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THE ASSESSMENT OF FEASIBILITY AND EFFECTIVENESS OF PEDESTRIAN FACILITIES

Dea Meirina Sari[1*], Nahry[1], Heddy R. Agah[1]

[1] *Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI Depok, Depok 16424, Indonesia*

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ABSTRACT

Pedestrians are frequently perceived as one of the sources of traffic congestion due to their illegal occupancy of the roadway. The goal of this study is to examine this issue by investigating the feasibility of pedestrian facilities and the effectiveness of utilizing a pedestrian bridge at a certain congested area: the north-bound traffic in Jalan Lenteng Agung, Jakarta. The feasibility of a facility is represented by an indicator of the Level of Service (LOS), i.e. the space occupied by one pedestrian, and is supported by an assessment from the pedestrian's point of view, using a questionnaire covering various aspects of the issue. The assessment of its geometric feasibility is also carried out, using the design specifications issued by the Directorate General of Bina Marga (1990) to strengthen the analysis. Meanwhile, the effectiveness of using a pedestrian bridge is represented by the ratio of pedestrian bridge users to the total number of people crossing the street. Data collection related to pedestrian flow is carried out using web cameras. The analysis shows that the LOS of all the segments of the pedestrian facilities ranges from LOS A to LOS C, in which LOS C represents the pedestrian bridge. LOS measures, supported by the geometric feasibility assessment results, signify that the facilities are not yet feasible; the speed of pedestrian flow needs to be increased using geometric improvement and the elimination of all disturbances throughout the facilities. Meanwhile, the effectiveness of using the pedestrian bridge is only 50.26% (meaning it is "quite useful"); the remaining percentage of pedestrians cross the road by navigating through the road traffic. The questionnaire results show that people are indeed aware of the importance of the safety issues related to bridge usage; however, they are reluctant to use it due to the physical barriers. The improvement generated from the analysis may help increase bridge use and its LOS, and eventually reduce the disturbance of vehicle flow.

Keywords: Crossing bridge; Effectiveness; Feasibility; Level of service; Pedestrian

1. INTRODUCTION

In general, there tend to be many pedestrians and dense vehicular traffic in downtown areas. Although vehicles and pedestrians have their own separate spaces for movement, sometimes these spaces are inadequate. As the vehicle and pedestrian spaces overlap, each vehicle becomes like a king while each pedestrian becomes essentially nonexistent (Alexander, 2010). Consequently, it important form of transportation in urban areas, pedestrians' needs should be considered as an integral part of the road transport system (Gehl, 2011). Pedestrian facilities include pedestrian bridges and supporting facilities such as sidewalks. Pedestrians have rights in

* Corresponding author's email: dheyaa62@gmail.com, Tel. +62-21-7270029, Fax. +62-21-7270028
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traffic, such as the rights to access to support facilities (sidewalks, crossing spaces, and other facilities) and priority when crossing intersections in choosing a crossing facility that best supports their safety (Law of Republic Indonesia Number 22 Year 2009). According to Article 132 of Law of Republic Indonesia Number 22 Year 2009, in addition to having rights in traffic, pedestrians also have obligations; for example, they have to use the road space that is intended specifically for them, pay attention to the flow of traffic, and be marked with special, easy-to-recognize symbols or signs if they have a disability.

One example of traffic congestion as a result of pedestrian movement can be observed in the traffic moving in a northern direction on Lenteng Agung Street. In that area, many pedestrians walk on the vehicle roadway because vehicles are occupying the pedestrian spaces. In addition, there are also pedestrians who cross streets at random locations instead of at the specified locations at intersections, resulting in further traffic congestion. In order to solve this problem, the Jakarta Transportation Agency built a pedestrian crossing bridge there, expecting it to improve traffic flow. In order to see the effectiveness of the pedestrian facilities usage in this area, it is necessary to assess the feasibility of facilities from pedestrians point of view as well as the design standard requirement of pedestrian facilities, and to assess the level of usage of such facilities.

The concept of LOS is widely used in road traffic planning as well as in planning for pedestrian traffic and events (Kretz, 2011). In transportation science, LOS is the concept of breaking the continuous range of traffic-state-dependent quality and availability of traffic infrastructure into manageable number of (mostly six) levels. Pedestrian LOS schemes are based either on density alone or on special elements that are situation-dependent (like the width of sidewalks). Kretz (2011) developed an extension of the original density-based LOS schemes for use in microscopic simulation of pedestrian traffic. The Highway Capacity Manual (HCM) approach to estimating LOS based on densities and flow speeds remains a robust design tool and measure for areas where local capacity is the key design issue. However, the full consideration of all factors determining a LOS for pedestrians is far wider and includes the consideration of at least five broad environmental factors: comfort, convenience, safety, security and economy (Colin, 2000).

