Analysis of Pedestrian Bridge Requirements (Case Study: Pajajaran Road, In Front of Al-Mi'raj Grand Mosque)

Muhamad Iqbal Berlian[1], A.R. Indra Tjahjani[1]

[1]Civil Engineering Department, Universitas Pancasila, Jakarta , Indonesia
Corresponding author: iqbalberlian2@gmail.com

ABSTRACT

Increased urban activity and heavy traffic flow on Pajajaran Road, Bogor City, have created conflicts between vehicles and pedestrians in front of the Al-Mi'raj Grand Mosque. This study aims to evaluate the existing pelican crossing facility and determine the appropriate crossing facility. Data were collected through a two-day field survey, covering pedestrian volume, vehicle volume, vehicle speed, pelican crossing service time, and interviews with 20 pedestrians. The facility requirement was analyzed using the $P \times V^2$ method. Results indicate a maximum pedestrian volume of 407 persons/hour and a maximum vehicle volume of 7,436 vehicles/hour. Averaging four observation periods on a Monday yielded P = 333.5 persons/hour and V = 7,303 vehicles/hour, resulting in a P × V² value of 1.78 × 10¹⁰. This value meets the criteria for a grade-separated crossing. User evaluation revealed a waiting time of up to 84 seconds at the pelican crossing, and 100% of respondents expressed a preference for a pedestrian bridge. Consequently, a pedestrian bridge is recommended as the crossing facility for the study location.

Keywords: *Needs Analysis, Pedestrian Bridge, Pedestrians*

1. INTRODUCTION

Bogor City is one of the cities in Indonesia experiencing population and economic growth that has led to increased public mobility. This situation intensifies interactions between vehicle traffic and pedestrians, particularly in urban corridors characterized by high levels of commercial activity, public services, and social interaction. In transportation planning, pedestrian facilities must be provided to mitigate conflicts between pedestrians and vehicles and to offer safe crossing spaces. Jalan Raya Pajajaran, specifically the section in front of the Al-Mi'raj Grand Mosque, is a location with significant vehicle traffic and pedestrian activity. Although a Pelican crossing is already installed at this site, preliminary observations indicate that the waiting time to trigger the crossing phase is quite long, and some pedestrians do not fully understand how to operate the crossing button. These conditions potentially increase waiting times while diminishing both comfort and the sense of safety. When planning crossing facilities, the selection of the appropriate facility type requires consideration of pedestrian numbers, vehicle volumes, operational conditions, and the characteristics of vehicle-pedestrian conflicts [1], [2].

Several studies in Indonesia indicate that the need for crossing facilities can be determined using the $P \times V^2$ parameter. Intari et al. [3] utilized pedestrian and vehicle volumes to recommend grade-separated crossings for locations with high traffic flows. Fazastya and Kartika [4] demonstrated a need for pedestrian overpasses (JPO) at several points along Jalan Transyogi Cibubur. Meanwhile, Siwanto and Teguh [5] showed that at-grade facilities can become ineffective when safe crossing opportunities based on critical gaps are severely limited. Unlike studies that determine facilities solely based on $P \times V^2$ this research combines $P \times V^2$ results with an operational evaluation of the Pelican crossing and an assessment of pedestrian perceptions. The objective of this study is to evaluate the existing crossing facilities and determine the most suitable facility for the section of Jalan Raya Pajajaran in front of the Al-Mi'raj Grand Mosque.

2. THEORETICAL BASIS AND RESEARCH METHODOLOGY

2.1 Theoretical Basis

Crossing facilities are part of the pedestrian system, serving to guide and protect pedestrians as they cross the flow of traffic. Fruin [2] explains that pedestrian space planning must consider movement characteristics, space requirements, interactions with vehicles, as well as aspects of safety and comfort. In locations with high volumes of both vehicle and pedestrian traffic, the selection of facilities must take into account the level of conflict and the opportunities for pedestrians to cross safely. Guidelines from the Ministry of Public Works and Housing (PUPR) categorize crossing facilities into at-grade crossings and grade-separated crossings. At-grade crossings include zebra crossings and pelican crossings, while grade-separated crossings include pedestrian bridges and underpasses. Facility selection can be determined using the $P \times V^2$ parameter, where P represents the flow of crossing pedestrians and V represents the two-way vehicle traffic flow. A high $P \times V^2$ value serves as the basis for determining the need for crossing facilities [1]. A pedestrian is defined as any person walking within the road traffic environment. In

