Evaluation of Midblock Pedestrian Crossing Facility in The Surakarta City, Indonesia

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Abstract. Pedestrians are the most vulnerable travellers to traffic accidents. It is necessary to provide pedestrian crossing facility that meet the standards of eligibility for pedestrian’s safety when crossing the road without disrupting traffic flow. This study aims to evaluate the suitability of type, road marking and signs of the existing midblock pedestrian crossing facility against the applicable guidelines. The midblock pedestrian crossing facility studied consist of three Zebra Crossings and five Pelican Crossings in the Surakarta City, Indonesia. Pedestrian and vehicle volume data has been collected through a survey of traffic. The guideline of determining the type of midblock pedestrian crossing facility using the PV^2 criteria, while the guideline of pedestrian crossing road marking and signs using Regulation of the Minister of Transportation of the Republic of Indonesia No. PM 34 Year 2014. The study results indicate that in general, type, road marking and signs of the existing midblock pedestrian crossing facilities are inconsistent with the recommendations of the applicable guidelines. PV^2 criteria fail to identify the type of pedestrian crossing facility, which should be provided in the given conditions. The compliance of the pedestrian to cross the road on Zebra Crossing and Pelican Crossings is very low. The infrastructure design, road markings and signs of the existing midblock pedestrian crossing is less consideration of pedestrian safety. It is necessary to rectify the guidelines relating to current midblock pedestrian crossing facility.

1. Introduction
An increase in number of people and goods movements is marked by an increase in pedestrian and vehicle volume on the urban roads. This has resulted in traffic congestion problems and road user safety on the roads. Pedestrians are travelers who are the most vulnerable to traffic accidents. Pedestrian safety in urban areas tends to be neglected. Lack of adequate pedestrian facilities, especially midblock pedestrian crossing facilities, has an impact on pedestrian safety.

According to World Health Organization study, the Road Safety Program shows that in 1990 road traffic accidents were in the ninth position out of ten causes of death, but in 2020 the ranking will rise in the third place. [1] reveals that pedestrians account for 22% of fatalities on roadways around the world. More than 500 pedestrian fatalities every day on roadways in developing countries [2]. [3] shows that 65% of road accidents involve pedestrian deaths. Some of the factors causing traffic accidents are not concentrating when driving or walking; do not look at traffic before crossing the road; do not pay attention to traffic signs and traffic lights when crossing the road; do not understand the traffic rules; ignorance of road users’ knowledge of road markings, traffic signs and lack of awareness to comply with...
the applicable traffic regulations; and non-functioning pedestrian facilities because of incompatibility with applicable guidelines [4, 5, 6].

Traffic safety for road users in midblock pedestrian crossing facilities is very important. Therefore, it is necessary to conduct study on the evaluation of type, road marking and sign of the existing midblock pedestrian crossing facility in the Surakarta City, Indonesia. The results of the study were set as the basis for improving the performance of midblock pedestrian crossing facility and improving the pedestrian crossing guidelines that apply in Indonesia.

2. Pedestrian Crossing Warrant

Pedestrian crossing facility consists of four types namely zebra crossing, pelican crossing, pedestrian bridge and tunnel [7]. Zebra and pelican crossings are the type of at-grade crossing facility. Zebra crossing is a pedestrian crossing facility that is equipped with a marker to provide constancy in the trajectory, while the pelican crossing is equipped with a marker and traffic lights. Pedestrian bridge and tunnel are the type of not at-grade crossing facility. The pedestrian bridge is an infrastructure that crosses over the road, while the tunnel crosses below the road.

Midblock pedestrian crossing facility warrants based on the PV² criteria were first reported by the Department of Transport in the United Kingdom [8]. These warrants are presented in the form of a V versus P, demarcating the type of at-grade crossing facility that should be provided. Indonesia adopted the PV² criteria to determine the type of midblock pedestrian crossing facility [7]. Table 1 shows the selection of midblock at-grade pedestrian crossing facility based on PV² criteria.

| PV²   | P (pedestrian/hour) | V (vehicle/hour) | Type of Pedestrian Crossing |
|-------|---------------------|------------------|-----------------------------|
| > 10⁸ | 50 - 1.100          | 300 - 500        | Zebra Crossing              |
| > 2 x 10⁸ | 50 - 1.100       | 400 - 750        | Divided Zebra Crossing     |
| > 10⁸ | 50 - 1.100          | > 500            | Pelican Crossing            |
| > 2 x 10⁸ | > 1.100           | > 300            | Pelican Crossing            |
| > 2 x 10⁸ | 50 - 1.100        | > 750            | Divided Pelican Crossing    |
| > 2 x 10⁸ | > 1.100           | > 400            | Divided Pelican Crossing    |

