (Balsas, 2001). Therefore, it is obvious that university policy makers should encourage people to walk to create sustainable campuses with fewer externalities (environmental, economic, and social problems) so; the pedestrian-oriented campus will be a primary focus of future studies (Grenis, 2009).

Universities should encourage people to shift their travel modes from cars to other types of travel, especially walking (Balsas, 2003). Improving walkable paths can encourage people to increase their walking trips (Park, 2008). Providing walking facilities in addition to other effective policies (e.g., restricting automobile traffic within a campus and limiting automobile parking spaces on campus) can encourage the large numbers of students who live on campus to walk to their destinations. Walking has many health benefits and no cost (Balsas, 2003), which is important for students with small budgets. Universities must save land, energy, and money for the future. Improving pedestrian facilities and encouraging less driving are primary strategies to achieve this aim (Toor and Havlick, 2004). To improve streets on campus, designers should have a good understanding of the needs of street users, including disabled users.

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In other words, planners should know which street factors affect walking conditions for various types of pedestrians.

Level of service is a tool for describing existing conditions and facilities and assessing the overall quality of service, infrastructure and street furnishings (Asadi-Shekari and Zaly Shah, 2011; Asadi-Shekari et al., 2013a,b; Moeinaddini et al., 2013). To provide a suitable and clear context for evaluating pedestrian infrastructure, it is necessary to review the current efforts that propose a pedestrian level of service (PLOS). The quality of street conditions for pedestrians is commonly assessed by a PLOS.

There are various approaches to PLOS models. Some previous PLOS methods emphasize the pedestrian flow and volume and the sidewalk capacity (e.g., Benz, 1986; Fruin, 1971 and Pushkarev and Zupan, 1971, 1975). Fruin (1971) proposed the first PLOS method based on sidewalk capacity and volume. HCM (2000) considered these indicators as well as speed to evaluate PLOS. This method has been criticized because pedestrians were treated like vehicles. Some important indicators, such as qualitative factors, facilities and furnishings, are not considered in these types of models.

Other approaches consider pedestrian facilities. Lautso and Murole (1974) considered the influence of environmental factors on walking. Sarkar (1993) suggested a qualitative model to assess streets. In this model system coherence, safety, comfort, convenience, continuity, security, and attractiveness were the primary factors. This model considered six pedestrian service levels ranging from A to F. PLOS A indicated pedestrian-friendly streets, whereas service level F indicated incomplete streets. Khisty (1994) developed a quantitative method based on Sarkar's model. Some studies have also considered convenience facilities, shady trees, benches, and pedestrian-scale lighting (e.g., Dixon, 1996; Jensen, 2007; Sarkar, 2002).

Other methods are sensitive to safety indicators, such as vehicle speed and volume and traffic buffers (e.g., Mozer, 1994; Landis et al., 2001). Landis et al. (2001) introduced a PLOS based on existing sidewalks, sidewalk width, motorized vehicle speed, motorized vehicle volume, lateral separation of pedestrians from motorized vehicles, and the total number of (through) lanes. This model is commonly used as a reference for other studies. FDOT (2009) used similar indicators to assess the PLOS. Although these models attempted to propose different effective factors, they did not consider some prominent furnishings and facilities that are essential for inclusive walking conditions (e.g., wheelchair accessible drinking fountains and tactile pavement).

Mozer (1994) proposed an LOS model for bicyclists and pedestrians. According to Mozer's model, facility design factors include the requirements of the Americans with Disabilities Act. However, it does not have specific or direct regulations or standards to measure. Therefore, these factors are insufficient to evaluate street conditions for disabled pedestrians. The scores are also based on the user's judgment. Sarkar (2002) developed a pedestrian level of service based on the needs of all pedestrians, but this model considers few standards and details for evaluating inclusive walking conditions. In addition, some important furnishings and facilities (e.g., tactile pavement for disabled users) are not mentioned in this method. This model also has financial and human resources limitations and some bias in the PLOS calculation.

Most LOS studies use questionnaires, direct observations, and video techniques to collect data. Usual analytical methods used in PLOS models are simulation (e.g., Miller et al., 2000), regression analysis (e.g., Landis et al., 2001 and Petritsch et al., 2006) and point systems (e.g., Jaskiewicz, 1999; Mozer, 1994; Dixon, 1996; Gallin, 2001). Dixon (1996) and Gallin (2001) developed a point system that is useful for rating street conditions. The point systems used by Dixon and Gallin are easy to follow, but the weights of the various indicators are arbitrarily chosen. This system can be enhanced by adding more indicators and avoiding bias.

What is most surprising about the previous studies on the evaluation of walking conditions is the lack of reliable and easy to follow measures to collect data and evaluate streets for all pedestrians with different abilities. Although PLOS models have been developed in different contexts, the results of these models are not sufficient for universal use (Singh and Jain, 2011). One of the reasons for this has been an approach to street evaluation that considers pedestrian indicators from a macro-level view instead of a micro-level view. Thus, researchers have not been successful in developing methods to assess micro-level walking conditions (Park, 2008). In addition, the majority of PLOS methods have assumed pedestrians without disabilities (NCHRP, 2008). As a result, the current PLOS models only cover a narrow range of street conditions and may not be applicable to all situations.

Consequently, this research proposes a PLOS model that covers various street conditions for pedestrians with different ranges of abilities. This method is useful for improving existing streets and is easily interpreted. Accordingly, the objectives of this paper are divided into different stages. The identification of effective facilities that affect walking conditions is the first stage. The second step is the proposal of complete guidelines for pedestrian facilities based on the combination of effective factors achieved in the first step. The introduction of a practical measure through a point system that covers the majority of pedestrian facilities and infrastructures is the third stage. The final stage is the assessment of campus streets by utilizing the proposed model to identify street problems and to present issues for improvements.

This research presents opportunities for universities to achieve sustainable design guidelines for pedestrians on campuses. This model attempts to evaluate intersection and roadway segment facilities on campus streets. For the purpose of this research, the main ring road on the Universiti Teknologi Malaysia (UTM) campus was chosen to examine this method.

Materials and method

Indicators and guidelines

This study attempts to consider the majority of pedestrian facilities based on current urban street guidelines. The process of reviewing guidelines was continued until all indicators and standards were repeated. Therefore, 27 indicators ((1) slower traffic speed, (2) buffer and barriers (curb and furnishing zone), (3) fewer traffic lanes, (4) mid-block crossing, (5) landscape and trees, (6) facilities (fire hydrants), (7) furniture (trash receptacles), (8) footpath pavement, (9) marking (crosswalk), (10) corner island, (11) sidewalk on both sides, (12) advance stop bar, (13) width of footpath, (14) driveway, (15) lighting, (16) signing, (17) bollard, (18) slope, (19) curb ramp, (20) wheelchair-accessible drinking fountain, (21) tactile pavement (guiding), (22) tactile pavement (warning), (23) ramp, (24) grade, (25) signal, (26) bench and seating area and (27) drinking fountain) were selected from 20 street guidelines in various countries. This selection from various cities is useful to cover different contexts. This study attempts to consider all facilities that influence the quality of walking on campus by referring to various urban street guidelines. These factors describe sidewalk and crossing facilities and the overall street condition to accommodate all pedestrian needs. These indicators are evaluated at the Universiti Teknologi Malaysia (UTM).

Method

This research proposes a PLOS based on a point system to rate streets. It attempts to evaluate pedestrian facilities on campus streets. These indicators do not have the same effects on the PLOS, so each of them may have a specific coefficient. Therefore, mathematically, the PLOS can be defined as follows (refer to Eq. (1)):

$$\mathrm{PLOS} = \sum_{i=1}^{27} c_i Pl_i \tag{1}$$

where PLOS = pedestrian level of service; i = indicator number; c = coefficient of pedestrian indicator; PI = pedestrian indicator score.

