Pedestrian facilities evaluation using Pedestrian Level of Service (PLOS) for university area: Case of Bandung Institute of Technology

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Abstract. Promotion of walking activities can be done by applying the concept of walkability through infrastructure improvement of pedestrian facilities. Knowledge of how well a highway can be pedestrian friendly and secure through pedestrian assessment become important. The pedestrian level of service (PLOS) is the most common approach to assessing the quality of pedestrian facility operations. This research evaluated pedestrian facilities by using several PLOS methods. i.e. HCM (2000), Trip Quality (Jazkiewicz, 1999), Gainesville (Dixon, 1996), and Australian (Main Roads WA, 2006), for the case of university area at Bandung Institute Technology. Data collection techniques used consisted of traffic counting survey and observation. Improvement recommendations are given to poorly rated performance indicators in the PLOS evaluation. The results of PLOS evaluations is vary and improvement of pedestrian facilities are still required on some indicator such as maintenance, effective width, lighting, access and supporting facility, crossing facilities, and potential conflict with vehicle.

1 Introduction

Walking is a mode of transportation that can never be separated from a travel chain. Whatever type of transportation mode used to reach a destination must involve walking activity. Walking mode may be the key point in encouraging shifting mode from private to public in the sustainable transport. Walking assessment was already described comprehensively in [1]. This paper would like to examine more detail to the pedestrian level of service (PLOS) for the specific area such as in university area. Four method of PLOS were used i.e. HCM, Trip Quality, Gainesville, and Australian PLOS [2-6]. The case of some sidewalks and walkways in the area of Bandung Institute of Technology campus were applied accordingly. Result of the various PLOS analysis could give better pictures of the facilities issues to improvement. Similar work had been done by Sdoukopoulos for pedestrian network in Thessaloniki and Karatas in METU Campus [7].

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2 Notes on Plos Methods

Generally, the PLOS method can be distinguished into two approaches. The first approach was that only concerns on pedestrian flow. HCM (2000) is a good example of the first method. In this method, the concept of traffic flow characteristic was adopted to the pedestrian flow on the specific passageway. The second approach considered into the quality of the walking environment, especially interaction between pedestrian flow and vehicle movement. On the other hand, it was about safety issue on the pedestrian facilities. Beside that, the issue of walking comfort somehow was taking into account. Example of this approach was (Walking) Trip Quality. Other methods, such as Gainesville and Australian PLOS combined those two approaches into their method. In term consideration issues, the following table described issue comparison of the PLOS methods [4].

Table 1. Issue Comparison of PLOS Dimensions

PLOS Dimension	HCM (2000)	Trip Quality (Jaskiewicz, 1999)	Gainesville (Dixon, 1996)	Australian (Main Roads WA, 2006)
User characteristics	x	x	x	x
Traffic	Volume and pedestrian speed	x	Volume and vehicle speed	Volume and mix of path user
Safety and comfort	x	Enclosure/definition, overhang, buffer, shade trees, transparency, vehicle speed, and lighting.	Potential conflict with vehicle (sidestreet and driveway), pedestrian delay, reduced turn conflict implementation, crossing width, vehicle speed, median, buffer, bench/lighting, shade trees, and VLOS.	Crossing facilities, environment (buffer), potential conflict with vehicle, and personal security (lighting and sight distance).
Land use	x	Enclosure/definition, building articulation, complexity of network, complexity of space, dan transparency.	Continuity, off-street/parallel alternative facilities, TDM and multimodal.	Connectivity
Infrastructure	Effective width and capacity	Width and surface quality	Effective width, total width, barrier, median and surface quality.	Access, width, and surface quality.

The level of service for pedestrian facilities focused more on the characteristic of the facilities. The user perception and some user effort to walk were not being considered deeply. On the contrary, in the walkability method, how the user interacted with the facilities in order to do the walking were being main consideration [1].

Further discussion the method that used in this is as follow. The pedestrian level of service (PLOS) as a result of thorough measurement of walking conditions on a route, path, or pedestrian facility [8]. The PLOS is directly related to the factors affecting mobility, comfort, and safety that reflect pedestrian perceptions of how much a facility can be pedestrian friendly.

HCM (2000) explains that the main performance to be measured in assessing PLOS is the space available for walking, in other words HCM (2000) only considering the capacity of pedestrian facilities. The parameters reviewed in the assessment are volume, average velocity, module, and pedestrian volume-capacity ratio. For the practicality of field observations, the flow or volume of passing pedestrians can be used as a service measure to assign PLOS from A to F.