transportation planning, pedestrians are road users who require facilities that are safe, comfortable, accessible, and well connected to surrounding activities. Pedestrians are an integral part of traffic; consequently, their movement and the facilities supporting it must be managed to ensure they can walk within the traffic environment both comfortably and safely. However, pedestrians are often overlooked in transportation planning, despite the fact that all people are pedestrians categorized by short, medium, and long-distance walking. A road crosser is a pedestrian who crosses vehicular traffic flow. Such movement requires facilitation through traffic management measures, crossing markings, crossing signals, or grade-separated crossing facilities, depending on site conditions [1].

2.1.1 Previous Research

Intari et al. [3] conducted research in front of Sultan Ageng Tirtayasa University, using pedestrian and vehicle volumes in a $P \times V^2$ analysis and recommending a pedestrian overpass for conditions with high traffic flow. Azikin et al. [6] employed vehicle volumes, pedestrian volumes, and user questionnaires; their initial findings suggested a zebra crossing, while the need for a pedestrian overpass emerged based on projections. Fazastya and Kartika [4] analyzed three locations along Jalan Transyogi Cibubur and identified sites that met the criteria for a pedestrian overpass. Siwanto and Teguh [5] demonstrated that evaluating critical gaps can reveal the ineffectiveness of at-grade facilities when opportunities for safe crossing are severely limited. Nawir and Rusmiyanti [7] indicated that the evaluation of pedestrian overpass facilities must also consider ease of access and the quality of service experienced by users. Based on previous research, the $P \times V^2$ approach is relevant for determining the need for crossing facilities; however, the numerical results must be interpreted in conjunction with the operational conditions of existing facilities. This study supplements the analysis by evaluating Pelican crossing waiting times, vehicle speeds, and pedestrian perceptions to provide supporting information for the recommendations.

2.1.2 At-Grade Crossings

2.1.2.1 Determination of Crossing Facilities

The determination of crossing facilities is based on a comparison between the pedestrian crossing flow (P) and the average peak hour traffic flow (V). The facilities considered for implementation are as follows:

a. Median Strip: A median located on the road center line where pedestrians can pause before completing the crossing.
b. Zebra Crossing: A formal crossing designated to give pedestrians priority when crossing.
c. Pelican Crossing: A zebra crossing equipped with traffic signals.
d. Grade Separated Crossing: A crossing that is not at the same level as the roadway, such as a bridge or underpass.

2.1.2.2. Technical Specifications for Crossing Facility Planning

Crossing facilities may be installed subject to the following conditions:

a. **Zebra Crossing.** Zebra crossings are placed on roads where pedestrian crossing volumes or vehicle traffic flows are sufficiently low, allowing pedestrians to easily find a safe opportunity to cross.
b. **Zebra Crossing with Flashing Lights.** With this facility, pedestrians may cross when traffic flow provides a sufficient gap for safe passage. Drivers are alerted to reduce speed and/or stop, yielding the right-of-way to pedestrians.
c. **Pelican Crossing**. A Pelican Crossing is a zebra crossing equipped with signal lights for both pedestrians and vehicles. The pedestrian crossing phase is activated by pressing a control button, initiating a preset crossing duration. This facility is beneficial for locations with high pedestrian crossing volumes. At intersections equipped with traffic lights, a Pelican crossing can be installed as an integrated part of the traffic signal system.

All criteria for determining at-grade crossing facilities can be seen in Table 1.