The coefficient of pedestrian indicators (c) presents the effectiveness of each pedestrian facility for the PLOS, so the importance and priority of each indicator is illustrated by c. This coefficient is estimated by evaluating the importance of the facility for various guidelines. Considering guidelines is important in this stage because current LOS research and studies do not encompass all critical indicators due to various limitations, as discussed in this paper. For example, a limited number of effective factors for improving walking conditions for disabled persons have been proposed in PLOS studies. However, several prominent factors are suggested by developed guidelines, including wheelchair-accessible drinking fountains (Boodlal, 2001) and guiding and warning tactile pavement (UTTIPEC, 2009). There are three categories of pedestrian facilities in the different guidelines. Some guidelines suggest that some indicators be considered on streets but offer no standard for how they should be provided. Some guidelines present indicators that are more than simple suggestions but do not provide complete standards. In addition, some guidelines present both complete descriptions and standards for some indicators. These categories can indicate the depth of evaluation (D) for each indicator. Table 1 shows the different category checklists for the City of Tacoma (2009) guidelines. When an indicator is considered by many guidelines, this indicates that the facility is essential for better walking conditions. Therefore, this indicator may have a higher coefficient. In addition, when a facility is important, there are more details and standards for it in the guidelines. Therefore, the depth of evaluation (D), which is a rating method that categorizes the indicators and number of guidelines that consider specific indicators, was applied to calculate c. Table 2 shows D for each indicator and guideline. Table 3 presents the number of guidelines that evaluate indicator i with depth of evaluation j (N_{ij} Table). Therefore, the coefficient of each pedestrian indicator is defined as follows (refer to Eq. (2)):

$$c_i = \sum_{j=1}^{3} D_j N_{ij} \tag{2}$$

where c = coefficient of pedestrian indicator; i = indicator number; j = depth of evaluation number; D = depth of evaluation; $D_1 = 1$ (incomplete); $D_2 = 2$ (semi complete); $D_3 = 3$ (complete); N = number of guidelines; (N_{ij} = number of guidelines that evaluate indicator i with depth of evaluation j), such that

$C_1 = (7 \times 1) + (0 \times 2) + (10 \times 3) = 37$
$C_2 = 38$, $C_3 = 15$, $C_4 = 32$, $C_5 = 38$, $C_6 = 17$, $C_7 = 16$, $C_8 = 32$, $C_9 = 22$, $C_{10} = 15$, $C_{11} = 39$, $C_{12} = 9$, $C_{13} = 56$, $C_{14} = 23$, $C_{15} = 31$, $C_{16} = 24$, $C_{17} = 18$, $C_{18} = 34$, $C_{19} = 31$, $C_{20} = 2$, $C_{21} = 7$, $C_{22} = 17$, $C_{23} = 15$, $C_{24} = 25$, $C_{25} = 27$, $C_{26} = 19$, $C_{27} = 8$.

Based on Eq. (2), all coefficients of pedestrian indicators are calculated. Therefore, to achieve the PLOS, only PI_i is needed. PI_i is calculated by comparing the standards of guidelines that are combined for each indicator with the existing street conditions. This combined guideline is defined as the complete street guideline for pedestrians. PI_i is a number between 0 and 1. The best fit between the existing condition and the complete pedestrian street guideline achieves the highest point (1), and no fit is 0. There are also some points for conditions that have some fit between 0 and 1. Table 4 shows how PI_i is calculated for each indicator. Table 5 also shows the references for the different indicator standards. To facilitate understanding of the PLOS value that is achieved by calculating C_i s and PI_is based on Eq. (1), in a special rating system, the percentage of PLOS is defined. This value is the percentage of existing PLOS of the ideal PLOS (with the best fit between existing conditions and complete pedestrian street guidelines for all indicators; all PI_is are equal to 1). The percentage of PLOS is indicated as follows (refer to Eq. (3)):

$$\mathrm{PLOS\%} = \frac{\mathrm{PLOS}}{\sum_{i=1}^{27} C_i} \times 100 \tag{3}$$

where PLOS% = percentage of pedestrian level of service; PLOS = pedestrian level of service; i = indicator number; c = coefficient of pedestrian indicator.

Table 6 shows various classifications for the PLOS% rating and their interpretations. PLOS A indicates the highest pedestrian-friendly conditions. PLOS B may be acceptable with some improvements. PLOS C requires more attention and improvement. PLOS ratings below this require considerable improvement.

Analysis results

Different campus streets can be evaluated with this PLOS model because it has the potential to be used in different contexts. The case study used in this research involves the main ring around the academic area at UTM. The length of this street is 2168.45 m (refer to Fig. 1). All coefficients of pedestrian indicators and PI_is were calculated based on Tables 3 and 4. As a result, the following PLOS, PLOS%, and PLOS grades for the main ring are found (refer to Eqs. (1) and (3) and Tables 4 and 6):

PLOS = $(37 \times 1) + (38 \times 0.59) + (15 \times 1) + (32 \times 0.48) + (38 \times 0.55) + (17 \times 0.16) + (16 \times 0.6) + (32 \times 0.38) + (22 \times 0.08) + (15 \times 0) + (39 \times 0.51) + (9 \times 0.05) + (56 \times 0.38) + (23 \times 0) + (31 \times 0.02) + (24 \times 0.5) + (18 \times 0) + (34 \times 0.37) + (31 \times 0) + (2 \times 0) + (7 \times 0) + (17 \times 0) + (15 \times 0) + (25 \times 0.37) + (27 \times 0) + (19 \times 0.64) + (8 \times 0) = 225.15$.

Therefore, PLOS% = $(225.15/647) \times 100 = 35$.

Therefore, the PLOS grade for this street is D.

Some facilities that are evaluated in this method are essential indicators of inclusive walking conditions for old and disabled pedestrians (e.g., footpath pavement, slope, curb ramp, wheelchair-accessible drinking fountain, tactile pavement (guiding and warning), ramp, grade, signals, and seating area). In addition, the current PLOS not only shows the street problems but also suggests improvements to obtain a higher PLOS value. For instance, adding 40 fire hydrants leads to the best fit between the existing conditions and the complete guideline standards for indicator number 6, and this issue will increase the PLOS grade (refer to Table 4). The following improvements are recommended to promote the standards of the main ring at UTM for pedestrians (refer to Table 4):

- At least 3194.03 m^2 furnishing zone adjacent to the curb should be added.
- At least 8 mid-block crossings should be provided.
- At least 551.2 m of street should have standard trees, and trees that are not 7.6 m from the intersection should be removed.
- At least 40 fire hydrants should be added.
- Standard trash receptacles should be added for at least 1768.45 m of street.
- Approximately 320.82 m^2 of street pavement should be maintained, and the width of the sidewalks should be equal to or more

Table 1
Category check table for the City of Tacoma (2009) guideline.

Indicator[a]	Not considered (0)	Just suggested (1)	Suggested with descriptions, not complete standards (2)	Complete standards (3)
1				x
2				x
3				x
4				x
5			x	
6		x		
7		x		
8				x
9				x
10			x	
11				x
12			x	
13				x
14			x	
15				x
16			x	
17			x	
18		x		
19				x
20	x			
21		x		
22			x	
23	x			
24		x		
25				x
26		x		
27		x		

[a] (1) Slower traffic speed, (2) buffer and barriers (curb and furnishing zone), (3) fewer traffic lane, (4) mid block crossing, (5) landscape and tree, (6) facility (fire hydrant), (7) furniture (trash receptacle), (8) footpath pavement, (9) marking (crosswalk), (10) corner island, (11) sidewalk on both sides, (12) advance stop bar, (13) width of footpath, (14) driveway, (15) lighting, (16) signing, (17) bollard, (18) slope, (19) curb ramp, (20) wheelchair accessible drinking fountain, (21) tactile pavement (guiding), (22) tactile pavement (warning), (23) ramp, (24) grade, (25) signal, (26) bench and seating area and (27) drinking fountain.

than 1.5 m; 2855.29 m^2 of street should be paved with standard width, slope, and grade.