The applied of Trip Quality method to define nine qualitative PLOS evaluation steps to analyze the pleasures, safety, and comfort of pedestrians when traveling on a pedestrian facility [3]. The complexity of network, building articulation, complexity of space, overhang, buffers, shade trees, transparency, and physical components were components to be considered. Score of 1 to 5 are applied to each parameter assessed, with a score of 5 reflecting excellent conditions and 1 reflecting very poor conditions. Each parameter score summed and averaged to get PLOS value from A to F.

The Gainesville PLOS evaluation method was developed to be applied in the city of Gainesville (Florida) as part of mobility plans for congestion management [4]. The basic

criteria for PLOS assessment used consist of six categories, the type of pedestrian facility provided, the conflict between pedestrians and motor vehicles, the existence of supporting facilities (amenities) to accommodate the movement of pedestrians, vehicular level of service (VLOS), maintenance, and TDM and support for multimodal transport. The total score obtained from the sum of each category score determines the PLOS value with a score of 1 to 21 (A - F).

In Australian PLOS method which is an amendment of a study conducted for Main Roads Western Australia by BSD Consultants [8], PLOS assessment is done on three factors, namely physical characteristics, location factor, and user factor. The condition of the pedestrian facility is explained by PLOS from scale A (ideal pedestrian condition condition) to PLOS E (condition of pedestrian facility unsuitable), based on assessment of factors affecting PLOS. Meanwhile PLOS F provides additional information for pedestrian facilities with low access points for disabled.

2.1 Data collection

The data required in PLOS evaluation are grouped into three categories: traffic data of vehicles and pedestrians, infrastructure (road geometry and condition of pedestrian facilities), and land use (related to the condition of buildings, facilities, or spaces around the pedestrian path). All data is obtained through traffic counting survey and observation. The traffic counting survey is conducted on weekdays between Monday and Friday for two-hour from 11:00 to 13:00 (observation period per 15 minutes) which is lunch break time for each observation segment. While observation time for observation activities can be done anytime, either on weekdays or weekends. It should be noted that the PLOS rating of lighting or personal security should be done at night to represent the actual condition and evaluation of PLOS for sidewalk in this study is done on one side only that are beside BNI Bank - Salman Mosque - One Eighty Café. It can be said that walking facilities is reviewed within the constraint of the corridor not as a network, therefore evaluation for complexity of the network on the PLOS Trip Quality method is not done. The pedestrian facility reviewed is divided into five segments of observation.

Table 2. Segmentation of Observation Location

Segment	Location	Type of Facility	Segment Length (m)
1	Ganesha Street Corridor (beside BNI Bank)	Sidewalk	180.3
2	Ganesha Street Corridor (beside Salman Mosque)	Sidewalk	199.5
3	Ganesha Street Corridor (beside One Eighty Café)	Sidewalk	107
4	Corridor of Physics Study - Civil Engineering	Walkway	119.5
5	Corridor of Civil Parking Field	Walkway	82.5

Fig. 1 Preview of Observation Location

3 Data analysis and discussion

Basically, there are five aspects of the assessment that being considered as the important aspects to evaluate. There are:

- Dimension: related to the capacity of the pedestrian facility provided. A pedestrian facility should be able to accommodate existing pedestrian traffic;
- Safety: related to the risk of pedestrian accidents due to conflicts with motor vehicles. Pedestrian facilities should be designed using the principle of potential conflict reduction;
- Security: related to the environmental safety of pedestrian facilities. The pedestrian facilities provided should make pedestrians feel safe because pedestrians can be seen and see the surrounding environment and are designed with anti-criminal principles;
- Comfort: deals with the comfort of pedestrian facilities for use. Comfort can be felt by pedestrians from the availability of protection against weather or rest areas, and others;
- Convenience: deals with the ease and suitability of pedestrian facilities for all groups of pedestrians use.

These five aspects are considered sufficient to get an idea of pedestrian level of service so that these five aspects should be used as a basis for planning a pedestrian facility. Some assessment criteria on the Trip Quality PLOS method such as building articulation and space complexity did not include into five aspects of the PLOS assessment that are considered important by the author. The main reason is that these two assessment criteria emphasize aesthetic values rather than functional values that illustrate how attractive the environment is to enjoy. Moreover, in this case, the assessment of building articulation or the complexity of the space is not very meaningful in assessing pedestrian facilities in the campus area which is using different aspects of environmental design compared to roads in urban city.