Taking into account pedestrians’ perceptions for assessing the pedestrian LOS is another useful strategy for providing a comfortable and safe walking environment (Lei et al., 2013). Dandan et al. (2007) have studied the methods of assessing the pedestrian level of service by analyzing the relationship between the pedestrians' subjective perceptions and the quality of the road’s physical facilities, as well as the traffic flow operations. In terms of pedestrians’ perceptions, O' Flaherty (1997) took into consideration the factors that influence the use of segregated crossing facilities, sorted in order of increasing importance: distance, convenience, aesthetics, environmental considerations, and safety. Carr (2009) considered the elements related to comfort, time, convenience, availability of motorized vehicles, and land use patterns as factors that affect walking distance.

2. METHODOLOGY

Characteristics of pedestrian flow are identified prior to the analysis of the feasibility of the facilities. They are represented by the measures of flow, speed, density, and space. Data is obtained from direct observation of the study area (Figure 1) ‒namely, traffic moving in a northern direction on Lenteng Agung Street‒ using a video camera. It generates data concerning the volume and travel time on the segments of pedestrian facilities. Such data are then applied to the following formulas to find the measurements of pedestrian characteristics (Munawar, 2005):

$$Q = \frac{v_{15}}{15\ W_E} \tag{1}$$

$$V_S = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\frac{1}{V_i}} \tag{2}$$

$$D = \frac{Q}{V_s} \tag{3}$$

$$S = \frac{V_s}{Q} = \frac{1}{D} \tag{4}$$

where;

Q : Flow of pedestrian (p/m/minute)
v_{15} : Peak 15-minute volume (p/15 minute)
W_E : Effective width (m)
V_S : Space mean speed (m/minute)
n : Number of pedestrian observed
V_i : Speed of each observed pedestrian (m/minute)
D : Density (p/m^2)
S : Space (m^2/p)
p : Pedestrian

Figure 1 shows that the path marked BG is the link that represents the pedestrian crossing bridge, while DE is the road pavement of Lenteng Agung Street that is still frequently used by pedestrians to cross this street, even though the path EFGH is equipped with a guardrail for preventing this action. The traffic flow at the time of this observation was very heavy. The survey was done on Sunday, the 21st of September in 2014, between 10:00 and 11:30 pm. In addition to recording the movement of pedestrian flow, it also measured the geometric dimensions of the sidewalk facilities and the pedestrian bridge. Furthermore, the variables that represent the characteristics of pedestrians are calculated by applying Equations 1–4.

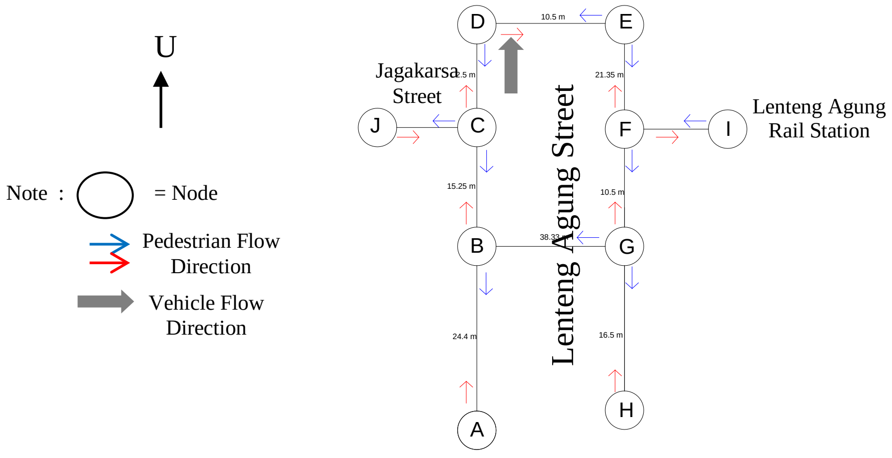

Figure 1 Network of pedestrian facilities at Lenteng Agung Street - North Direction

In order to assess the feasibility of segments of the pedestrian facilities, including the pedestrian bridge, we apply the Level of Service (LOS) as the measure of assessment. LOS is determined based on the measurement of the space of each segment by applying the Highway Capacity Manual 1985 specification (Table 1).

