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Benefit-cost analysis for signalised pedestrian crossing implementation in Jakarta, Indonesia

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Abstract
To create a sustainable, safe, and dynamic transportation system, it is crucial to prioritize pedestrian safety. Pedestrians are considered vulnerable road users, and the severity of their injuries in motor vehicle accidents is relatively high. This study aims to evaluate the cost benefits by comparing the estimated reduction in accident losses with the costs incurred for improving crossing facilities using pelican crossings. The average accident loss is calculated in areas with crosswalks, along with the investment costs for enhancing pedestrian facilities by adding signals. From this, the benefits of reducing accident losses due to improved pedestrian facilities can be estimated. In the Polda Metro Jaya (PMJ) jurisdiction, the average accident loss at locations with zebra crossings is IDR 144,988,136, while the measurement cost based on the Transportation Agency's work plan is IDR 175,000,000. The benefit-cost analysis yields a ratio of 0.207, indicating that enhancing pedestrian crossing safety will provide long-term benefits.

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Keywords: pedestrian, accident, pedestrian-facilities, measurement, pelican-crossing

Introduction

Pedestrians are recognized as vulnerable road users, and the severity of their injuries in motor vehicle accidents is notably high. Ensuring pedestrian safety is currently one of the most challenging issues for transportation engineers. According to data from the Integrated Road Safety Management System (IRSMS) within the Polda Metro Jaya (PMJ) jurisdiction (covering DKI Jakarta, Bekasi, Depok, and South Tangerang), there were 2,646 pedestrian accidents over the past three years. The annual data indicates an increase from 837 accidents in 2020 to 931 accidents in 2022, highlighting the need for greater attention to pedestrian safety in urban areas.

Figure 1. Number of Accidents by Time Period in Polda Metro Jaya 2021-2023

The highest number of accidents, predominantly non-serious injuries, occurs during the night. The morning and afternoon periods also show a high number of non-serious injuries but have relatively fewer serious and moderate injuries compared to the night. The number of serious injuries peaks during the night, followed by the dawn period. Moderate injuries are least frequent and do not show significant variation across the time periods, although they are slightly higher during the night and dawn compared to other times.

IRSMS data also classifies accidents based on their location, such as on the road or in crossing areas. This data underscores the necessity of improving pedestrian facilities in the PMJ jurisdiction to ensure that travelers not only feel comfortable but also safe.