Table 3. Mapping of PLOS Evaluation Criteria

Criteria	HCM (2000)	Trip Quality	Gainesville	Australian
Dimension	- Width	- Width	- Width	- Width
Safety	x	- Enclosure/definition - Buffer - Vehicle speed	- Driveways and sidestreets - Reduced turn conflict implementation - Crossing width - Vehicle speed - Medians - Buffer	- Crossing facilities - Potential conflict with vehicle
Security	x	- Transparency - Lighting	- Reduced turn conflict implementation	- Personal security
Comfort	- Space for walking	- Overhang - Buffer - Shade trees - Surface quality	- Buffer - Benches or lighting - Shade trees - Vehicle LOS - Maintenance	- Surface quality - Path environment - Path user volume - Mix of path user
Convenience	x	- Complexity of network	- Continuity - Offstreet/parallel alternative facilities - Pedestrian signal delay - TDM/multimodal	- Access - Support Facilities - Connectivity

3.1 Overview of evaluation results

From the PLOS evaluation results using four PLOS evaluation methods obtained varying PLOS values even for the same observation segment. This difference is indeed expected to occur due to the different assessment factors considered in the evaluation of each method. But basically the aspects of the assessment discussed in each method are almost similar.

Table 4. PLOS Evaluation Results

Segment	Location	Type of Facility	PLOS/Score			
			HCM (2000)	Trip Quality	Gainesville	Australian
1	1	Sidewalk	A / 5.51 p/min/m	C / 3.15	C / 13.5	D/F / 58
2	1	Sidewalk	C / 23.33 p/min/m	B / 3.6	C / 12.5	C/F / 71
3	1	Sidewalk	A / 4.44 p/min/m	C / 3.08	C / 13.5	C/F / 70
4	2	Walkway	A / 7.19 p/min/m	B / 3.6	B / 16.5	B/F / 121
5	3	Walkway	C / 23.67 p/min/m	A / 3.98	B / 14.5	B/F / 109

Significant differences in PLOS values were obtained from the evaluation of the HCM method (2000) with the other three methods. The most extreme example can be seen in the evaluation of PLOS in segment 1, namely sidewalk beside Bank BNI in Ganesha Street corridor. The HCM (2000) method provides excellent evaluation results of PLOS A for this segment, whereas the Trip Quality and Gainesville methods provide a much lower value of PLOS C which means fair or standard, even the Australian method provides very low evaluations of D Indicates that the condition of existing pedestrian paths is poor. The comfort of the pedestrian is minimal and there are safety issues in the pedestrian environment.

This can happen because the HCM (2000) method does not take into account the environmental conditions of pedestrian facilities and rely solely on the parameters of the capacity-based or pedestrian flow assessment. If a PLOS pedestrian facility is only assessed using the HCM (2000) method it can provide misleading results related to the actual condition of the pedestrian facility. As in the case of segment 1, actual current conditions exhibit poor surface quality or maintenance with low pedestrian volume but are rated very well by the HCM method (2000) or in segment 4, where the actual walkway conditions are convenient to use based on Trip Quality method or safe from conflicts with vehicles based on Gainesville and Australian methods but rated standard by the HCM method (2000) as the ease of pedestrians to move (related to capacity and current) is slightly disturbed because of the possibility of minor conflict between pedestrians walking side by side or low speed due to limited walkway area.

The use of the HCM (2000) method is likely more suitable for evaluating the capacity of pedestrian facilities in areas with high pedestrian volumes using pedestrian facilities provided as the main pedestrian site, not on road in roadside sidewalks. The advantages of the HCM method (2000) when compared with three other methods apart from the ease of assessment and simple data requirements are the ability to describe the use of pedestrian facilities that are subject to change over time and can be compared with the capacity provided by pedestrian facilities. The evaluation results of the Trip Quality method in the study sites tend to provide a moderate to excellent value, namely PLOS A - C. PLOS evaluation with Trip Quality method is highly qualitative considering the environmental design of pedestrian facilities and few attention to traffic factors that only involve vehicle speed criterion.

From the results of the evaluation it appears that the Gainesville and Australian PLOS evaluation methods yield the same PLOS value in almost every observation segment with values that tend to be lower than the PLOS values of other methods. This possibility occurs

because both methods involve quantitative and qualitative parameters related to the pedestrian volume, infrastructure and environmental characteristics of pedestrian facilities, in contrast to the HCM method (2000) which involves only quantitative or quantitative parameters Trip Quality method is dominated by qualitative assessment parameters. The incorporation of quantitative and qualitative parameters on PLOS evaluation, as in both methods, can improve the reliability of the assessment results.