Table 1. Criteria for determining at-grade crossing facilities [1]

PV	***P* (person/hour)**	***V* (vehicle/hour)**	**Initial Recommendation**
≤ 10			No crossing needed
> 10	50 - 100	300 - 500	Zebra crossing
> 2 × 10	50 - 1100	400 - 750	Zebra crossing with safety features
> 10	50 - 1100	> 500	Pelican crossing
> 10	> 1100	> 500	Pelican crossing
> 2 × 10	50 - 1100	> 700	Pelican crossing with a waiting median strip
> 2 × 10	> 1100	> 400	Pelican crossing with a waiting median strip

2.1.3 Grade-Separated Crossings

Grade-separated crossings consist of pedestrian bridges and underpasses. These facilities are beneficial when located on roads with high volumes of pedestrians and vehicles, particularly on roads with high-speed traffic. The construction of pedestrian bridges are recommended on road sections with heavy traffic, high pedestrian volumes, and frequent pedestrian accidents. Bridges are also recommended when surface-level crossing facilities, such as Zebra crossings and Pelican crossings, disrupt existing traffic flow. In contrast, constructing underground pedestrian crossings (underpasses) requires more complex planning than building pedestrian bridges. The construction of underpasses is recommended when surface-level crossings (Zebra crossings

and Pelican crossings) and pedestrian bridges are not in a feasible option. Underpasses are also ideal on roads with heavy traffic and high pedestrian volume, provided site conditions permit their construction. Furthermore, the V value used is based on the average flow during the four (4) busiest hours. All criteria for determining grade-separated crossing facilities can be seen in Table 2.

Table 2.Criteria for determining grade-separated pedestrian crossing facilities [1]

PV^2	P (person/hour)	V (vehicle/hour)	Initial Recommendation
$> 5 \times 10^8$	100 – 1250	2000 – 5000	*Zebra Cross*
$> 10^{10}$	3500 – 7000	400 – 750	*Zebra Cross* With Barrier
$> 5 \times 10^9$	100 – 1250	> 5000	*Pelican Crossing* / Bridge
$> 5 \times 10^9$	> 1250	> 2000	*Pelican Crossing* / Bridge
$> 10^{10}$	100 – 1250	> 7000	Bridge
$> 10^{10}$	>1250	>3500	Bridge

2.2 Research Methodology

This study employs a quantitative-descriptive approach utilizing field surveys. The observation site is located on Jalan Raya Pajajaran, in front of the Al-Mi'raj Grand Mosque, covering a 100-meter segment with the crossing point situated at the segment's midpoint. Surveys were conducted over two days, Sunday and Monday, across four time slots: 11:00–12:00, 12:00–13:00, 14:00–15:00, and 15:00–16:00. Primary data collected included pedestrian volume, two-way vehicle volume, vehicle speed, Pelican crossing service timing, and pedestrian perceptions. Interviews were conducted with 20 respondents in the vicinity of the site [8,9].

2.2.1 Data Collection

Pedestrian volume was recorded based on the number of people crossing at the Pelican crossing location during each time slot. Vehicle volume was recorded for both directions of travel during the same periods. Vehicle speeds were observed for both northbound and southbound traffic. The condition of the Pelican crossing was evaluated by recording the waiting time until the crossing phase and the time available for crossing. Interviews utilized closed ended questions regarding the facility's functionality, safety, and comfort.

2.2.2 Analysis Stages

The analysis stages comprised of several stages, begins with tabulation of pedestrian and vehicle volumes; as well as identification of observation periods with high volumes. Subsequently, the average pedestrian volume (P) and vehicle volume (V) across the four periods on Monday; and the PV^2 were calculated. The calculated parameters then were compared against the established criteria, followed by evaluation of vehicle speed and Pelican crossing operations. Lastly, the result of interview data were inrepreted to formulate the evidence-based recommendations.