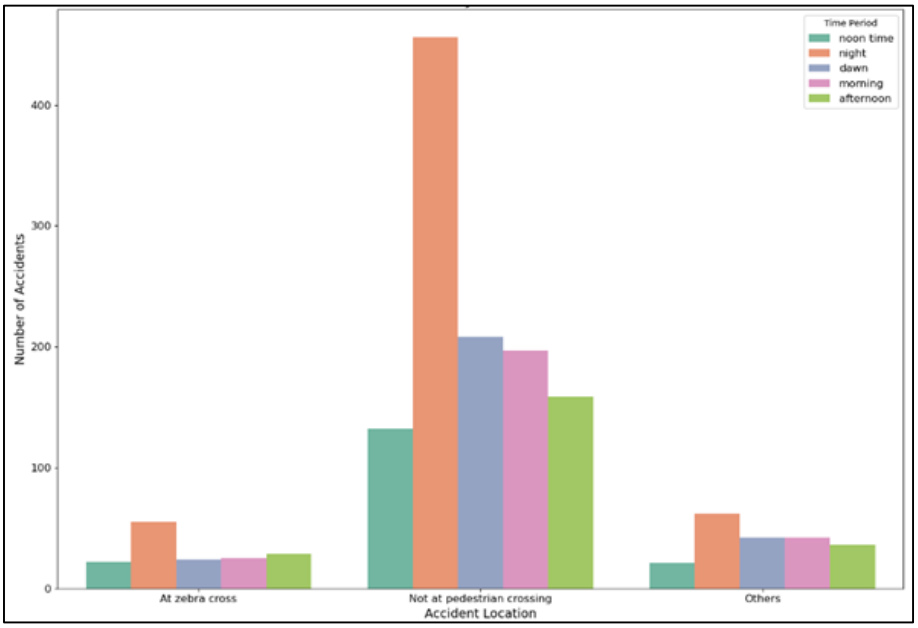

Fig 1: Number of Accidents by Locations and Time Period

The number of accidents that occur not at pedestrian crossings are higher than at zebra crosses as depicted in Figure 1. The accident figures at zebra crossings necessitates the different types of facilities that enhance the pedestrian level of safety when crossing. One area for development is crossing facilities, as many current crossing areas only have zebra crossings. Research has shown that pedestrian behavior at midblock crossings can inform policy recommendations related to pedestrian safety. Additionally, studies have found that individuals tend to pay more attention to traffic when crossing alone. This forms the basis for conducting a Benefit-Cost Analysis of improving crossing facilities in DKI Jakarta, focusing on the estimated reductions in accident losses.

Literature Review

Pedestrian Crossing

Signalized pedestrian crossings are essential elements of urban infrastructure, designed to improve pedestrian safety and regulate traffic flow. These crossings are equipped with traffic signals that manage the movement of both pedestrians and vehicles, ensuring safe road crossings for pedestrians. This literature review examines various aspects of signalized pedestrian crossings, including their design, effectiveness, and impact on pedestrian behavior and safety.

Pedestrian behavior at signalized crossings is influenced by several factors, such as signal timing, crossing distance, and the presence of other pedestrians. Found that pedestrians are more likely to comply with signals when the waiting time is shorter and when other pedestrians are also waiting to cross. Additionally, the presence of countdown timers can enhance compliance by informing pedestrians of the remaining time to cross.

Signalized pedestrian crossings can be controlled by traffic signals that change automatically or by signals that change only when a pedestrian presses a button to obtain a green light. One type of signalized pedestrian crossing used in Great Britain and other countries is the pelican crossing (pelican = pedestrian light-controlled). This is a push-button-activated signaling system, where flashing yellow lights for vehicles appear at the end of the crossing phase. When the flashing yellow light is displayed, vehicles may proceed through the pedestrian crossing provided there are no pedestrians on it. The purpose of the yellow blinking light phase is to reduce waiting times for motor vehicles. Experience shows that push buttons are infrequently used (Dahlen & Toftenes, 1979; Huang & Zegeer, 2001) [2, 1].

Table 1: The effects of signalised pedestrian crossings on accidents reduction

Types of Accidents Affected	Percentage change in the number of accidents	
	Best estimate	95% confidence interval
Signalised Pedestrian Crossing vs. no Crosswalk at Midblock	-49	(-81; +35)
Signalised Pedestrian Crossing vs. no Crosswalk at Junction	-2	(-48; +84)
Signalised Pedestrian Crossing vs. Marked Crosswalk	-27	(-59; +29)
Pelican Crossing vs. no Crosswalk	-20	(-34; -2)
Pelican Crossing vs. Marked Crosswalk	3	(-25; +42)

***Source*:** Elvik *et al*., 2009

Table 1 shows the effects of signalized pedestrian crossing installation on the existing type of crossings. Despite their benefits, signalised pedestrian crossings are not without challenges. One of the main issues is the potential for signal violations by both pedestrians and drivers. Signal violations are a significant problem at signalised crossings, particularly during peak traffic periods. These violations can undermine the safety benefits of signalised crossings and increase the risk of accidents. Additionally, the installation and maintenance of signalised crossings can be costly, particularly in urban areas with high traffic volumes.

Effectiveness of Signalised Pedestrian Crossings

The effectiveness of signalised pedestrian crossings in

improving pedestrian safety has been widely studied. A study by Retting *et al*. (2003) [12] found that signalised crossings can reduce pedestrian crashes by up to 50%. This reduction is attributed to the clear indication of when it is safe for pedestrians to cross, thereby reducing the likelihood of conflicts with vehicles. Additionally, signalised crossings can improve the overall flow of traffic by reducing the need for pedestrians to cross at unsignalised locations, which can disrupt traffic flow and increase the risk of accidents.

Impact on Pedestrian Behavior

Signalised pedestrian crossings also influence pedestrian behavior (Bendak, 2021) [1]. The need to integrate the behaviour into crossing design was applied in a study on children pedestrians (Ištoka Otković, 2021) [9]. Studies have shown that pedestrians are more likely to comply with traffic signals at signalised crossings compared to unsignalised ones. For instance, a study by Oxley *et al*. (1997) [10] found that compliance rates at signalised crossings were significantly higher, particularly among older pedestrians. This increased compliance can be attributed to the clear and unambiguous signals provided at these crossings, which reduce the uncertainty and risk associated with crossing the road.