- At least 67 standard crosswalks should be added.
- Three existing corner islands should be maintained according to standards.
- 1000.2 m of sidewalk for one side of street and 903.33 m for the other side should be added.
- Sixty-nine rows of standard stop bars should be added.
- Two existing driveways should be maintained according to standards.

Table 2
Depth of evaluation for pedestrian guidelines and indicators.

Guideline[a]	Indicator[b]																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	1	2	1	2	3	0	1	0	1	0	3	0	2	1	2	1	1	3	1	0	1	1	0	2	1	1	0
2	0	1	0	2	2	1	1	1	0	0	0	0	3	0	1	1	0	0	0	0	0	0	1	0	1	2	0
3	1	1	0	0	2	0	0	1	1	0	3	0	3	0	1	1	1	1	0	0	1	1	0	2	1	0	0
4	0	2	0	0	2	0	0	1	1	1	0	0	2	0	2	1	2	1	0	0	0	0	0	0	0	0	0
5	3	0	0	0	1	0	0	1	0	0	0	0	3	0	1	0	0	3	0	0	0	0	0	3	0	0	0
6	3	1	0	1	0	1	0	0	0	0	0	0	3	0	2	0	2	0	1	0	0	0	0	0	0	0	0
7	1	3	0	1	2	2	0	0	2	0	0	0	3	3	2	1	2	2	3	0	0	0	2	0	3	2	0
8	0	3	0	3	2	3	3	3	1	1	3	0	3	3	2	3	2	3	3	0	0	2	2	3	3	3	2
9	3	3	1	2	3	0	1	1	0	0	3	0	3	0	1	2	0	1	0	0	0	0	0	0	0	2	1
10	3	3	1	3	2	3	2	3	3	2	3	3	3	3	3	3	0	3	3	0	1	1	1	3	3	1	1
11	3	2	3	2	3	0	2	3	2	2	0	0	3	2	2	1	0	1	2	0	0	0	1	0	3	1	0
12	3	2	0	0	0	0	0	3	0	0	3	0	3	2	0	1	0	3	2	0	0	0	0	3	2	0	0
13	1	0	0	0	2	0	0	0	0	0	3	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0
14	3	2	0	2	1	1	1	1	1	0	3	1	3	0	0	1	1	0	2	0	0	0	0	0	1	0	0
15	1	1	0	1	2	1	0	0	0	0	3	0	3	0	1	0	0	0	0	0	0	0	0	0	0	1	0
16	1	2	0	2	1	1	0	3	1	2	0	0	3	0	0	1	0	3	3	1	0	3	2	3	0	1	1
17	3	3	3	3	3	1	2	3	3	2	3	3	3	3	3	3	2	2	3	1	3	3	3	1	3	1	1
18	3	2	2	2	3	1	2	3	1	0	3	0	2	1	3	1	2	3	2	0	0	1	1	1	1	2	0
19	1	2	1	3	2	1	0	2	2	3	3	0	3	3	2	1	1	3	3	0	0	3	2	3	2	1	1
20	3	3	3	3	2	1	1	3	3	2	3	2	3	2	3	2	2	1	3	0	1	2	0	1	3	1	1

[a] 1 – Clarke (2008), 2 – City of Calgary (2008), 3 – Sutherland and Morrish (2006), 4 – City of Whittlesea (2009), 5 – NARRABRR SHIR COUNCIL (2001), 6 – City of Charles Sturt (2009), 7 – Heramb (2007), 8 – Vanderslice (1998), 9 – Ashland City Council (1999), 10 – Access Minneapolis (2008), 11 – CDOT (2007), 12 – Pima County (2005), 13 – Neighborhood Streets Project Stakeholders (2000), 14 – City of Aurora (2007), 15 – Burden (1999), 16 – Boodlal (2001),17 – UTTIPEC (2009), 18 – NewYork city department of transportation (2009), 19 – RDM (2010), 20 – City of Tacoma (2009).

[b] (1) Slower traffic speed, (2) buffer and barriers (curb and furnishing zone), (3) fewer traffic lane, (4) mid block crossing, (5) landscape and tree, (6) facility (fire hydrant), (7) furniture (trash receptacle), (8) footpath pavement, (9) marking (crosswalk), (10) corner island, (11) sidewalk on both sides, (12) advance stop bar, (13) width of footpath, (14) driveway, (15) lighting, (16) signing, (17) bollard, (18) slope, (19) curb ramp, (20) wheelchair accessible drinking fountain, (21) tactile pavement (guiding), (22) tactile pavement (warning), (23) ramp, (24) grade, (25) signal, (26) bench and seating area and (27) drinking fountain.

Table 3
N_{ij} for evaluating the coefficients.

Dept of evaluation[a]	Indicator[b]																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	7	4	4	3	3	9	5	6	7	2	0	1	0	2	5	11	4	6	2	2	4	4	4	3	5	8	6
2	0	8	1	7	10	1	4	1	3	5	0	1	4	3	7	2	7	2	4	0	0	2	4	2	2	4	1
3	10	6	3	5	5	2	1	8	3	1	13	2	16	5	4	3	0	8	7	0	1	3	1	6	6	1	0

[a] $D_1 = 1$ (incomplete), $D_2 = 2$ (semi complete), $D_3 = 3$ (complete).
[b] (1) Slower traffic speed, (2) buffer and barriers (curb and furnishing zone), (3) fewer traffic lane, (4) mid block crossing, (5) landscape and tree, (6) facility (fire hydrant), (7) furniture (trash receptacle), (8) footpath pavement, (9) marking (crosswalk), (10) corner island, (11) sidewalk on both sides, (12) advance stop bar, (13) width of footpath, (14) driveway, (15) lighting, (16) signing, (17) bollard, (18) slope, (19) curb ramp, (20) wheelchair accessible drinking fountain, (21) tactile pavement (guiding), (22) tactile pavement (warning), (23) ramp, (24) grade, (25) signal, (26) bench and seating area and (27) drinking fountain.

- Pedestrian-scale lighting should be added for 3821.68 m of street.
- Public transit and crossing signs should be considered.
- At least 146 rows of bollards should be provided.
- At least 146 standard curb ramps should be provided.
- Drinking fountains and wheelchair-accessible drinking fountains should be considered.
- Tactile paving should be provided for 3888.38 m of street.
- At least 155 rows of warning tiles should be considered.
- At least 9 standard ramps should be considered.
- At least 44 standard pedestrian signals should be provided.
- Standard seating areas should be added for 1568.45 m of street.