From the evaluation results can also be seen that This occurs because the walkway reviewed excels in overhang criteria with the roof usage, the physical component of which is due to its excellent surface conditions, the availability of adequate illumination and crossing facilities and the limited potential for conflict with the vehicle when compared to the sidewalk reviewed.

3.2 Performance Indicators for Improvement

Based on PLOS evaluation results, the performance indicators or evaluation criteria of PLOS that need to improve are as follows.

Table 5. Performance Indicators That Requires Improvement

Segment	Location	Type of Facility	Performance Indicator			
			HCM (2000)	Trip Quality	Gainesville	Australian
1	1	Sidewalk	x	- Surface quality - Transparency* - Building articulation* - Complexity of spaces* - Lighting	- Driveways and sidestreets - Maintenance	- Surface quality - Crossing facilities - Access - Support facilities - Potential conflict with vehicle - Personal security
2	1	Sidewalk	Effective width	- Transparency* - Lighting	- Minimum 1.53 meter wide and barrier free - Maintenance	- Crossing facilities - Access - Path width - Support facilities - Personal security
3	1	Sidewalk	x	- Transparency* - Building articulation* - Complexity of spaces* - Lighting	- Driveways and sidestreets - Maintenance	- Access - Support facilities - Potential conflict with vehicle - Personal security
4	2	Walkway	x	- Transparency* - Building articulation*	x	- Access
5	3	Walkway	Effective width	- Effective width - Building articulation*	- Minimum 1.53 meter wide and barrier free	- Access - Path width - Support facilities

*Recommendations regarding these performance indicators are not provided because they are outside the realm of the authors' studies

3.3 Recommendations for Improvement

Result of the various PLOS analysis could give better pictures of the facilities issues to improvement. One PLOS method might not capture all issue. The general recommendation for improvement that can be given are:

- Surface quality/maintenance; (1) repairing pedestrian pavement by replacing broken or broken tile or tactile indicator and tile installation on the missing part and (2) the use of high durability pavement and routine vegetation intrusion pruning on the surface of the pedestrian path.
- Effective width; (1) applying the concept of sidewalk café or parklet which is more suitable for segment condition 2, (2) provides a guardrail on pedestrian path for trading area with comparison of pedestrian width and trade area width maximum 1: 1.1 or equal to 1.4 meters of pedestrian width with an effective width of 0.6 meters if the cost component becomes a limitation in segment 2, and (3) widening effective width to segment 5 by closing the existing drainage by using a gutter inlet.
- Lighting/personal security; Providing pedestrian lights on segments 1, 2, and 3 with a light illumination level of 6 lux in the horizontal and 11 lux in the vertical direction.
- Access; (1) installation of the curb ramp at the intersection and ramp point near the entrance to the sidewalks of segments 1, 2, and 3 and (2) if the cost does not become a limitation, the installation of ramps in segments 4 and 5 and wheelchair access in Segment 5 can be done, (3) the use of sign to remind the stairs in segment 4 and signs to direct the wheelchair user to use the ramp in the entrance through the main gate south of ITB on segment 5 can be done if the cost becomes boundary.
- Support facilities; (1) installation of detectable warning at the intersection point and near the obstruction on all segments and (2) installation of guiding tactile indicators on segments 4 and 5. (3) adding signs or information boards on all segments.
- Crossing facility; Provision of zebra cross facilities in segments 1, 2, and 3.
- Potential conflicts with vehicles; The use of warning signs that many passers-by and vehicles passing in and out into the sidewalks of segments 1 and 3.

3.4 Improvement Impact to Updated PLOS Value

With assumption of all improvement had been carried out, new value of PLOS can be calculated. It was not about just to achieve the value of each PLOS became A but it can be considered as how much effort needed to achieve a better value of PLOS. Table 6 to Table 9 below show the new value after improvement. Noted that the red color indicates changes and number inside the brackets is PLOS score before improvement. From the table it appears that recommendations related to effective width improvements only affect the value of HCM method and not for the other three methods. Overall, however, the PLOS aggregate value of each method for all segments has met the desired PLOS improvement targets.