In addition to assessing the current LOS, we also assess the LOS of the proposed improved facilities, i.e. the facilities that have been repaired geometrically. Moreover, the geometric feasibility of the facilities is also assessed using the specifications of the pedestrian bridge and sidewalk in accordance with the guide for sidewalk design issued by the Directorate General of Bina Marga in 1990 and the Standar Nasional Indonesia (SNI) SNI-03-2443-1991 (SNI-03-2443-1991 concerning Sidewalk Specification, 1991).

Meanwhile, as the LOS indicates the feasibility of the pedestrian facility in terms of the pedestrian flow, the feasibility of facilities from the pedestrian's point of view is qualitatively assessed through a questionnaire concerning various aspects of this investigation, including their rating of the facilities concerning certain issues, the frequency with which they use the crossing bridge, and their reasons for using or not using the bridge. The questionnaires were distributed (and returned) to 50 respondents on Tuesday, the 2nd of December in 2014, between 16:40 and 18:00 Waktu Indonesia Barat (WIB).

Table 1 Level of service of pedestrian facility

Level of Service	Space (m^2/p)	The expected flow and speed		
		Speed (m/minute)	Flow (p/m/minute)	V/C
A	≥ 12	≥ 79	≤ 6,5	≤ 0.08
B	≥ 4	≥ 76	≤ 23	≤ 0.28
C	≥ 2	≥ 73	≤ 33	≤ 0.4
D	≥ 1.5	≥ 69	≤ 46	≤ 0.6
E	≥ 0.5	≥ 46	≤ 82	≤ 1
F	< 0.5	< 46	Variation	

Source: Highway Capacity Manual, 1985

Even though the pedestrian bridge has been functioning well, there are still quite a few pedestrians who cross the road without using it. Consequently, the effectiveness of the pedestrian bridge is measured by assessing the ratio of pedestrians who use the pedestrian bridge to the total number of pedestrians crossing the roadway within a 90-minute observation period. Afterwards, this ratio is categorized into certain qualitative measurements using the Criteria of Pedestrian Crossing Bridge Usage (Table 2) to represent the level of the bridge's effectiveness.

Table 2 Criteria of pedestrian crossing bridge usage (Dwihasti & Tjan, 2006)

Level of Usage	Crossing Bridge Usage (%)
Very unuseful	0–20
Unuseful	21–40
Quite useful	41–60
Useful	61–80
Very useful	81–100

In order to strengthen the analysis of these pedestrian facilities, we also conducted an analysis of pedestrians' travel characteristics, such as their points of origin and destination, and the mode of transportation they used before and after using the pedestrian facilities.

3. RESULTS AND DISCUSSION

3.1. Geometric Feasibility of Pedestrian Facilities

From the geometric measurements, the dimensions of the pedestrian facilities are compared to the specifications of a pedestrian bridge and a sidewalk in accordance with the guidance on sidewalk design issued by the Directorate General of Bina Marga in 1990 and SNI-03-2443-1991 about sidewalk specifications. As indicated in Table 3, the existing geometric condition of the sidewalk satisfies the requirements in over 50% of the technical criteria; in other words, 7 out of the 12 technical criteria are fulfilled. This fact signifies that several geometric components of the sidewalk and the pedestrian bridge need to be improved, including the width, the rise, and the slope of the bridge, as well as the sidewalk width in several segments.

Table 3 The geometric assessment on pedestrian facilities

No.	Technical Criteria	Specific Requirements	Existing Conditions	Remark
1	The maximum height of stairs	0.15 m	0.18 m	Unsatisfied
2	The minimum width of stairs	0.3 m	0.3 m	Satisfied
3	Width of Pedestrian Bridge	2–2.5 m	Stair: 1.27 m; 0.82 m; Straight part: 1.9 m	Unsatisfied
4	Bridge supports do not interfere with the pedestrian	Do not interfere with the pedestrian	Not interfere	Satisfied
5	Minimum height of the lowest part of bridge from the highway pavement surface	5.1 m	5.7 m	Satisfied
6	Minimum length of rest space	1.5 m	1.36 m	Unsatisfied
7	Longitudinal slope	20^{o}–50^{o}	60^{o}	Unsatisfied
8	Minimum height of free space of sidewalk	2.5 m	> 2.5 m	Satisfied
9	Minimum Free Side Space	0.3 m	Free space on the east side is 1m; West side has no free side	Satisfied Unsatisfied
10	Minimum width of sidewalk around the shopping area	2 m	1.45m and 1.7m	Unsatisfied
11	Sidewalk barrier	Curb or barrier	East sidewalk: curb / barrier	Satisfied
			West sidewalk: no curb / barrier	Unsatisfied
12	Sidewalk level higher than pavement surface	Compulsion	West sidewalk: same level	Unsatisfied
			East sidewalk: higher level	Satisfied