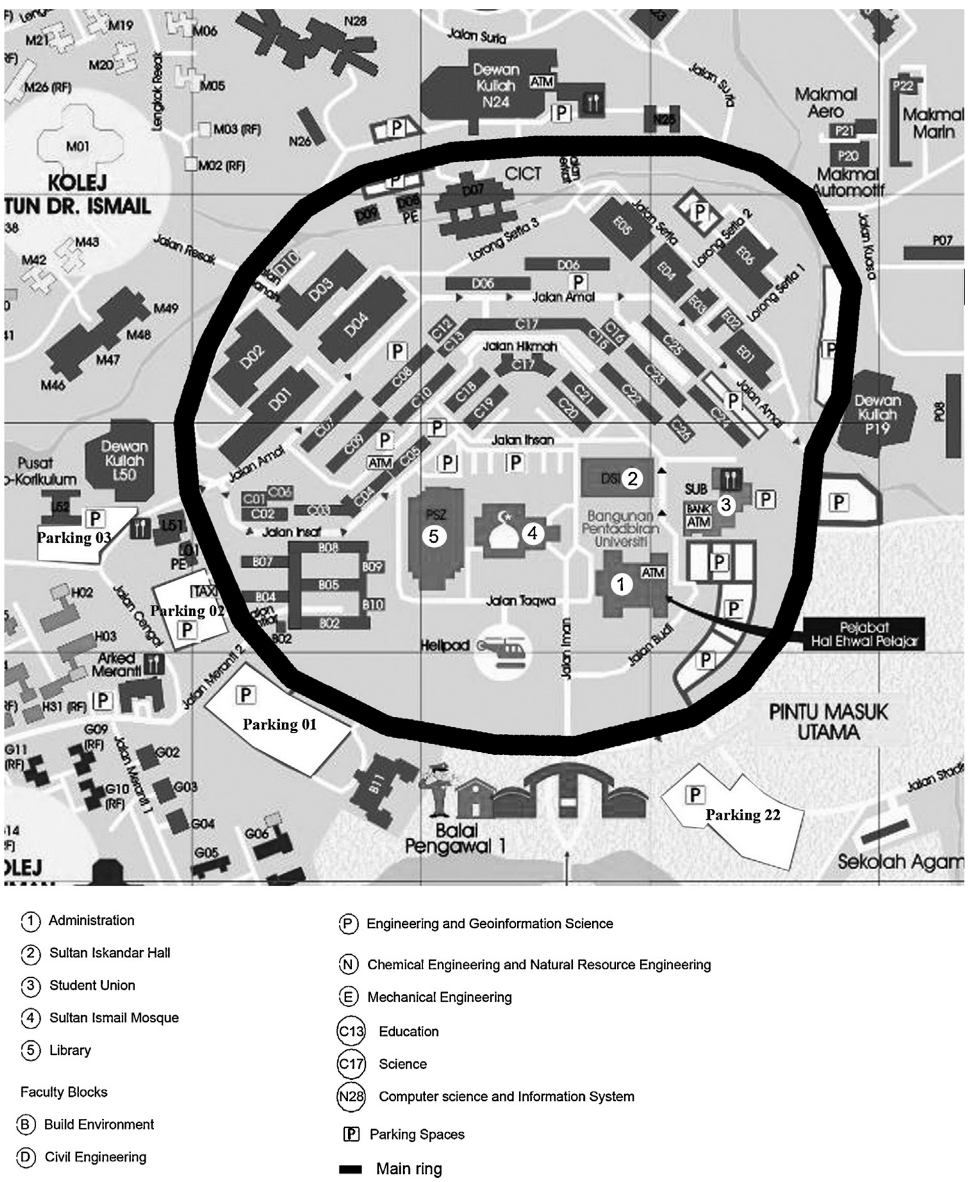

Fig. 1. UTM Main ring.

Source: UTM.

Table 4
Pedestrian indicators (PI_i) calculation.

Indicator/Standards /Calculation Descriptions	Calculation Results
(1) Slower traffic speed (speed)	
Standard: 35 km/h in UTM campus (based on university standard) $PI_1 = \begin{cases} 0 & \text{if } S > 35 \\ 1 & \text{if } S \leq 35 \end{cases}$ S = Average vehicle speed in street	$S = 32.32$ $S \leq 35$ so $PI_1 = 1$
(2) Buffer and barriers	
Standard: Curb Standard: Min width for curb is 0.15m, min height is 0.10 - 0.15m Furnishing zone Standard: Min width is 1.2 m but between 1.8 and 2.4m width is recommended $PI_2 = (CI+FI)/2$ $CI = CL/N_1$ CL = Standard curb length (m) N_1 = Length of curb that street needs (m) $FI = C/N_2$ C = Area of furnishing zone adjacent to the curb (m^2) $N_2 = \begin{cases} \text{length of street} \times 1.2 & \text{if } W < 1.20\text{ m} \\ \text{length of street} \times W & \text{if } W \geq 1.20\text{ m} \end{cases}$ W = Width of furnishing zone adjacent to the curb (m) If W varies in different parts of street $FI = (\sum_{i=1}^{k} FIC_i \times L_i)$/(length of street (both sides) - length of intersections) i = 1,2,3,..,k (different parts of street with various width of the furnishing zone) $FIC_i = C_i/n_i$ C_i = Area of furnishing zone adjacent to the curb in section i (m^2) $n_i = \begin{cases} (\text{length of street (in section i)}) \times 1.2 & \text{if } W < 1.20\text{ m} \\ (\text{length of street(in section i)}) \times W & \text{if } W \geq 1.20\text{ m} \end{cases}$ L_i= Length of street in section i (m)	$CL = 3888.38$m $N_1 = CL$ $CI = 1$ $C_1 = 3194.03\times0 = 0$ $C_2 = 130.4\times1.4 = 182.56$ $C_3 = 239.5\times1.6 = 383.2$ $C_4 = 115\times1.2 = 138$ $C_5 = 209.45\times1.7 = 356.06$ $n_1 = 3194.03\times1.2 = 3832.8$ $n_2 = 130.4\times1.4 = 182.56$ $n_3 = 239.5\times1.6 = 383.2$ $n_4 = 115\times1.2 = 138$ $n_5 = 209.45\times1.7 = 356.06$ $FIC_1 = 0$ $FIC_2 = 1$ $FIC_3 = 1$ $FIC_4 = 1$ $FIC_5 = 1$ FI = $(0\times3194.03 + 1\times 130.4$ $+1\times 239.5 + 1\times 115 + 1\times$ $209.45)/3888.38 = 0.18$ $PI_2 = (1+0.18)/2 = 0.59$
(3) Fewer traffic lane (number of travel lane)	
Standard:2 lanes $PI_3 = \begin{cases} 0 & \text{if No lane} > 2 \\ 1 & \text{if No lane} \leq 2 \end{cases}$	Number of lane = 2 $PI_3 = 1$
(4) Mid block crossing	
Standard: • Crosswalk frequency is various but not farther apart than 60-90 m and not closer than 45 m and does not prohibit crossing for more than 120 m • Typical width of mid block crossing is 3 m but where the sidewalk is wider than 3.7m the crosswalk maybe wider than standard width	$n_1 = 160.95/120 = 1$ $c_1 = 1$ $P_1 = 1$ $n_2 = 215.2/120 = 2$ $c_2 = 0$ $P_2 = 0$

Table 4 (*Continued*)