The type of midblock not-at-grade pedestrian crossing facility is placed at road with the following criteria:

- Vehicle speed on the road is 70 km/hour
- Strategic areas, where the pedestrian are not possible to cross the road
- Cross the road only on the pedestrian bridge
- PV² > 2 x 10⁸ with P > 1.100 pedestrian/hour and V > 750 vehicle/hour

3. Pedestrian Crossing ROAD MARKINGS and SIGNS

Road Markings are a signs that is on the road surface or above the road surface, which includes equipment or signs that form longitudinal lines, transverse lines, and other symbols that serve to guide and control traffic on a roadway. Figure 2 shows the Zebra and Pelican crossings road markings and signs [9].
4. Methodology

4.1. Location of Study
The location of studies are as follows:
- Zebra Crossing at Jenderal Urip Sumoharjo road in front of Gede Market
- Zebra Crossing at Dr. Radjiman road in front of Klewer Market
- Pelican Crossing at Brigjend. Slamet Riyadi road in front of Solo Grand Mall
- Pelican Crossing at Kolonel Sutarto road in front of Moewardi Hospital
- Pelican Crossing at Kapten Mulyadi road in front of Assegaf Mosque
- Pelican Crossing at Brigjend. Slamet Riyadi road in front of Purwosari Station
- Pelican Crossing at Adi Sucipto road in front of Regina Pacis School
- Pelican Crossing at Jenderal Urip Sumoharjo road in front of Jebres Station

4.2. Stages of Study
Stages of study can be explained as follows:
- Secondary and primary data collection. Required data includes pedestrian and vehicle volume, road geometry, pedestrian behavior, road markings and signs.
- Data analysis and technical calculation. The data analysis results are used to determine the performance of roads and type of midblock pedestrian crossing facility, to identify characteristics of pedestrian, road markings and signs of midblock pedestrian crossing facility.
- Discussion. The analysis results are discussed in detail to find out drawback of the existing midblock pedestrian crossing facility. This is used as the basis for improving the performance of midblock pedestrian crossing facility and rectifying the pedestrian crossing guidelines that apply in Indonesia.
- Conclusion. Drawing conclusions from the study results.

4.3. Data Collection
In this study, secondary data is obtained from Department of Transportation, Communication and Information Technology Surakarta such as traffic light specifications of Pelican Crossing. Primary data obtained from field surveys include traffic counting, road geometry, road markings and signs. The traffic counting surveys were carried out at the busiest four hours’ traffic conditions.

5. Analysis and Result

5.1. Performance of Road
The performance of road at midblock pedestrian crossing facility area needs to be calculated, in order to find out the road level of service (LOS). The performance of road is calculated by using the Indonesian
standard method namely the Indonesian Highway Capacity Manual 1997 [10]. Table 2 shows summary of the LOS of road at all studies location.

**Table 2. Summary of the level of service of road at all studies location.**

| Road Name                        | Volume (pcu/hour) | Capacity (pcu/hour) | Degree of Saturation | Speed (km/hour) | Level of Service |
|----------------------------------|-------------------|---------------------|----------------------|-----------------|-----------------|
| Jenderal Urip Sumoharjo road (Gede Market) | 2,044             | 4,932               | 0.41                 | 42              | B               |
| Dr. Radjinman road (Klewer Market) | 1,025             | 3,183               | 0.32                 | 52              | B               |
| Brigjen. Slamet Riyadi road (Solo Grand Mall) | 2,196             | 3,985               | 0.55                 | 41              | B               |
| Kolonel Sutarto road (Moewardi Hospital) | 2,651             | 5,706               | 0.46                 | 46              | B               |
| Kapten Mulyadi road (Assegaf Mosque) | 2,498             | 3,206               | 0.78                 | 34              | C               |
| Brigjen. Slamet Riyadi road (Purwosari Station) | 2,091             | 3,009               | 0.69                 | 44              | B               |
| Adi Sucipto road (Regina Pacis School) | 3,514             | 4,904               | 0.72                 | 38              | D               |
| Jenderal Urip Sumoharjo (Jebres Station) | 2,427             | 3,227               | 0.75                 | 32              | C               |

Analysis results show that in general the performance of roads at the studies area is categorized as still in good condition, where the LOS ranges between B and C. LOS B means traffic flow is stable with little delay, while LOS C means traffic flow is stable with delays that are still acceptable. Adi Sucipto road (Regica Pacis School) has the worst LOS i.e. D, where the flow is approaching unstable. Adi Sucipto road is the primary arterial road, during the morning peak hour many students, workers and the community passing through this road going to school and workplace.