Design and Implementation

The design of signalised pedestrian crossings involves several considerations, including the placement of signals, timing of pedestrian phases, and the integration of crossings with other traffic control measures. According to the placement of pedestrian signals should be based on pedestrian demand, traffic volume, and the physical characteristics of the crossing location. The timing of pedestrian phases is crucial to ensure that pedestrians have sufficient time to cross safely, and this timing should be adjusted based on the average walking speed of pedestrians, which can vary by age and physical ability.

Accident Cost

Based on the Ministry of Public Works, the unit cost of traffic accidents (BSKE) is the cost of traffic accidents caused by a traffic accident for each class of traffic accidents. The unit cost of traffic accidents in the 2003 base year (T0) for city roads can be taken from the table. With inflation adjustments based on Trading Economics data, inflation from 2003 to 2022 was 1.66, so there was an Accident Cost adjustment as follows.

Table 2: Unit Cost of Traffic Accidents on city roads

No	Accident/Severity Classification	BSKE 2003 (T0)	Inflation	BSKE 2022 (Tn)
1	Fatal	Rp 131.205.000	1.66	Rp 348.005.300
2	Major	Rp 18.997.000		Rp 50.532.020
3	Minor	Rp 12.632.000		Rp 33.601.120

***Source*:** Department of Public Works, 2005

Methodology

The research flow is shown in Figure 2. From the results of the analysis of the phenomenon of accidents that occurred in DKI Jakarta, a basis was obtained to develop research to be able to provide appropriate analytical results. In the early stages of the research, by knowing a few samples of the location of the accident that had been facilitated only by zebra crossing. So that the average accident loss is calculated in the crossing area where there is a crosswalk, as well as investment costs incurred as a result of increasing pedestrian facilities by adding signals. From this, it can be estimated the benefits of reducing accident losses due to increased pedestrian facilities.

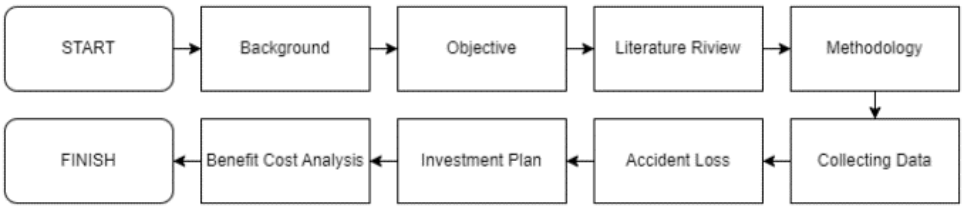

Fig 2: Research Flow Chart

Result

Accident Loss

The initial stage was to collect data to determine the average annual loss for each location where pedestrian accidents occurred in the zebra crossing area. It is obtained that each year there are several different locations with the highest average loss occurring in 2022 of IDR 200,681,645 per location as in Table 3. The following table is the average accident loss for 3 years.