3.2. Pedestrian Characteristics and Level of Service

Pedestrian characteristics are represented by their flow, speed, space, and density, as depicted in Table 4 and Table 5. They are determined from the observation of the 15-minute peak volume and width of the segment using the Equations 1–4. The LOS is assessed for two different states. In the first state, we use the width of the existing space that is occupied by the pedestrians and appropriate for walking (in which at some points the pedestrian space is disrupted by the presence of street vendors and parked motorcycles) as the effective width. In the second state, the effective width is represented by the width of the sidewalk in an undisrupted state. The LOS of each segment is determined by applying Table 1. The LOS for the two states are shown in Tables 4 and 5, respectively.

The Hypothetical Test (Munawar, 2005) reveals that space mean speed of male group and the one of female group are identical, and the space mean speed of the groups that are categorized by age (i.e. group of elder people, group of adults, and group of children) are also identical.

From Table 4, it is clear that segments AB/BA, BC/CB, and FG/GF have LOS B. It shows that pedestrians still have enough space to choose as they walk at a free flow speed (i.e. the possible highest speed) or pass other pedestrians. Meanwhile, segment BG/GB (i.e. the pedestrian bridge) has LOS C, which means that the space is merely for walking at a normal speed, especially when they walk in the same direction as the other pedestrians. When they walk in the opposite direction from the others, conflict will arise and the overall travel speed will be slightly decreased.

Table 4 Level of service of the existing condition (sidewalk on disrupted state)

Segment	v_{15}	Length of segment	Actual width (without disruption)	Effective width	Flow (Q)	Space mean speed (Vs)	Density (D)	Space (S)	LOS
	p	m	m	m	(p/m/min)	(m/min)	(p/m²)	(m²/p)	
AB/BA	84	21.35	1	0.8	7.000	72.069	0.097	10.296	B
BC/CB	156	27.45	1	0.8	13.000	97.331	0.134	7.487	B
BG/GB	212	38.33	0.82	0.62	17.236	37.623	0.458	2.183	C
FG/GF	166	12.2	2	1	11.067	75.115	0.147	6.787	B
GH/HG	56	10.675	2	1	3.733	62.043	0.060	16.619	A

Table 5 Level of service of the undisrupted state

Segment	v_{15}	Length of Segment	Actual width (without disruption)	Effective width	Flow (Q)	Space mean speed (Vs)	Density (D)	Space (S)	LOS
	p	m	m	m	(p/m/min)	(m/min)	(p/m²)	(m²/p)	
AB/BA	423	21.35	1.7	1.5	3.733	72.069	0.052	19.304	A
BC/CB	662	27.45	1.7	1.5	6.933	97.331	0.071	14.038	A
BG/GB	853	38.33	0.82	0.62	17.236	37.623	0.458	2.183	C
FG/GF	596	12.2	1.45	1.35	8.198	75.115	0.109	9.163	B
GH/HG	288	10.675	1.45	1.35	2.765	62.043	0.045	22.435	A

Table 5 shows that on the actual width (without disruption), segments AB/BA and BC/CB will have better LOS (i.e. LOS A) if disturbances such as street vendors and illegal parking do not exist. In this LOS, pedestrians could walk at free flow speed and it would not cause conflict among the pedestrians. Segment FG/GF is still at LOS B as long as there are no disturbances along the segment so that the pedestrians do not have to walk outside the sidewalk. Furthermore, at the second state, the LOS at segment BG/GB (the pedestrian bridge) is not changed since there are no disturbances such as beggars and street vendors along it.

From the discussion about the LOS in both states, and the reference to the LOS A as the target LOS of such facilities, it is apparent that the current condition of the facilities is not yet fully feasible, even if there were no street vendors or parked motorcycles. One way to reach LOSA is to improve the width of segment FG/GF and segment BG/GB.