2.2.3 Calculation Criteria for Pedestrian Crossing Facilities

Calculation criteria for pedestrian crossing facilities based on the Guidelines for Planning Pedestrian Facilities in Urban Areas, Directorate General of Highways in 1995.The general method for identifying potential conflicts involves measuring the interaction between vehicles and pedestrians using the PV or PV^2 metric (Eq 1), where P represents the volume of pedestrians crossing in a 100-meter length of road, and V represents the hourly vehicle volume on an undivided two-way road.

$$PV^2 = P \times V^2 \quad (1)$$

3. RESULTS AND DISCUSSION

3.1 Locations

The research site is located on Jalan Raya Pajajaran, Bogor City, specifically in front of the Al-Mi'raj Grand Mosque. A pelican crossing is available at the site as an at-grade crossing facility. Activities in the vicinity of the site result in fairly intensive interaction between pedestrians and vehicles. Figure 1 shows the location of the research site and the crossing facility under observation.

3.2 Pedestrian Volume

Pedestrian volume serves as a key parameter in determining the need for crossing facilities. Observations were conducted over two days across four time periods. As shown in Table 3, the highest volume occurred on Monday between 11:00 and 12:00, reaching 407 pedestrians per hour, whereas on Sunday, the peak volume was 294 pedestrians per hour between 12:00 and 13:00. This difference indicates that the characteristics of the observation day influence the intensity of pedestrian activity in the vicinity of the site.These results indicate that the peak pedestrian volume on Sunday occurred between 12:00 and 13:00 at 294

pedestrians/hour, whereas the peak volume on Monday occurred between 11:00 and 12:00 at 407 pedestrians/hour.

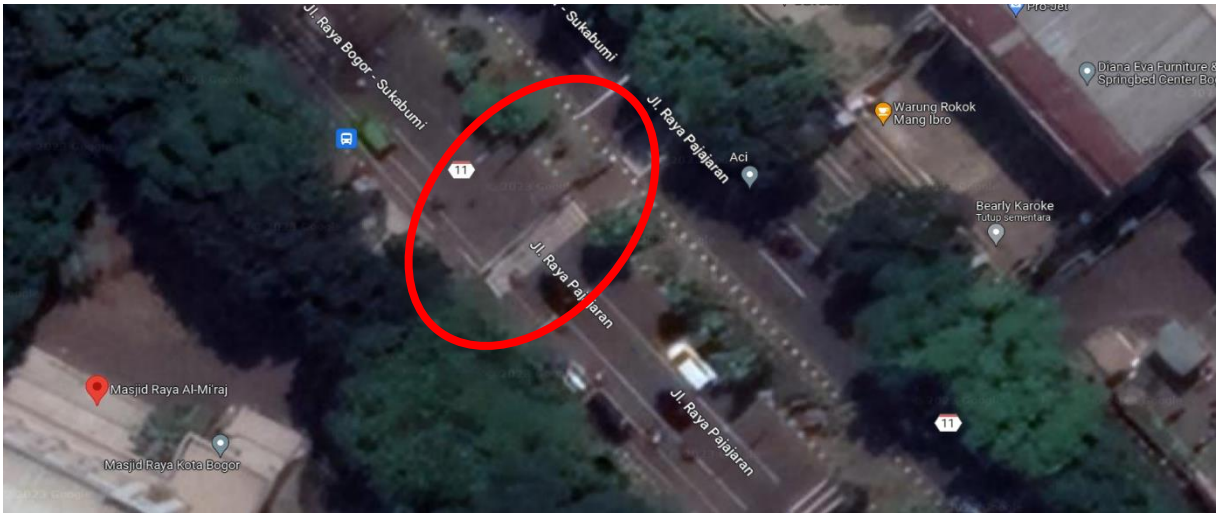

Figure 1. Research location
(Source: Google Maps)

Table 3. Peak hour pedestrian volume results

Day	Peak Hour	*P* (pedestrian/hour)
Sunday	11.00 - 12.00	238
	12.00 - 13.00	294
	14.00 - 15.00	232
	15.00 - 16.00	273
Monday	11.00 - 12.00	407
	12.00 - 13.00	361
	14.00 - 15.00	296
	15.00 - 16.00	270

3.3 Vehicle Volume

Vehicle volume is a crucial parameter because higher traffic flow limits the opportunities for pedestrians to find a gap for crossing. Data in Table 4 show the peak vehicle volumes of 6,748 vehicles/hour on Sunday (between 11:00 and 12:00) and 7,436 vehicles/hour on Monday (between 12:00 and 13:00). These conditions indicate that the location experiences high traffic flow on both days of observation. High vehicle volumes increase the potential for conflict when pedestrians cross. Therefore, vehicle volume needs to be analyzed in conjunction with pedestrian volume using the P × V² parameter.