5.2. Type of Midblock Pedestrian Crossing Facility

PV^2 analysis is used to determine the type of midblock pedestrian crossing facility that are adjusted to the pedestrian volume (P) and vehicle volume (V) at the study location. P is pedestrian volume crossing the road in 100 m pedestrian crossing area (pedestrian/hour). V is vehicle volume in two directions of traffic (vehicle/hour). P and V values used are the average pedestrian and vehicle volume in the busiest four hours. An example of the PV^2 analysis to determine type of midblock pedestrian crossing facility at Jenderal Urip Sumoharjo road in front of Gede Market can be seen in Table 3. The analysis result recommends the type of midblock pedestrian crossing facility in the form of Divided Pelican Crossing.

**Table 3. Type of midblock pedestrian crossing facility at Jenderal Urip Sumoharjo road in front of Gede Market.**

| Time Period (hour) | P (pedestrian/hour) | V (vehicle/hour) | PV^2               | Type of Midblock Pedestrian Crossing |
|--------------------|---------------------|------------------|--------------------|-------------------------------------|
| 06.00-07.00        | 401                 | 1,560            | 976,436,685        | Zebra Crossing                      |
| 07.00-08.00        | 454                 | 2,044            | 1,896,133,416      | Divided Pelican Crossing            |
| 11.00-12.00        | 343                 | 2,011            | 1,387,754,368      |                                     |
| 12.00-13.00        | 277                 | 1,941            | 1,043,377,185      |                                     |
| Average            | 369                 | 1,889            | 1,315,940,271      |                                     |

The analysis results of the determination of the type of midblock pedestrian crossing facility based on PV^2 values at each study location can be seen in Table 4. PV^2 analysis recommends Divided Pelican Crossing for all studies location.
Table 4. Summary of type of midblock pedestrian crossing facility at all studies location.

| Road Name                                   | P (pedestrian/hour) | V (vehicle/hour) | PV²          | Type of Midblock Pedestrian Crossing | Existing  | Recommendation |
|---------------------------------------------|---------------------|------------------|--------------|-------------------------------------|-----------|----------------|
| Jenderal Urip Sumoharjo road (Gede Market)  | 369                 | 1,889            | 1,315,940,271| Zebra Crossing                      | Divided   | Pelican Crossing |
| Dr. Radjiman road (Klewer Market)           | 712                 | 930              | 615,508,696  | Zebra Crossing                      | Divided   | Pelican Crossing |
| Brigjend. Slamet Riyadi road (Solo Grand Mall) | 139                 | 2.105            | 616,014,888  | Zebra Crossing                      | Divided   | Pelican Crossing |
| Kolonel Sutarto road (Moewardi Hospital)     | 90                  | 2.452            | 542,400,228  | Pelican Crossing                    | Divided   | Pelican Crossing |
| Kapten Mulyadi road (Assegaf Mosque)         | 127                 | 2.123            | 571,164,243  | Pelican Crossing                    | Divided   | Pelican Crossing |
| Brigjend. Slamet Riyadi road (Purwosari Station) | 95                  | 1.973            | 369,645,267  | Pelican Crossing                    | Divided   | Pelican Crossing |
| Adi Sucipto road (Regina Pacis School)       | 91                  | 3.250            | 956,053,318  | Pelican Crossing                    | Divided   | Pelican Crossing |
| Jenderal Urip Sumoharjo road (Jebres Station) | 57                  | 2.221            | 278,802,777  | Pelican Crossing                    | Divided   | Pelican Crossing |

5.3. Characteristic of Pedestrian

Analysis of pedestrian volume data at midblock pedestrian crossing facility is carried out to identify the characteristics of pedestrian include compliance crossing road at the location of pedestrian crossing facility, use of traffic lights facility (at Pelican Crossing) and violation of the applicable regulations. Summary of the compliance crossing road at the midblock pedestrian crossing facility at all the studies location can be seen in Figure 2.