$PI_4 = \begin{cases} \sum P_i / \text{total number of sections that are more than 120m} \\ 0 \quad \text{if total length of street is less than 120m and } c_i = 0 \end{cases}$ $P_i = \begin{cases} 1 & \text{if} \quad Pc_i \geq 1 \\ Pc_i & \text{if} \quad Pc_i < 1 \end{cases}$ $Pc_i = c_i / n_i$ i = 1, 2, 3, ..., k (different sections of street between intersections that are more than 120 m) c_i = Number of standard mid block crossing in section i n_i = Length of street in section i / 120	n_3 = 135.4/120 = 1 c_3 = 1 P_3 = 1 n_4 = 250.8/120 = 2 c_4 = 1 P_4 = 0.5 n_5 = 136.15/120 = 1 c_5 = 0 P_5 = 0 n_6 = 227/120 = 2 c_6 = 2 P_6 = 1 n_7 = 238.2/120 = 2 c_7 = 0 P_7 = 0 n_8 = 348/120 = 3 c_8 = 1 P_8 = 0.33 PI_4=(1+0+1+0.5+0+1+0 +0.33)/8 = 0.48
(5) Landscape and tree	
Standard: • Tree branches should have a vertical clearance of at least 2.4 m (1) • Trees should be at least 7.6 m far from intersection (2) • Trees should be no more than 9 m apart to provide continuous tree canopy • Trees should be planted on both sides of streets $PI_5 = (P_1+P_2+P_3)/3$ $P_1 = C/N$ $C = \begin{cases} ((\text{Length of street with tree} - \text{total length of intersections and their considered standard limitations}) \times 9)/D & \text{if } D > 9 \\ \text{Length of street with tree} - \text{total length of intersections and their considered standard limitations} & \text{if } D \leq 9 \end{cases}$ D = Distance between trees (m) N = Length of street (both sides)-total length of intersections and their considered standard limitations (m) If D varies in different parts of street $P_1 = \sum_{i=1}^{k} C_i / \sum_{i=1}^{k} N_i$ i =1, 2, 3,..., k(different parts of street with various distances between trees) $C_i = \begin{cases} ((\text{Length of street with tree in section i} - \text{considered standard limitations}) \times 9)/D & \text{if } D > 9 \\ \text{Length of street with tree in section i} - \text{considered standard limitations} & \text{if } D \leq 9 \end{cases}$ N_i = Length of street (in section i) - considered standard limitations (m) $P_2 = F/N$ F = C - length of street that does not have first standard condition N= Length of street (both sides)-total length of intersections and their considered standard limitations (m) If D varies in different parts of street $P_2 = \sum_{i=1}^{k} F_i / \sum_{i=1}^{k} N_i$ i =1, 2, 3,..., k $F_i = C_i$ - length of street that does not have first standard condition in section i N_i = Length of street (section i)- considered standard limitations (m) $P_3 = NI/I$ NI = Number of intersections with second standard condition I = Number of total intersections	C = 3004.38 N = 3555.58 P_1 = 3004.38/3555.58 = 0.84 F = 3004.38-0 = 3004.38 P_2 = 3004.38/3555.58 = 0.84 NI = 0 I = 11 P_3 = 0/11= 0 PI_5 = (0.84+0.84+0)/3 = 0.55

Table 4 (*Continued*)

(6) Facility (Fire hydrant)	
Standard: • It should be located in the furnishing zone when zone is 1.2 m or behind the sidewalk with a min of 1.8 m clear for pedestrian zone • The distance from the nearest fire hydrant to the front door of a building should not exceed 45 m • It should be 9 m far from intersection • Min 0.6 m from the face of curb should be provided	$C = 8$ $N = 2168.45/45 = 48$ $P = 8/48 = 0.16$ $PI_6 = 0.16$
$PI_6 = \begin{cases} 1 & \text{if} \quad P \geq 1 \\ P & \text{if} \quad P < 1 \\ 0 & \text{if} \quad \text{there is no need for fire hydrant} \end{cases}$ $P = C/N$ C = Number of standard fire hydrants N = Total fire hydrants that street needs	
(7) Furniture (Trash receptacle)	
Standard : • It should be centered in furnishing zone when zone is 0.9 m wide or greater • It should be 9 m far from intersection • Min 0.6 m from the face of curb should be provided • One receptacle should be located at each playground, and adjacent to benches • It should have min1.2 m clearance from bus stop infrastructure • It should be provided every 200 - 400 m like bench	$C = 2615.5$ $N = 4383.95$ $PI_7 = 0.6$
$PI_7 = C/N$ C = Length of street with standards trash receptacle area + their support length (m) N = Length of street (both sides) (m)	
(8) Footpath Pavement	
Standard: • It should be stable ,anti skid smooth and continuous • Surface discontinuities may not exceed 1.25 cm and vertical discontinuities should be between 0.6 cm and 1.25 cm	$C_1 = (14.15\times2.45) - 0$ $= 34.67$ $W_1 = 2.45$ $N_1 = 14.15\times2.45=34.67$ $PC_1 = 34.67/34.67 = 1$ $C_2 =(48.9\times8)- 50 = 341.2$ $W_2 = 8$ $N_2 = 48.9\times8 = 391.2$ $PC_2 = 341.2/391.2 = 0.87$ $C_3 = (135.3\times1.3) - 71.1$ $= 104.79$ $W_3 = 1.3$ $N_3 = 135.3\times1.5$ $= 202.95$ $PC_3 = 104.79/202.95 =$ 0.52 $C_4 = (1654.5\times1.2)-$ $161.17 = 1824.23$ $W_4 = 1.2$ $N_4 =1654.5\times1.5$

Table 4 (*Continued*)

$PI_8 = C/N$ C = Area of standard pavement (m^2) $N = \begin{cases} (\text{length of street (both sides)} - \text{length of intersections}) \times 1.5 & \text{if } W < 1.50\text{ m} \\ (\text{length of street(both sides)} - \text{length of intersections}) \times W & \text{if } W \geq 1.50\text{ m} \end{cases}$ W = Width of footpath (m) If W varies in different parts of street $PI_8 = (\sum_{i=1}^{k} PC_i \times L_i)$/(length of street (both sides) - length of intersections) i = 1, 2, 3, ..., k (different parts of street with various width of the footpath) $PC_i = C_i/N_i$ C_i = Area of standard pavement in section i (m^2) $N_i = \begin{cases} (\text{length of street (in section i)}) \times 1.5 & \text{if } W < 1.50\text{ m} \\ (\text{length of street in section i}) \times W & \text{if } W \geq 1.50\text{ m} \end{cases}$ L_i = Length of street in section i (m)	= 2481.75 PC_4 = 1824.23/2481.75 = 0.73 C_5 =(198.95×0.9) - 38.55 = 140.5 W_5 = 0.9 N_5 =198.95×1.5 =298.42 PC_5 = 140.5/298.42 = 0.47 C_6 = (50.05×2.8) - 0 = 140.14 W_6 = 2.8 N_6 = 50.05×2.8 = 140.14 PC_6 = 140.14/140.14 = 1 C_7 =1903.53×0 = 0 W_7 = 0 N_7 = 1903.53×1.5 = 2855.29 PC_7 = 0/2855.29 = 0 PI_8 = (1×14.15+0.87×48.9+0.52×135.3+0.73×1654.5+0.47×198.95+1×50.05+0×1903.53)/3888.38 = 0.38
(9) Marking (crosswalk)	
Standard: There are two types of cross walks a and b: a: Ladder or longitudinal : • Min cross walk width is 3 m but desirable width is 5 m • Space between strips is 0.3 - 1.5 m • Width of strips is 0.3 - 0.6 m b: Parallel or standard transverse : • Cross walk width is 3 - 4.5 m but min 1.9 m • Width of two strips is 0.15 - 0.30 m	C = 6 N = 73 P = 6/73 = 0.08 PI_9 = 0.08
$PI_9 = \begin{cases} 1 & \text{if } P \geq 1 \\ P & \text{if } P < 1 \end{cases}$ P = C/N C = Number of standard crosswalk markings N = Number of crosswalks that street needs(mid block and cross walk at intersections)	
(10) Corner island	
Standard: • The pedestrian crossings should be at 90 degrees across the turn lane • Do not place benches ,… or other features in the center island which may attract pedestrian	C = 0 N = 3 PI_{10} = 0
PI_{10} = C/N C = Number of standard corner island N = Total corner island that street has PI_{10} = 1 if there is no corner island	

Table 4 (*Continued*)