Table 4. Volume results for sunday and monday

Day	Peak Hour	*V* (vehicle volume / hour)
Sunday	11.00 - 12.00	6748
	12.00 - 13.00	6694
	14.00 - 15.00	6321
	15.00 - 16.00	6282
Monday	11.00 - 12.00	7339
	12.00 - 13.00	7436
	14.00 - 15.00	7358
	15.00 - 16.00	7080

3.4 PV^2 Analysis

The PV^2 calculation was conducted on Jalan Raya Pajajaran, Bogor City, in front of the Al-Mi'raj Grand Mosque. The data regarding pedestrian and vehicle volumes on Jalan Raya Pajajaran, Bogor City, specifically in front of the Al-Mi'raj Grand Mosque, are as shown in Table 5. To determine the appropriate facilities, the average pedestrian and vehicle volumes from four observation periods on a Monday were used, as that day exhibits higher volume characteristics. The calculations were performed as follows:

$$P = \frac{407 + 361 + 296 + 270}{4} = 333.5\ person/hour$$

$$V = \frac{7339 + 7436 + 7358 + 7080}{4} = 7303\ vehicle/hour$$

$$P \times V^2 = 333.5 \times 7303^2 = 17{,}786{,}301.5 \approx 1.78 \times 10^{10}$$

The P × V² value of 1.78 × 10¹⁰ falls within the criteria for grade-separated crossings specified in the applicable guidelines [1]. Consequently, the study location quantitatively meets the requirements for recommending a pedestrian overpass (JPO). These results align with the study by Intari et al. [3], which utilized the PV^2 metric and recommended grade-separated crossings for locations with high vehicle and pedestrian volumes. Fazastya and Kartika [4] also demonstrated the need for pedestrian overpasses at locations characterized by high levels of vehicle-pedestrian interaction. However, the present study provides additional operational evidence, as the existing pelican crossing still results in waiting times and a perception of inconvenience. Thus, the recommendation for a pedestrian overpass is supported not only by the PV^2 value but also by the operational conditions of the existing facility [10].

Table 5. Total number of pedestrians and vehicles in the PV^2 calculation

Day	Peak Hour	P (pedestrian/hour)	V (vehicle volume/hour)	$P \times V^2$
Sunday	11.00 - 12.00	238	6748	10,837,449.952
	12.00 - 13.00	294	6694	13,174,032.984
	14.00 - 15.00	232	6321	9,269,569,.12
	15.00 - 16.00	273	6282	10,773,542.052
Monday	11.00 - 12.00	407	7339	21,921,394.847
	12.00 - 13.00	361	7436	19,961,168.656
	14.00 - 15.00	296	7358	16,025,488.544
	15.00 - 16.00	270	7080	13,534,128.000

3.5 Average Speed

Vehicle speeds were observed in two directions, north and south, on Sundays and Mondays. The results in Table 6 shows an average speed range of 42.83–46.70 km/h. These speeds limit opportunities for pedestrians to cross comfortably, particularly when traffic volume is high. These findings support the need for facilities that separate vehicle and pedestrian traffic at the study site. The speed range of 42.83–46.70 km/h indicates that vehicles are traveling at a relatively high speed for a crossing location. This condition serves as a supporting factor when considering grade-separated facilities.