The analysis results show that in general the compliance crossing road at the Zebra Crossing is very low, especially at Brigjend. Slamet Riyadi road in front of Solo Grand Mall, which is 14.7%. While the percentage the compliance crossing road at the Zebra Crossing at Jenderal Urip Sumoharjo road in front of Gede Market and Dr. Radjiman road in front of Klewer Market are 52.5% and 55.7%, consecutively.

Similarly, the analysis results show that in general the compliance crossing road at the Pelican Crossing is very low, especially on the Kapten Mulyadi road in front of Assegaf Mosque and Adi Sucipto road in front of Regina Pacis School, which are 30.8% and 31.2%, consecutively.

Figure 2. Compliance crossing road at the midblock pedestrian crossing facility.
Figure 3 shows summary of the compliance using traffic lights facility at the Pelican Crossing. The analysis results show that in general the compliance using traffic lights facility at the Pelican Crossing is very low, especially at Adi Sucipto road in front of Regina Pacis School, in which 100%. While the percentage the compliance using traffic lights facility at the Pelican Crossing on Kapten Mulyadi road in front of Assegaf Mosque, Kolonel Sutarto road in front of Moewardi Hospital and Brigjend. Slamet Riyadi road in front of Purwosari Station are 91.0%, 73.6% and 33.7%, consecutively. Note: the traffic lights facility of Pelican Crossing at Jenderal Urip Sumoharjo road in front of Jebres station does not work.

![Use of the traffic light facility at Pelican Crossing](image)

**Figure 3.** Compliance using traffic lights facility at the Pelican Crossing

5.4. *Road Markings and Signs of Midblock Pedestrian Crossing Facility*

Road markings and signs of existing midblock pedestrian crossing facility is compared to the pedestrian crossing guideline that apply in Indonesia. In this case the comparison includes size and placement of road markings and signs at the midblock pedestrian crossing facility. Figure 4 shows the road markings, signs and infrastructure of the existing midblock pedestrian crossing facility. Table 5 shows the comparison of road markings and signs between existing midblock pedestrian crossing facility and guideline at all studies location.

| Road Name                                      | Road Marking | Signs               |
|------------------------------------------------|--------------|---------------------|
| Jenderal Urip Sumoharjo road (Gede Market)     | Consistent   | Not available       |
| Dr. Radjiman road (Klewer Market)              | Consistent   | Not available       |
| Brigjend. Slamet Riyadi road (Solo Grand Mall) | Consistent   | Not available       |
| Kolonel Sutarto road (Moewardi Hospital)       | Inconsistent | Not available       |
| Kapten Mulyadi road (Assegaf Mosque)           | Inconsistent | Not available       |
| Brigjend. Slamet Riyadi road (Purwosari Station)| Inconsistent | Not available       |
| Adi Sucipto road (Regina Pacis School)         | Inconsistent | Not available       |
| Jenderal Urip Sumoharjo (Jebres Station)       | Inconsistent | Not available       |
Zebra Crossing facilities are in accordance with applicable guideline in terms of size and placement of road marking. However, the signs are not available. In contrary, Pelican Crossing facilities are not in accordance with applicable guideline in terms of size and placement of road marking also the signs are not available. Pelican Crossing markers should be two full lines that crossing the traffic lane (see Figure 1.b), not transverse lines arranged across the traffic lane like Zebra Crossing markers (see Figure 1.a). For the Jenderal Urip Sumoharjo road in front of Jebres station (see Figure 4.h) there is no stop line markings.

6. Discussion

PV² analysis recommends Divided Pelican Crossing for all study locations. This type of midblock pedestrian crossing facility does not match to the existing type of midblock pedestrian crossing facility. Some things that need to be considered in using PV² analysis are:
This method was adopted from the United Kingdom. Traffic conditions in Indonesia are different from that in the United Kingdom, where the amount of traffic in Indonesia is higher than in the United Kingdom. When the PV^2 analysis is used for Indonesian case so it will tend to recommend Divided Pelican Crossing, which is the safest type of road crossing (highest ranking).

This method does not distinguish the type of road, whether one-way, two-way, two-lane or other. Thus, for certain road conditions, PV^2 recommendation is not in accordance with the conditions in the field. As an example, the Kapten Mulyadi road is recommended by PV^2 analysis to use Divided Pelican Crossing. This is not possible to install a pedestrian refuge on the road because the Kapten Mulyadi road is a 2-lane 2-way road with a narrow road width, see Figure 5.