(11) Sidewalk on both sides	
Standard: Two sidewalks should be provided on both sides of street	$l_1 = 929.2$ $N_1 = 1929.4$ $P_1 = 929.2/1929.4 = 0.48$ $n = 0.48$ $l_2 = 1055.65$ $N_2 = 1958.98$ $P_2 = 1055.65/1958.98 = 0.54$ $m = 0.54$ $PI_{11} = (0.48+0.54)/2 = 0.51$
$PI_{11} = (n+m)/2$ $n = \begin{cases} 1 & \text{if} \quad P_1 \geq 1 \\ P_1 & \text{if} \quad P_1 < 1 \end{cases}$ $P_1 = l_1/N_1$ l_1 = Length of sidewalk in one side (m) N_1 = Length of street – length of intersections in one side (m) $m = \begin{cases} 1 & \text{if} \quad P_2 \geq 1 \\ P_2 & \text{if} \quad P_2 < 1 \end{cases}$ $P_2 = l_2/N_2$ l_2 = Length of sidewalk in opposite side (m) N_2 = Length of street – length of intersections in other side (m)	
(12) Advance stop bar	
Standard: • It should be provided on streets with at least two travel lanes in each direction in advance of crossings • Stop and yield lines can be used from 1 to 15 m in advance of crossings, depending upon location • Strip width should be 0.3 - 0.6 m	$C = 4$ $N = 73$ $P = 4/73 = 0.05$ $PI_{12} = 0.05$
$PI_{12} = \begin{cases} 1 & \text{if} \quad P \geq 1 \\ P & \text{if} \quad P < 1 \\ 0 & \text{if} \quad N = 0 \end{cases}$ $P = C/N$ C = Number of standard advance stop bars N = Total advance stop bars that street needs	
(13) Width of footpath	
Standard: Footpath zone should be min 1.5 m but between 1.8 and 2.4 m width is recommended	$C_1 = (14.15 \times 2.45) - 0 = 34.67$ $W_1 = 2.45$ $N_1 = 14.15 \times 2.45 = 34.67$ $PC_1 = 34.67/34.67 = 1$ $C_2 = (48.9 \times 8) - 50 = 341.2$ $W_2 = 8$ $N_2 = 48.9 \times 8 = 391.2$ $PC_2 = 341.2/391.2 = 0.87$ $C_3 = (135.3 \times 1.3) - 71.1 = 104.79$ $W_3 = 1.3$ $N_3 = 135.3 \times 1.5 = 202.95$ $PC_3 = 104.79/202.95 = 0.52$ $C_4 = (1654.5 \times 1.2) - 161.17 = 1824.23$ $W_4 = 1.2$ $N_4 = 1654.5 \times 1.5 = 2481.75$
$PI_{13} = C/N$ C = Area of standard footpath (m^2) $N = \begin{cases} \text{(length of street (both sides)} - \text{length of intersections)} \times 1.5 & \text{if } W < 1.50\text{ m} \\ \text{(length of street(both sides)} - \text{length of intersections)} \times W & \text{if } W \geq 1.50\text{ m} \end{cases}$ W = Width of footpath (m) If W varies in different parts of street $PI_{13} = (\sum_{i=1}^{k} PC_i \times L_i)/($ length of street (both sides) - length of intersections) i = 1, 2, 3, ..., k (different parts of street with various width of the footpath) $PC_i = C_i/N_i$ C_i = Area of standard footpath in section i (m^2) $N_i = \begin{cases} \text{(length of street (in section i)} \times 1.5 & \text{if } W < 1.50\text{ m} \\ \text{(length of streetin in section i)} \times W & \text{if } W \geq 1.50\text{ m} \end{cases}$ L_i = Length of street in section i (m)	

Table 4 (*Continued*)

	PC_4= 1824.23/2481.75= 0.73 C_5=(198.95×0.9)- 38.55 = 140.5 W_5 = 0.9 N_5 =198.95×1.5 = 298.42 PC_5 = 140.5/298.42 = 0.47 C_6 = (50.05×2.8) - 0 =140.14 W_6 = 2.8 N_6 = 50.05×2.8 =140.14 PC_6 = 140.14/140.14 = 1 C_7 =1903.53×0 = 0 W_7 = 0 N_7 = 1903.53×1.5 = 2855.29 PC_7 = 0/2855.29 = 0 PI_{13}=(1×14.15+0.87×48 .9+0.52×135.3+0.73× 1654.5+0.47×198.95+1× 50.05+0×1903.53) /3888.38= 0.38
(14) Driveway	
Standard: • It should not be wider than garage • It should be 9m far from major street intersection, 6m from other intersections • Min width is 3.6 m max width is 7.5 m • Driveways must be located at least 3 m from the outside of the trunk of any existing street trees • Max slope is 2% in sidewalk, 10% in flare and 8.3-10% in ramp	C = 0 N = 2 PI_{14} = 0/2 = 0
PI_{14} = C/N C = Number of standard driveways N = Total driveways that street has PI_{14} =1 if there is no driveway	
(15) Lighting	
Standard : • Enough light should be provided • Pedestrian scale is important • The light pole should be centered a min of 0.9 m off the face of curb and from any accessible structure such as shelter • It should be full cut off fixtures which focus light downwards • The light poles should be max 9 m apart to have enough light	C = 66.7 N = 3888.38 P = 66.7/3888.38 = 0.02 PI_{15} = 0.02

Table 4 (*Continued*)

$PI_{15}=\begin{cases}1 & \text{if} \quad P \geq 1\\ P & \text{if} \quad P < 1\end{cases}$ P = C/N C= $\begin{cases}((\text{Length of street with pedestrian lighting} - \text{total length of intersections}) \times 9)/D & \text{if } D > 9\text{ m}\\ \text{Length of street with pedestrian lighting} - \text{total length of intersections} & \text{if } D \leq 9\text{m}\end{cases}$ D = Distance between light poles (m) N = (length of street (both sides) -intersections length) (m) If D varies in different parts of street $PI_{15} = \sum_{i=1}^{k} C_i \,/\, \sum_{i=1}^{k} N_i$ i=1, 2, 3,...k (different parts of street with various distances between light poles) $C_i = \begin{cases}((\text{Length of street with pedestrian lighting in section i}) \times 9)/D & \text{if } D > 9\text{ m}\\ \text{Length of street with pedestrian lighting in section i} & \text{if } D \leq 9\text{ m}\end{cases}$ N_i = length of street in section i (m)	
(16) Signing	
Transit ,public facilities , crossing and way finding signs should be provided in street	$P_1 = 0$ $P_2 = 1$ $P_3 = 0$ $P_4 = 1$ $PI_{16} = (0+1+0+1)/4 = 0.5$
$PI_{16} = (P_1+P_2+P_3+P_4)/4$ P_1= Enough transit signs $P_1=\begin{cases}1 & \text{if} \quad \text{yes}\\ 0 & \text{if} \quad \text{no}\end{cases}$ P_2 = Enough public facilities signs $P_2=\begin{cases}1 & \text{if} \quad \text{yes}\\ 0 & \text{if} \quad \text{no}\end{cases}$ P_3 = Enough crossing signs $P_3=\begin{cases}1 & \text{if} \quad \text{yes}\\ 0 & \text{if} \quad \text{no}\end{cases}$ P_4 = Enough way finding signs $P_4=\begin{cases}1 & \text{if} \quad \text{yes}\\ 0 & \text{if} \quad \text{no}\end{cases}$	
(17) Buffer and barriers (bollard)	
Standard: • Removable and lockable bollards should be provided across both entrances spaced not more than 1.5 m apart to control vehicle access and also min 1.2 m apart to cross wheelchair user • Height of bollard is varies but it is around 0.75-1.2 m • Allow 0.45m clear space from the front of the curb • They should be high visible	C = 0 N = 146 P = 0/146 = 0 $PI_{17} = 0$
$PI_{17}=\begin{cases}1 & \text{if} \quad P \geq 1\\ P & \text{if} \quad P < 1\end{cases}$ P = C/N C = Number of standard bollards rows N = (total crosswalks + total median crosswalk sections that street needs)×2	

Table 4 (*Continued*)