Table 6. Average vehicle speeds on sundays

Day	Direction	V (km / hour)
Sunday	North	42,83
	South	46,70
Monday	North	43,31
	South	44,82

3.6 Evaluation of Crossing Facilities Based on User Perception

This evaluation serves as supporting information to assess the functionality, safety, and comfort of the pelican crossing. Twenty pedestrians were interviewed using closed-ended questions. The results indicate that 60% of respondents experienced difficulty crossing, 95% felt afraid when using the pelican crossing, 95% perceived the location as accident-prone, 60% felt fatigued while crossing, 70% considered the pelican crossing inadequate, and all respondents (100%) expressed a need for a pedestrian overpass. Evaluating crossing facilities should not rely solely on pedestrian and vehicle volumes; it must also consider the condition of the facilities and user perceptions. Ahmed et al. [11] developed the Pedestrian Crossing Level of Service (PCLOS) method, which integrates crossing condition indicators with field observation data and user perceptions [12]. Figure 2 shows Pedestrian Perceptions of Crossing Facilities.

User perception is a crucial aspect when evaluating the effectiveness of crossing facilities. Hariani et al. [14] demonstrated that the mere presence of a pedestrian overpass (JPO) does not automatically guarantee effective usage, as some pedestrians still prefer to cross directly across the roadway. Therefore, accessibility, comfort, and safety must be considered when planning crossing facilities.The interview survey results were analyzed based on the following criteria and showed in Table 7.

a. **Function**. Analysis of the questions regarding function, posed to 20 respondents, yielded the following results:
   - 60% of respondents reported experiencing difficulty when crossing. This finding is consistent with high traffic volumes and the waiting times associated with the pelican crossing.
   - 50% of respondents stated that they use the crossing facility regularly. This indicates the presence of repeat users, driven largely by activities centered around the mosque and the commercial buildings located across the street.

- All respondents (100%) expressed a need for a pedestrian overpass (JPO). This result reinforces the quantitative recommendations derived from PV^2 , although respondent perceptions serve as supporting data rather than a substitute for technical analysis.

b. **Safety**. Regarding safety, 19 out of 20 respondents (95%) reported feeling afraid when crossing, and 19 (95%) perceived the location as accident-prone. As this information is based on respondent perception, the results are treated not as verified accident frequency data, but rather as an indicator of safety concerns.

c. **Comfort**. Regarding comfort, 60% of respondents reported feeling fatigued when crossing, and 70% considered the pelican crossing inadequate. The crossing phase waiting time reaching up to 84 seconds is one factor explaining these complaints. Furthermore, the approximately 10 seconds available for crossing, combined with the behavior of some drivers who fail to stop at the designated locations, can increase user discomfort [15].