3.3. The Effectiveness of Pedestrian Bridge Use

The assessment of the effectiveness of the pedestrian bridge use is done by using a ratio of the percentage of pedestrians who use the bridge to the total number of pedestrians crossing the road within a 90-minute observation period (% of obedience) (Table 6). From this observation, we calculate the average percentage of pedestrians who use the bridge as 50.62% of all pedestrians. Based on Table 2, then, the bridge can be categorized as "quite useful". However, since the levels of "very useful" or even "useful" have still not been achieved, we can conclude that the existence of the bridge has not yet been truly effective.

Table 6 The number of pedestrians using and not using the pedestrian bridge

Time	Total Pedestrians						% of obedience
	Total Pedestrians		Use the Pedestrian Bridge		Do not use the bridge		
	Men	Women	Men	Women	Men	Women	
10:00–10:15	130	141	77	110	53	31	69.00
10:15–10:30	205	148	106	106	99	42	60.06
10:30–10:45	98	76	42	37	56	39	45.40
10:45–11:00	149	106	57	49	92	57	41.57
11:00–11:15	160	122	68	58	92	64	44.68
11:15–11:30	178	129	62	70	116	59	43.00
Total	1642		842		800		50.62
Average							

3.4. The Analysis of Travel Characteristics and Feasibility of Facilities from the Pedestrians' Point of View

Based on the questionnaire given to pedestrians in the study area, several issues related to the travel characteristics of pedestrians and the feasibility of the facilities from the pedestrians' point of view arose as follows:

From the Origin Destination (OD) matrix (Table 7) and the composition of the initial mode used before crossing the street (Figure 2), we see that the majority of the pedestrians' origin is Lenteng Agung Station, their destination is Jagakarsa Street (34%), and the initial mode of transportation they used before crossing Lenteng Agung Street is the train (38%). Both the OD Matrix and the composition of the initial mode emphasize that most of the pedestrians are associated with the utilization of the path from Jagakarsa Street to Lenteng Agung Rail Station and vice versa, either using the bridge or the roadway. This fact leads to the perception that the crossing bridge in this area is vital; its effectiveness highly influences the traffic flow of the vehicles on Lenteng Agung Street.

Table 7 Matrix of the origin and destination of respondents

O \ D	A	B	J	I	G
A	0	0	0	14%	8%
B	0	0	0	6%	4%
J	0	0	0	8%	6%
I	10%	2%	34%	0	2%
G	4%	0	0	2%	0

Note : The notations refer to Figure 1

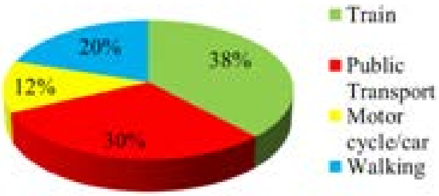

Figure 2 Composition of the initial mode before crossing Lenteng Agung Street

The result of the questionnaires concerning the frequency of bridge use indicates that people either never (26%), rarely (38%), often (4%), or always (32%) use the bridge. It also indicates that those who often and always use the bridge comprise only 36% of all pedestrians in this area. It likely supports the figure that indicates the percentage of obedience of a "quite useful" facility. Table 8 indicates that for the group of pedestrians who "often" and "always" use the pedestrian bridge, 62.5 % of them use the bridge for safety reasons, while for the group who "seldom" and "never" uses the bridge (Table 9) 72.22 % of the respondents are seldom or never use the bridge due to the "exhausting" reason.

Table 8 Distribution of reasons for using pedestrian bridge for respondents who "Often" and "Always" use it

	"Often" use pedestrian bridge	**"Always" use pedestrian bridge**	**Total**
Safety	25.00%	37.50%	62.50%
Forced by regulation	6.25%	12.50%	18.75%
More comfortable	6.25%	3.13%	9.38%
Heavy Traffic	0.00%	0.00%	0.00%
Bridge near to destination	3.13%	3.13%	6.25%
Miscellaneous	3.13%	0.00%	3.13%
Total	43.8%	56.3%	100.0%

Table 9 Distribution of reasons for using pedestrian bridge for respondents who "Never" and "Rarely" use it

Reasons	**"Never" use pedestrian bridge**	**"Rarely" use pedestrian bridge**	**Total**
Exhausting	5.56%	66.67%	72.22%
Longer walking distance	0.00%	16.67%	16.67%
Unsafe bridge	0.00%	0.00%	0.00%
Light traffic	0.00%	0.00%	0.00%
Miscellaneous	5.56%	5.56%	11.11%
Total	11.11%	88.89%	100.00%