(18) Slope	
Standard: Sidewalk slope $\leq$ 2%	$C_1 = (14.15\times2.45) - 0 = 34.67$ $W_1 = 2.45$ $N_1 = 14.15\times2.45 = 34.67$ $PC_1 = 34.67/34.67 = 1$ $C_2 = (48.9\times8) - 350 = 41.2$ $W_2 = 8$ $N_2 = 48.9\times8 = 391.2$ $PC_2 = 41.2/391.2 = 0.10$ $C_3 = (135.3\times1.3) - 71.1 = 104.79$ $W_3 = 1.3$ $N_3 = 135.3\times1.5 = 202.95$ $PC_3 = 104.79/202.95 = 0.52$ $C_4 = (1654.5\times1.2) - 161.17 = 1824.23$ $W_4 = 1.2$ $N_4 = 1654.5\times1.5 = 2481.75$ $PC_4 = 1824.23/2481.75 = 0.73$ $C_5 = (198.95\times0.9) - 38.55 = 140.5$
$PI_{18} = C/N$ C = Area of sidewalk with the standard slope (m^2) $N = \begin{cases}(\text{length of street (both sides)} - \text{length of intersections}) \times 1.5 & \text{if } W < 1.50\text{ m}\\(\text{length of street (both sides)} - \text{length of intersections}) \times W & \text{if } W \geq 1.50\text{ m}\end{cases}$ W = Width of the footpath (m) If W varies at different parts of street: $PI_{18} = (\sum_{i=1}^{k} DIC_i \times L_i)$/(length of street (both sides) - length of intersections) i = 1, 2, 3, ..., k (different parts of street with various width of the footpath) $DIC_i = C_i/N_i$ C_i = Area of the sidewalk with the standard slope in section i (m^2) $N_i = \begin{cases}(\text{length of street (in section i)}) \times 1.5 & \text{if } W < 1.50\text{ m}\\(\text{length of street (in section i)}) \times W & \text{if } W \geq 1.50\text{ m}\end{cases}$ L_i = Length of street (in section i) (m)	$W_5 = 0.9$ $N_5 = 198.95\times1.5 = 298.42$ $PC_5 = 140.5/298.42 = 0.47$ $C_6 = (50.05\times2.8) - 0 = 140.14$ $W_6 = 2.8$ $N_6 = 50.05\times2.8 = 140.14$ $PC_6 = 140.14/140.14 = 1$ $C_7 = 1903.53\times0 = 0$ $W_7 = 0$ $N_7 = 1903.53\times1.5 = 2855.29$ $PC_7 = 0/2855.29 = 0$ $PI_{18} = (1\times14.15+0.1\times48.9+0.52\times135.3+0.73\times1654.5+0.47\times198.95+1\times50.05+0\times1903.53)/3888.38 = 0.37$

Table 4 (*Continued*)

(19) Curb ramp	
Standard: • Curb ramps shall be located or protected to prevent their obstruction by parked vehicles • Minimum top landing is 1.2 × 1.2 m and the maximum slope is 2% • Minimum ramp width is 1.2 m and ramp slope is from 5% - 8.3% • Maximum flared side cross slope is 10%	C = 0 N =146 P = 0/146 = 0 $PI_{19} = 0$
$PI_{19} = \begin{cases} 1 & \text{if} \quad P \geq 1 \\ P & \text{if} \quad P < 1 \\ 0 & \text{if} \quad \text{street does not need a curb ramp} \end{cases}$ P = C/N C = Number of standard curb ramps N = Total number of curb ramps the street needs	
(20) Wheelchair accessible drinking fountain	
Standard : • Maximum height is 0.91 m • It should be located within furnishing zones near playgrounds or outdoor eating areas and adjacent to shelters • It should be provided every 400 m	C = 0 N = 2168.45 $PI_{20} = 0/2168.45 = 0$
$PI_{20} = C/N$ C = Street length with standard wheelchair accessible drinking fountains + their support length (m) N = Length of street (m)	
(21) Tactile Pavement (guiding tile)	
Standard : • A distance of 0.60 - 0.80 m from the edge of the footpath, boundary wall and any obstruction should be provided • Minimum width of 0.30 m and height of approximately 0.005 m for the raised portion of the surface should be considered • Tactile pavement should be colored (preferably canary yellow)	C = 0 N = 3888.38 $PI_{21} = 0$
$PI_{21} = \begin{cases} 1 & \text{if} \quad P \geq 1 \\ P & \text{if} \quad P < 1 \end{cases}$ P = C/N C = Length of the standard guiding tactile pavement (m) N = Length of guiding tactile pavement the street requires (m)	

Table 4 (*Continued*)

(22) Warning tile	
Standards: • Detectable warnings shall be placed at the bottom of curb ramps and other locations, such as raised crosswalks and raised intersections, both median and island borders, at the edge of transit platforms, where railroad tracks cross the sidewalk and when the walking direction changes • Detectable warnings must be installed across the full width of ramps and 0.60 m up the ramp. These warning should be set back 0.15 - 0.20 m from the bottom of the curb • Smooth surfaces should be provided adjoining the detectable warning to maximize contrast	$C = 0$ $N = 155$ $P = 0/155 = 0$ $PI_{22} = 0$
$PI_{22} = \begin{cases} 1 & \text{if} \quad P \geq 1 \\ P & \text{if} \quad P < 1 \end{cases}$ $P = C/N$ C = Number of standard warning tactile pavement rows N = Number of warning tactile pavement rows the street needs	
(23) Ramp	
A walking surface which has a running slope greater than 5% Standard: • Max slope is 8.3% • Min width is 1.2 m • Suitable handrail should be provided	$C = 0$ $N = 9$ $PI_{23} = 0$
$PI_{23} = \begin{cases} 1 & \text{if} \quad P \geq 1 \\ P & \text{if} \quad P < 1 \\ 1 & \text{if} \quad \text{street does not need ramp} \end{cases}$ $P = C/N$ C = Number of standard ramps N = Number of ramps the street needs	
(24) Grade	
Standard: Sidewalk grade ≤ 5%	$C_1 = (14.15\times2.45) - 0 = 34.67$ $W_1 = 2.45$ $N_1 = 14.15\times2.45 = 34.67$ $PC_1 = 34.67/34.67 = 1$ $C_2 = (48.9\times8) - 350 = 41.2$ $W_2 = 8$ $N_2 = 48.9\times8 = 391.2$ $PC_2 = 41.2/391.2 = 0.10$ $C_3 = (135.3\times1.3) - 71.1 = 104.79$ $W_3 = 1.3$ $N_3 = 135.3\times1.5 = 202.95$ $PC_3 = 104.79/202.95 = 0.52$ $C_4 = (1654.5\times1.2) -$ $161.17 = 1824.23$

Table 4 (*Continued*)