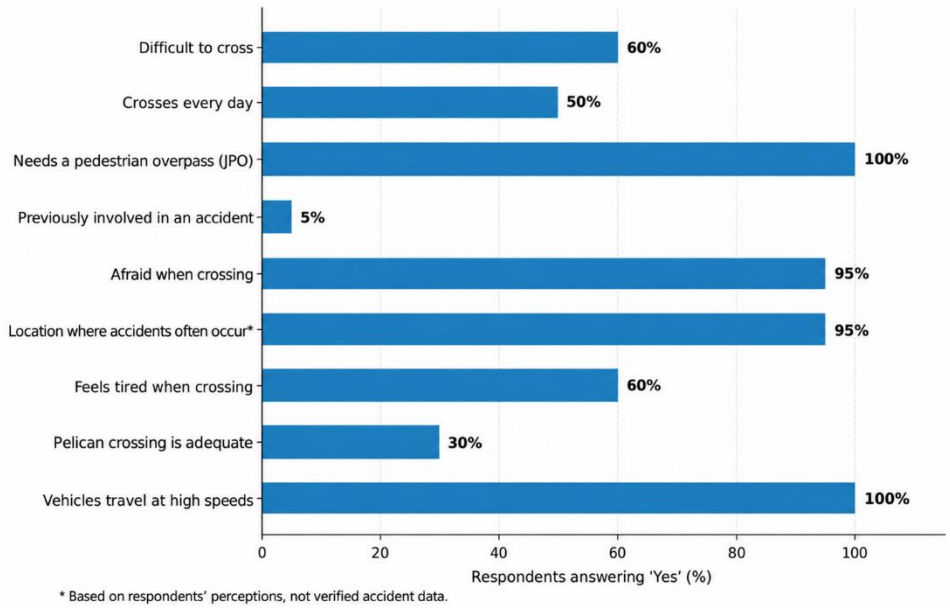

Figure 2 Pedestrian perceptions of crossing facilities

Table 7. Pedestrian interview data

No.	Question	In front of Grand Mosque	
		Yes	No
1	Functionality		
	1. Do you experience difficulty crossing?	12	8
	2. Do you use this Pelican crossing every day?	10	10
	3. Do you think a bridge is needed at this location?	20	0
2	Safety		
	1. Have you ever been involved in an accident while crossing?	1	19
	2. Do you feel afraid when using this Pelican crossing?	19	1
	3. Do accidents frequently occur on this road?	19	1
3	Comfort		
	1. Do you find it tiring to cross?	12	8
	2. Is the current Pelican crossing adequate?	6	14
	3. Do passing vehicles travel at high speeds?	20	0
	TOTAL	119	61

3.7. Discussion

Overall, traffic volume, the operational conditions of the Pelican crossing, and user perceptions present a consistent picture. Peak pedestrian volume reached 407 persons/hour, peak vehicle volume was 7,436 vehicles/hour, and the average PV^2 value of 1.78×10^{10} met the criteria recommending a grade-separated crossing. Concurrently, the Pelican crossing wait time reached 84 seconds, and the majority of respondents reported experiencing difficulty, fear, or discomfort. These findings indicate that the issue at the site is not merely the volume of users but also the quality of service provided by the existing facility. These results align with the findings of Siwanto and Teguh [5], which demonstrate that at-grade facilities can be ineffective when opportunities for safe crossing are limited. Therefore, a pedestrian overpass (JPO) could be considered as a solution, subject to a technical feasibility study and detailed design before construction [13]. A pedestrian overpass is recommended as the crossing solution;

however, its implementation requires a technical feasibility study covering site selection and access points, clearance requirements, stair/ramp design, accessibility for persons with disabilities, lighting, drainage, safety, and cost estimates for construction and maintenance [16].

4. CONCLUSIONS

Based on observations, PV^2 analysis, an evaluation of the pelican crossing's operation, and user interviews, the following conclusions were drawn:

1. The highest pedestrian volume on Jalan Raya Pajajaran, in front of the Al-Mi'raj Grand Mosque, reached 407 pedestrians/hour on Monday between 11:00 and 12:00.
2. The existing pelican crossing does not yet provide optimal service. Waiting times reach 84 seconds and crossing times are approximately 10 seconds; furthermore, some users still experience difficulty, fear, and discomfort.
3. The average volumes across four periods on Monday were P = 333.5 pedestrians/hour and V = 7,303 vehicles/hour, resulting in a PV^2 value of 1.78×10^{10}. This value meets the criteria for a grade-separated crossing and supports the recommendation for a pedestrian overpass (JPO).

ACKNOWLEDGEMENTS

The author extends their gratitude to the management of Al-Mi'raj Grand Mosque, relevant parties in the vicinity of the study site, and all respondents who provided access, information, and support during the field survey. This support facilitated the collection of data on pedestrian and vehicle volumes, the evaluation of pelican crossing facilities, and user interviews.

BIBLIOGRAPHY

[1] Kementerian Pekerjaan Umum dan Perumahan Rakyat, Perencanaan Teknis Fasilitas Pejalan Kaki, Pd 03-2017-B, Lampiran Surat Edaran Menteri PUPR No. 02/SE/M/2018, Jakarta, 2018.

[2] J. J. Fruin, Pedestrian Planning and Design. New York: Metropolitan Association of Urban Designers and Environmental Planners, 1971.

[3] D. E. Intari, D. N. Setiawati, and M. Eliany, "Analisis kebutuhan fasilitas penyeberangan jalan di depan Universitas Sultan Ageng Tirtayasa Kota Serang," Fondasi: Jurnal Teknik Sipil, vol. 8, no. 2, 2019, doi: 10.36055/jft.v8i2.6664.