Table 3: Calculation of the average accident loss for 3 years

2020			2021			2022		
Location	**Total Accident**	**Accident Loss**	**Location**	**Total Accident**	**Accident Loss**	**Location**	**Total Accident**	**Accident Loss**
1	2	Rp 67,202,240	1	1	Rp 50,532,020	1	2	Rp 67,202,240
2	1	Rp 50,532,020	2	1	Rp 33,601,120	2	1	Rp 33,601,120
3	1	Rp 33,601,120	3	1	Rp 33,601,120	3	1	Rp 33,601,120
4	2	Rp 67,202,240	4	2	Rp 67,202,240	4	1	Rp 349,005,300
5	1	Rp 349,005,300	5	1	Rp 33,601,120	5	1	Rp 33,601,120
6	1	Rp 349,005,300	6	1	Rp 33,601,120	6	1	Rp 349,005,300
7	1	Rp 50,532,020	7	1	Rp 349,005,300	7	1	Rp 33,601,120
8	1	Rp 349,005,300	8	1	Rp 33,601,120	8	1	Rp 349,005,300
9	1	Rp 33,601,120	9	1	Rp 33,601,120	9	1	Rp 33,601,120
10	1	Rp 349,005,300	10	1	Rp 50,532,020	10	1	Rp 349,005,300
11	1	Rp 50,532,020	11	1	Rp 33,601,120	11	1	Rp 33,601,120
12	1	Rp 50,532,020	12	1	Rp 33,601,120	12	1	Rp 349,005,300
13	1	Rp 33,601,120	13	1	Rp 33,601,120	13	9	Rp 1,017,872,940
14	1	Rp 349,005,300	14	1	Rp 50,532,020	14	1	Rp 33,601,120
15	1	Rp 33,601,120	15	1	Rp 349,005,300	15	1	Rp 349,005,300
16	1	Rp 33,601,120	16	1	Rp 33,601,120	16	1	Rp 33,601,120
17	1	Rp 33,601,120	17	1	Rp 349,005,300	17	1	Rp 33,601,120
18	1	Rp 33,601,120	18	1	Rp 33,601,120	18	1	Rp 50,532,020
19	1	Rp 349,005,300	19	1	Rp 50,532,020	19	4	Rp 134,404,480
20	1	Rp 33,601,120	20	1	Rp 349,005,300	20	1	Rp 50,532,020
……. …….								
Average Loss/Location		Rp 123,864,913	Average Loss/Location		Rp 98,316,307	Average Loss/Location		Rp 200,681,645
Total Location		37	Total Location		57	Total Location		22

Reduction of Accident Cost

Based on the results of the obtained losses, estimates were made to calculate the reduction in accidents and the average reduction in accident costs, using Elvik's sources (2009) as a reference. It was found that each year, various locations experienced different levels of average loss reduction, with the highest average reduction occurring in 2022, amounting to IDR 36,247,034 per location. Table 4 provides an estimate of the average loss reduction over the past three years.

Table 4: Calculation of the average reduction of loss for 3 years

2020			2021			2022		
Location	**Reduced no of Accidenta**	**Reduction of Loss**	**Location**	**Reduced no of Accidents**	**Reduction of Loss**	**Location**	**Reduced no of Accidents**	**Reduce Loss**
1	1	Rp 32,929,098	1	1	Rp 24,760,690	1	1	Rp 32,929,098
2	1	Rp 24,760,690	2	1	Rp 16,464,549	2	1	Rp 16,464,549
3	1	Rp 16,464,549	3	1	Rp 16,464,549	3	1	Rp 16,464,549
4	1	Rp 32,929,098	4	1	Rp 32,929,098	4	1	Rp171,012,597
5	1	Rp171,012,597	5	1	Rp 16,464,549	5	1	Rp 16,464,549
6	1	Rp171,012,597	6	1	Rp 16,464,549	6	1	Rp171,012,597
7	1	Rp 24,760,690	7	1	Rp171,012,597	7	1	Rp 16,464,549
8	1	Rp171,012,597	8	1	Rp 16,464,549	8	1	Rp171,012,597
9	1	Rp 16,464,549	9	1	Rp 16,464,549	9	1	Rp 16,464,549
10	1	Rp171,012,597	10	1	Rp 24,760,690	10	1	Rp171,012,597
11	1	Rp 24,760,690	11	1	Rp 16,464,549	11	1	Rp 16,464,549
12	1	Rp 24,760,690	12	1	Rp 16,464,549	12	1	Rp171,012,597
13	1	Rp 16,464,549	13	1	Rp 16,464,549	13	5	Rp498,757,741
14	1	Rp171,012,597	14	1	Rp 24,760,690	14	1	Rp 16,464,549
15	1	Rp 16,464,549	15	1	Rp171,012,597	15	1	Rp171,012,597
16	1	Rp 16,464,549	16	1	Rp 16,464,549	16	1	Rp 16,464,549
17	1	Rp 16,464,549	17	1	Rp171,012,597	17	1	Rp 16,464,549
18	1	Rp 16,464,549	18	1	Rp 16,464,549	18	1	Rp 24,760,690
19	1	Rp171,012,597	19	1	Rp 24,760,690	19	2	Rp 65,858,195
20	1	Rp 16,464,549	20	1	Rp171,012,597	20	1	Rp 24,760,690
……. …….								
Average Reduction of Loss/Location		Rp 60,693,807	Average Reduction of Loss/Location		Rp 48,174,990	Average Reduction of Loss/Location		Rp 98,334,006
Total no of Locations		37	Total no of Locations		57	Total no of Locations		22

Several case studies have demonstrated the effectiveness of signalised pedestrian crossings in improving pedestrian safety. For instance, a study by Fitzpatrick *et al.* (2006) [8] examined the impact of signalised crossings in Austin, Texas,

and found a significant reduction in pedestrian crashes following the installation of these crossings. Similarly, a study by Turner *et al*. (2006) in New Zealand found that signalised crossings led to a 40% reduction in pedestrian crashes at high-risk locations.