$PI_{24} = C/N$ C = Area of sidewalk with the standard grade (m^2) $N = \begin{cases} (\text{length of street (both sides)} - \text{length of intersections}) \times 1.5 & \text{if } W < 1.50\text{ m} \\ (\text{length of street (both sides)} - \text{length of intersections}) \times W & \text{if } W \geq 1.50\text{ m} \end{cases}$ W = Width of footpath (m) If W varies in different portions of the street $PI_{24} = (\sum_{i=1}^{k} DIC_i \times L_i)/(\text{length of street (both sides)} - \text{length of intersections})$ i=1, 2, 3, ... k (different parts of street with various width of the footpath) $DIC_i = C_i/N_i$ C_i = Area of the sidewalk with the standard grade in section i (m^2) $N_i = \begin{cases} (\text{length of street (in section i)}) \times 1.5 & \text{if } W < 1.50\text{ m} \\ (\text{length of street (in section i)}) \times W & \text{if } W \geq 1.50\text{ m} \end{cases}$ L_i = Length of the street (in section i) (m)	$W_4 = 1.2$ $N_4 = 1654.5 \times 1.5 = 2481.75$ $PC_4 = 1824.23/2481.75 = 0.73$ $C_5 = (198.95 \times 0.9) - 38.55$ $= 140.5$ $W_5 = 0.9$ $N_5 = 198.95 \times 1.5 = 298.42$ $PC_5 = 140.5/298.42 = 0.47$ $C_6 = (50.05 \times 2.8) - 0 = 140.14$ $W_6 = 2.8$ $N_6 = 50.05 \times 2.8 = 140.14$ $PC_6 = 140.14/140.14 = 1$ $C_7 = 1903.53 \times 0 = 0$ $W_7 = 0$ $N_7 = 1903.53 \times 1.5 = 2855.29$ $PC_7 = 0/2855.29 = 0$ $PI_{24} = (1 \times 14.15 + 0.1 \times 48.9 + 0.52$ $\times 135.3 + 0.73 \times 1654.5 + 0.47 \times 19$ $8.95 + 1 \times 50.05 + 0 \times 1903.53)$ $/3888.38 = 0.37$
(25) Signal	
Standard: • Accessible pedestrian signals must be at least 3 m from each other at a crossing and 1.5 m from other traffic signals (1) • The device should be placed no closer than 0.75 m and at most 3 m away from the curb (2) • It should not be more than 1.5 m from the crosswalk (3) • An adequate countdown timer should be provided (4) • A wheelchair user should be able to reach the button (5) • An audible signal is needed (6) $PI_{25} = (SPI+CPI+WPI+API)/4$ $SPI = \begin{cases} 1 & \text{if} & P_1 \geq 1 \\ P_1 & \text{if} & P_1 < 1 \end{cases}$ $P_1 = SP/N$ SP = Signals with first, second and third standard conditions N = Total number of signals the street needs $CPI = \begin{cases} 1 & \text{if} & P_2 \geq 1 \\ P_2 & \text{if} & P_2 < 1 \end{cases}$ $P_2 = C/N$ C = Signals with fourth standard condition $WPI = \begin{cases} 1 & \text{if} & P_3 \geq 1 \\ P_3 & \text{if} & P_3 < 1 \end{cases}$	SP = 0 N = 44 SPI = 0/44 = 0 C = 0 CPI = 0 W = 0 WPI = 0 A = 0 API = 0 $PI_{25} = 0$

Table 4 (*Continued*)

$P_3 = W/N$ W = Signals with fifth standard condition $API = \begin{cases} 1 & \text{if} \quad P_4 \geq 1 \\ P_4 & \text{if} \quad P_4 < 1 \end{cases}$ $P_4 = A/N$ A = Signals with sixth standard condition $PI_{25} = 0$ If there is no signal	
(26) Bench and seating area	
Standard : • It should be in planting and frontage zone • It should be located a min of 0.6 m setback from the face of the curb • It should be min 9 m from an intersection • It should be provided in all bus stops • It should be provided every 200 - 400 m • A space of 1.2 m should be provided at the end of seats to enable strollers and wheelchairs to be parked • All seating should be set back at least 0.6 m from pedestrian traffic routes • A space of 1.5 m should be provided between the front edge of the seat and any stationary obstacle such as a water fountain, trash receptacle or sign post	C = 2815.5m N = 4383.95m $PI_{26} = 0.64$
$PI_{26} = C/N$ C = Length of street with standards seating area + their support length (m) N = Length of street (in both sides) (m)	
(27) Drinking fountain	
Standard: • It should be located within furnishing zone near playgrounds or outdoor eating areas and adjacent to shelters and paved areas along walkways and plazas • It should be provided every 400 m • It should be located at least 0.6 m far from the pedestrian traffic routes	C = 0 N = 2168.45 $PI_{27} = 0/2168.45 = 0$
$PI_{27} = C/N$ C = Length of street with standards drinking fountains + their support length (m) N = Length of street (m)	

Table 5
References for standards of the indicators.

Indicator[a]	References
1	UTM standard (based on university standard)
2	g1, g4, g7, g8, g9, g10, g16
3	g11
4	g2, g8, g19, g20
5	g1, g2, g3, g8
6	g7, g8, g10
7	g8, g10, g11, g17, g18
8	g10, g17, g19, g20
9	g7, g8, g10, g11, g17, g19, g20
10	g10, g11, g16, g17, g18, g19, g20
11	g1, g3, g8, g9, g10, g12, g13, g14, g15, g17, g18, g19, g20
12	g10, g17, g20
13	g2, g3, g7, g8, g10, g11, g12, g14, g19, g20
14	g7, g8, g10, g11, g12, g17, g19, g20
15	g1, g10, g11, g17, g20
16	g8, g9, g10, g17, g20
17	g8, g17, g18, g20
18	g8, g10, g16, g18, g19
19	g8, g10, g17, g19, g20
20	g16, g17
21	g17
22	g16, g17, g19, g20
23	g17
24	g10, g16, g19
25	g7, g8, g10, g17, g19, g20
26	g7, g8, g9, g18
27	g8

Guidelines: g1 – Clarke (2008), g2 – City of Calgary (2008), g3 – Sutherland and Morrish (2006), g4 – City of Whittlesea (2009), g5 – NARRABRR SHIR COUNCIL (2001), g6 – City of Charles Sturt (2009), g7 – Heramb (2007), g8 – Vanderslice (1998), g9 – Ashland City Council (1999), g10 – Access Minneapolis (2008), g11 – CDOT (2007), g12 – Pima County (2005), g13 – Neighborhood Streets Project Stakeholders (2000), g14 – City of Aurora (2007), g15 – Burden (1999), g16 – Boodlal (2001), g17 – UTTIPEC (2009), g18 – NewYork city department of transportation (2009), g19 – RDM (2010), g20 – City of Tacoma (2009).

[a] (1) Slower traffic speed, (2) buffer and barriers (curb and furnishing zone), (3) fewer traffic lane, (4) mid block crossing, (5) landscape and tree, (6) facility (fire hydrant), (7) furniture (trash receptacle), (8) footpath pavement, (9) marking (crosswalk), (10) corner island, (11) sidewalk on both sides, (12) advance stop bar, (13) width of footpath, (14) driveway, (15) lighting, (16) signing, (17) bollard, (18) slope, (19) curb ramp, (20) wheelchair accessible drinking fountain, (21) tactile pavement (guiding), (22) tactile pavement (warning), (23) ramp, (24) grade, (25) signal, (26) bench and seating area and (27) drinking fountain.

Table 6
PLOS% interpretation.

PLOS% rating	Model score	Interpretation
A	80–100	Highest quality (very pleasant), many important pedestrian facilities present
B	60–79	High quality (acceptable), some important pedestrian facilities present
C	40–59	Average quality (rarely acceptable), pedestrian facilities present, but there is room for improvement
D	20–39	Low quality (uncomfortable), minimal pedestrian facilities
E	1–19	Lowest quality (unpleasant)
F	0	There is no standard pedestrian facility (very unpleasant)

Discussion and conclusions

To make campuses more pedestrian-oriented, appropriate infrastructures and facilities should be provided in on streets. To achieve this aim, a practical PLOS is proposed to evaluate pedestrian facilities and indicate improvements. Previous studies have considered a PLOS for a limited range of pedestrian facilities and abilities, but it can also be used in campus contexts for various facilities and pedestrian abilities (e.g., old and disabled pedestrians). This effort was first made to fulfill the needs of all pedestrians with different abilities on campus streets. This PLOS model uses various facilities extracted from a wide range of developed guidelines. In addition, a rating system is used to develop an easy-to-follow methodology for evaluating campus streets for pedestrians. The proposed PLOS is universally applicable because the final standard conditions are a combination of the universal standards of developed guidelines. This complete guideline is useful for the maintenance and future growth of university campus streets. Campus designers can also prioritize indicators based on their coefficients (importance) to manage financial resources (refer to Eq. (2)).

This PLOS can be developed in further research using a similar process for other street users (e.g., motorized and non-motorized) with respect to encouraging people to use sustainable transport modes. The developed model can help campus designers to produce efficient and safe networks to support pedestrians and other street users. This evaluation model can be developed in the form of software to make its use more convenient. This model can also be utilized for other land uses, such as urban and rural areas, with appropriate adjustments.

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