These figures imply that although people are indeed aware of the importance of safety, they are also reluctant to use the bridge due to physical barriers. These results lead us to challenge the local authorities to provide better pedestrian facilities—particularly the crossing bridge—that comply with the human physical characteristics . The previous assessment of geometric feasibility also emphasizes this idea. Regarding the position of the bridge, 64.44% of respondents assess that the current position of the bridge is appropriate. In addition, the fact that only 18.76% of respondents are using the bridge for regulation reasons, shows that people are not paying sufficient attention to regulations. This problem reveals the need for the local transportation authority to focus on law enforcement more intensively.

Figure 3 indicates the results of the respondents' assessment of the facilities' feasibility in some areas. Here, respondents value the feasibility of the facilities (on a scale of 0 to 100) in respect to four main issues, namely the illegality of bridge usage (named "illegal usage"), the completeness of the facility (i.e. lighting, roof, sidewalk pavement, etc.), convenience (cleanness, space, etc.), and its security. For the pedestrian bridge, the respondents gave the highest value of the feasibility to the issue of "illegal usage." Obviously, this result is caused by the absence of street vendors and beggars along the bridge. The lowest value concerning the feasibility of the bridge is dedicated to its convenience. This result is in line with the discussion of the current LOS, which indicates that the bridge needs improvement on its width to give more space to the pedestrians. Furthermore, for the sidewalk, security is considered as the best aspect since these people have not had any experiences of criminal cases on the sidewalk, while the illegal usage of the sidewalk is the issue that interferes the pedestrians at the most on using sidewalk. Overall, the figure implies that the pedestrian facility should be improved in all of these areas (since the highest value of feasibility is only 63.1 out of 100).

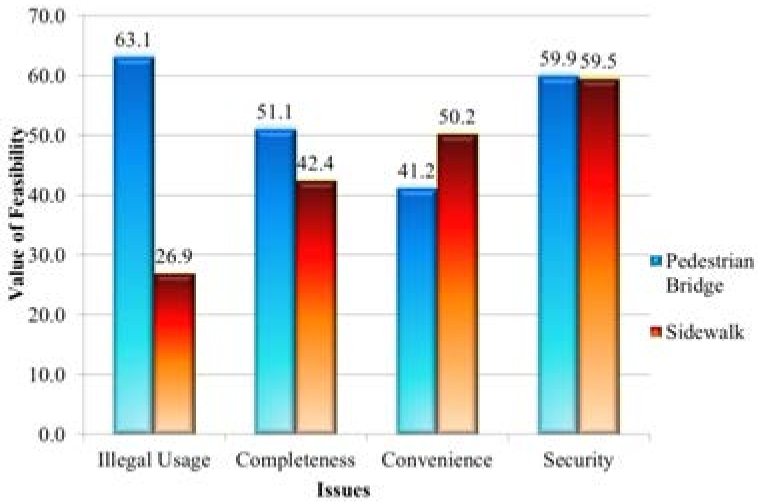

Figure 3 Feasibility of facilities on some issues from the pedestrians' point of view

4. CONCLUSION

Through the analysis of data from field observations and questionnaires distributed to respondents, we discovered that the feasibility of the pedestrian facilities on Lenteng Agung Street ranges from LOS C to LOS A, with LOS C pertaining to the pedestrian crossing bridge. Because we refer to the LOS A as the target LOS, we concluded that the current condition of the facilities is not yet fully feasible, even if illegal street vendors and illegal motorcycle parking were eliminated. The assessment of geometric feasibility emphasizes the need to improve the geometrics of the sidewalk and the pedestrian bridge—including the width, the rise, and the slope of the bridge, and the width of the sidewalk in several segments—in order to increase the space provided for the pedestrians and help overcome their reluctance to use the bridge due to physical barriers. This assessment of the effectiveness of bridge use reveals that it has not been utilized effectively. Only 50.62% of people use the bridge; everyone else crosses the street on the road pavement. These assessment results demonstrate the need for facilities that better accommodate pedestrians, and for more intensive law enforcement measures to help increase the effectiveness of the pedestrian bridge. Eventually, these improvements may help reduce the disturbance of vehicle flow due to pedestrian movement on the roadway.

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