Investment Plan

The measurement costs refer to the cost of procuring Pelican Crossing, which is based from the Transportation Service Work Plan, whose budget can be accessed openly online. Table 5 is data from several Department of Transportation that has been collected.

Table 5: Cost of Pelican Crossing Implementation based on City/Regency, Transportation Agency Work Plan

No	Source	Year	Implementation Cost
1	Bogor City Transportation Agency	2021	Rp 175.000.000
2	Pontianak City Transportation Agency	2019	Rp 100.000.000
3	Purworejo Regency Transportation Agency	2018	Rp 179.000.000

Based on some of the references obtained, it was determined that the Measurement Cost used was the Bogor City Transportation Agency Work Plan with a confectionary fee of IDR 175,000,000 because the location is closest to PMJ jurisdiction area and has the most recent plan year (2021).

Benefit Cost Analysis

An analysis of the perceived benefits of improving pedestrian crossing facilities is based on the calculations obtained as follows.

$$B/C = \frac{Reduce\ Cost\ Accident}{Measurement\ Cost} = \frac{Rp\ 98.334.006}{Rp\ 175.000.000} = 0.562$$

The results of the calculation of the B/C ratio of 0.562 mean that the profit from the project is less than the expenses, so the project is not feasible and needs to be reviewed. So, a recalculation is carried out by considering the payback period of the handling carried out on reducing accident costs with a B/C ratio limit of 1.

$$B/C = \frac{Reduce\ Cost\ Accident \times Time\ Period}{Measurement\ Cost}$$

$$Time\ Period = \frac{Measurement\ Cost \times B/C}{Reduce\ Cost\ Accident} = \frac{Rp\ 175.000.000 \times 1}{Rp\ 98.334.006} = 1.77 \approx 21\ Months$$

The benefits of improving pedestrian service facilities in the form of Pelican Crossing will begin to be felt after 21 months of operation. So that it can be concluded that it will provide benefits for pedestrian crossing safety in the long term.

Conclusion

Signalized pedestrian crossings are essential for enhancing pedestrian safety and managing traffic flow in urban areas. The design and implementation of these crossings require careful consideration of various factors, including pedestrian demand, traffic volume, and the physical characteristics of the crossing location. While signalized crossings have proven effective in reducing pedestrian crashes and improving compliance with traffic signals, challenges such as signal violations and high installation costs persist. Technological innovations, such as adaptive signal control technology and pedestrian detection systems, offer promising solutions to these challenges. Overall, signalized pedestrian crossings are a vital component of urban infrastructure, contributing to safer and more efficient transportation systems.

Despite the benefits of signalized pedestrian crossings, several challenges remain. One of the main challenges is ensuring compliance with traffic signals, particularly in areas with high pedestrian and vehicle volumes. Education and enforcement are critical to addressing this issue. Additionally, the design of pedestrian crossings must consider the needs of vulnerable populations, such as the elderly and people with disabilities, to ensure that they can cross safely (Fitzpatrick *et al*., 2016) [8].

Future research should focus on developing more advanced technologies to improve the safety and efficiency of pedestrian crossings. For example, using machine learning algorithms to predict pedestrian behavior and adjust signal timing accordingly could enhance safety. Additionally, integrating pedestrian crossings with other smart city technologies, such as traffic management systems and public transportation, could improve overall urban mobility (Liu *et al*., 2021).

Research results indicate that the annual cost of accident losses from 2020-2022 in the PMJ jurisdiction area is IDR 200,681,645, based on data from 22 locations. The estimation results suggest that improving crossing facilities could reduce accidents by 27 incidents, resulting in a reduced loss of IDR 98,334,006. When compared with the handling fee of IDR 175,000,000, the benefit-cost analysis ratio is 0.562. Therefore, it can be concluded that enhancing pedestrian crossing safety will provide long-term benefits.

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