[4] H. K. Fazastya and A. A. G. Kartika, "Analisis kebutuhan jembatan penyeberangan orang (JPO) di Jl. Transyogi Cibubur, Jatisampurna," Jurnal Teknik ITS, vol. 11, no. 3, 2022, doi: 10.12962/j23373539.v11i3.96094.

[5] J. Siwanto and J. Teguh, "Analisis kebutuhan jenis fasilitas penyeberang jalan berdasarkan gap kritis (Studi Kasus PT. Sido Muncul Ungaran – Jawa Tengah)," Media Komunikasi Teknik Sipil, vol. 16, no. 2, pp. 148–159, 2008, doi: 10.14710/mkts.v16i2.3690.

[6] M. T. Azikin, R. Balaka, and A. A. R. Mala, "Analisis kebutuhan jembatan penyeberangan orang (JPO) di depan Lippo Plaza," STABILITA, vol. 7, no. 1, 2019, doi: 10.55679/jts.v7i1.6290.

[7] D. Nawir and Rusmiyanti, "Studi analisis fasilitas jembatan penyeberangan orang di Kota Tarakan," Borneo Engineering: Jurnal Teknik Sipil, vol. 3, no. 1, pp. 60–72, 2019, doi: 10.35334/be.v3i1.919.

[8] F. H. Millatina, Ragam Teknik Sampling dan Instrumen Penelitian. Lampung: Universitas Islam Negeri Raden Intan Lampung, 2021.

[9] W. Setiaji, Analisis Kebutuhan Fasilitas Penyeberang Jalan di Magelang. Magelang: Universitas Tidar, 2021.

[10] D. Aditia, Perencanaan Fasilitas Pejalan Kaki untuk Meningkatkan Keselamatan, Kenyamanan, dan Aksesibilitas di Kawasan CBD Kabupaten Batang. Bekasi: PTDI STTD, 2022.

[11] T. Ahmed, M. Moeinaddini, M. Almoshaogeh, A. Jamal, I. Nawaz, and F. Alharbi, "A New Pedestrian Crossing Level of Service (PCLOS) Method for Promoting Safe Pedestrian Crossing in Urban Areas," *International Journal of Environmental Research and Public Health*, vol. 18, no. 16, p. 8813, 2021, doi: 10.3390/ijerph18168813.

[12] S. Chauhan, S. Dave, J. Shah, and A. Kedia, "Assessing Traffic Characteristics for Safe Pedestrian Crossings: Developing Warrants for Sustainable Urban Safety," *Sustainability*, vol. 16, no. 10, p. 4182, 2024, doi: 10.3390/su16104182.

[13] D. Libora and A. Savitri, "Safety Assessment of the Pedestrian Bridge of Sungai Panas Batam," *LEADER: Civil Engineering and Architecture Journal*, vol. 1, no. 2, pp. 182–189, 2023, doi: 10.37253/leader.v1i2.8099.

[14] M. L. Hariani, P. M. Rifqi, and A. S. Ayunindita, "The Effectiveness of Pedestrian Crossing Bridges for Urban Areas in Indonesia Based on Crossing Times and Pedestrian Perspective," *Asian Journal of Engineering, Social and Health*, vol. 3, no. 9, pp. 2020–2034, 2024, doi: 10.46799/ajesh.v3i9.383.

[15] Y. Darma, I. Davina, Z. Zardan, and F. Mauladea, "Analysis of Pelican Crossing as Pedestrian Facility in Banda Aceh, Indonesia," *Jurnal Arsip Rekayasa Sipil dan Perencanaan*, vol. 8, no. 1, pp. 39–47, 2025, doi: 10.24815/jarsp.v8i1.44954.

[16] I. M. Sugiharta and A. M. Mufadhdhal, "Technical and Functional Feasibility Study of a Pedestrian Overpass on the Bandung–Sumedang Highway," *CRANE: Civil Engineering Research Journal*, vol. 6, no. 2, pp. 1–14, 2025, doi: 10.34010/crane.v6i2.15993.