Based on this phenomena, PV^2 criteria needs to be revised based on traffic conditions in Indonesia and type of road [11].

Pedestrian compliance to cross the road at the Zebra and Pelican Crossings is very low, because:

- Lack of understanding of road users to the applicable regulations
- Pedestrian perception that there is no difference between crossing at the pedestrian crossing facility and outside the pedestrian crossing facility. This is due to the large number of motorized vehicle users do not comply with the rule that pedestrian have priority when crossing the road at pedestrian crossing facility
- There is no guardrail that directs pedestrian to the location of the pedestrian crossing facility
- The location of the traffic light pole is not right, see Figures 4g and 4h. It is impossible for the pedestrian to press the traffic light button and cross the road, because the distance of the traffic light pole is far from the stop line marker.
- Zebra and Pelican Crossings infrastructure have low pedestrian safety and comfort, where ramp access connecting to sidewalks is not designed according to applicable regulations. Pedestrians have potential to hit the median park at the end of pedestrian crossing facility, see Figure 5.

In order to improve the performance of the existing midblock pedestrian crossing facilities, it is necessary to rectify infrastructure design, road marking and signs; make guidelines and specifications of midblock pedestrian crossing facilities and enforce traffic regulations against regulatory violators in Surakarta City.

7. Conclusion
The study results show that in general, type, road marking and signs of the existing midblock pedestrian crossing facilities are inconsistent with the recommendations of the applicable guidelines. PV^2 analysis recommends Divided Pelican Crossing for all study locations. This method is overestimate in determining the type of midblock pedestrian crossing facility. It fails to identify the type of pedestrian crossing facility, which should be provided in the given conditions. Therefore, it is necessary to revise the PV^2 Criteria based on traffic conditions in Indonesia and type of road. Pedestrian compliance to
cross the road at the Zebra and Pelican Crossings is very low due to pedestrian perception and lack of understanding of the applicable regulations; Zebra and Pelican Crossings infrastructure have low pedestrian safety and comfort such as no guardrail, location of the traffic light far from the stop line marker. It is necessary to rectify infrastructure design, road marking and signs; make guidelines and specifications of midblock pedestrian crossing facilities and enforce traffic regulations against regulatory violators in Surakarta City to improve the performance of the existing midblock pedestrian crossing facilities.

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References
[1] World Health Organization, Pedestrian Safety: A Road Safety Manual for Decision-makers and Practitioners (World Health Organization, Geneva, 2013).
[2] World Health Organization, Make Walking Safe: A Brief Overview of Pedestrian Safety Around the World. WHO/NMH/VIP13.02 (World Health Organization, Geneva, 2013).
[3] A. Rahmah. Kajian Model Perilaku Pengambilan Keputusan Menyebrang Jalan Bagi Pejalan Kaki. Tesis. Universitas Indonesia, 2003.
[4] T. Harvey. A Review of Current Traffic Calming Techniques (University of Leeds, UK, 1995), see http://www.its.leeds.ac.uk/projects/primavera/p_calking.html.
[5] T. Kurniati, G. Hendra and Z. Dony. Evaluasi Penerapan Zona Selamat Sekolah di Kota Padang. Jurnal Rekayasa Sipil (Jurusan Teknik Sipil Fakultas Teknik, Universitas Andalas, Oktober 2010), Volume 6 No. 2, pp. 55-64.
[6] I. Kusmaryono, S. Ferry and W. Endang. Persepsi Pengguna Fasilitas Zona Selamat Sekolah (Jurnal Transportasi, Desember 2010), Volume 10 No. 3, pp. 205-214.
[7] Directorate General Bina Marga Indonesia. Pedestrian Facility Determination Procedures in Urban Areas No. 011/T/Bt/1995, Public Work.
[8] DoT. Roads and Traffic in Urban Areas (Publication of Institution of Highways and Transportation and Department of Transport, UK, 1987).
[9] Regulation of the Minister of Transportation of the Republic of Indonesia No. PM 34 Year 2014 about Road Markings.
[10] Directorate General Bina Marga Indonesia, Indonesian Highway Capacity Manual, 1997.
[11] U. Jain and R. Rastogi. Re-examination of PV² Criteria for Developing Pedestrian Crossing Warrants (Transportation Research Procedia 25, 2017) 1707-1716.