Table 6. Change of HCM (2000) PLOS Value

Segment	1	2	3	4	5
Volume (p/min/m)	5.51	16 (23.33)	4.44	7.19	16 (23.67)
PLOS	A	A (C)	A	A	A (C)

Table 7. Change of Trip Quality PLOS Value

Category	Segment				
	1	2	3	4	5
ENC: Enclosure	5	5	4	4	5
CPN : Complexity of network	-	-	-	-	-
BA : Building articulation	2	3	2	2	1
CS : Complexity of spaces	2	4	2	3	3
AWN : Overhang	3	3	3	5	5
BF : Buffer	5	5	5	5	5
ST : Shade trees	4	4	4	4	4
TR : Transparency	2	2	2	1	5
PC : Physical Condition					
(1) SC : Sidewalk condition and configuration					
a. Effective width	2	2	2	4	2
b. Surface quality	5 (1)	5 (3)	5 (4)	5	5
Average SC score	3.5	3.5	3.5	4.5	3.5
(2) VS : Vehicle speed	3	4	3	5	3
(3) L : Lighting	5 (2)	5 (2)	5 (2)	5	5
Average PC score	3.8333	4.1667	3.8333	4.8333	3.8333
Total	26.83 (25.17)	30.17 (28.83)	25.83 (24.67)	28.83	31.83
Average	3.35 (3.15)	3.77 (3.60)	3.23 (3.08)	3.60	3.98
PLOS	B (C)	B	C	B	A

Table 8. Change of Gainesville PLOS Value

Category	Criteria	Points	Segment				
			1	2	3	4	5
C1 : Pedestrian Facility Provided (Max. value = 10)	- Not continuous or non existent	0	6	6	6	4	4
	- Continuous on one side	4					
	- Continuous on both side	6					
	Minimum 1.53 m wide barrier and free	2	0	0	0	2	0
	Sidewalk width > 1.53 m	1	1	1	1	1	1
C2 : Conflicts (Max. value = 4)	Off street /parallel alternative facility	1	1	1	0	1	1
	Driveways and Sidestreets	1	0	1	0	1	1
	Pedestrian signal delay	0.5	0.5	0.5	0.5	0.5	0.5
	Reduced turn conflict implementation	0.5	0	0	0	0	0
	Crossing width ≤ 18.3 m	0.5	0.5	0.5	0.5	0.5	0.5
	Posted speed	0.5	0.5	0.5	0.5	0.5	0.5
	Medians present	1	0	0	0	0	0
C3 : Amenities (Max. value = 2)	Buffer ≥ 1 m	1	1	1	1	1	1
	Benches or pedestrian scale lighting	0.5	0.5	0.5	0.5	0.5	0.5
	Shade trees	0.5	0.5	0.5	0.5	0.5	0.5
C4 : Motor vehicle LOS (Max. value = 2)	- LOS E, F or travel lanes ≥ 6	0	2	0	2	2	2
	- LOS D and travel lanes < 6	1					
	- LOS A, B, C and travel lanes < 6	2					
C5 : Maintenance (Max. value = 2)	- Major or frequent problems	-1	2 (-1)	2 (0)	2 (0)	2	2
	- Minor or infrequent problems	0					
	- No problems	2					
C6 : TDM/Multimodal (Max. value = 1)	- No support	0	1	0	1	0	0
	- Support exists	1					
Total			16.5 (13.5)	14.5 (12.5)	15.5 (12.5)	16.5	14.5
PLOS			B (C)	B (C)	B (C)	B	B

Table 9. Change of Australian PLOS Value

Category	Criteria	Weight	Segment				
			1	2	3	4	5
Physical Characteristics	Access	5	4 (1)	4 (1)	4 (1)	1	1
	Path width	4	1	1	1	3	1
	Surface quality	5	4 (0)	4 (2)	4 (3)	4	4
	Crossing facilities	4	4 (0)	4 (0)	4 (0)	3	3
	Support facilities	2	4 (1)	4 (1)	4 (1)	5 (2)	2
Location Factors	Connectivity	4	4	4	4	4	4
	Path Environment	2	4	4	4	4	4
	Potential conflict with vehicle	3	1	2	0	4	4
User Factors	Path user volume	3	0	0	0	0	0
	Mix of path users	4	4	4	4	4	4
	Personal security	4	4 (1)	4 (1)	4 (1)	4	4
Total of weighted score			127 (58)	130 (71)	124 (70)	123 (121)	113
PLOS			B (D/F)	B (C/F)	B (C/F)	B/F	B/F

4 Conclusions

The results of the PLOS evaluation are obtained that in the same observation segment can have more than one PLOS value when the PLOS evaluation method used is different. It should be noted that there is no single method that can be used completely to evaluate the quality of the pedestrian facility operations (in this case sidewalk and walkway) accurately. From the evaluation result, it is found that sidewalk and walkway in ITB area still need improvement on performance indicators such as maintenance, effective width, lighting, access and supporting facilities, crossing facilities, and potential conflicts with vehicles.

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