

Pedestrian risk analysis at Jl. Raya Citayam – Jl. Boulevard Raya Grand Depok City intersection leg using pedestrian risk index

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Abstract. Based on data obtained from Korps Lalu Lintas Kepolisian Negara Republik Indonesia there are 4,007 traffic accidents involving pedestrian in this period (October 2017-March 2018), where 499 of them happened at intersection. The purpose of this research is to analyze the risk level of pedestrian when crossing the intersection leg (using Pedestrian Risk Index (PRI). The concept of TCT (Traffic Conflict Technique) is adopted and a designed group(s) of pedestrians are observed while crossing the streets at a zebra cross and while crossing the street without a zebra cross. Pedestrians are observed when crossing individually and in groups. Data extracted include time and distance to accidents, crossing directions, and speed. Results indicate that compared to the existence of zebra crossing and crossing direction, the number of pedestrian in group significantly determines the risk level.

1 Introduction

There are 4,007 accidents involving pedestrians in this period based on data obtained from Korps Lalu Lintas Republik Indonesia, where 499 of them happened at the intersection [1]. It should be noted that there are accidents not recorded in the database. According to UU 22/2009 on traffic and road transport, the pedestrian has the right to get priority when crossing the road [2]. However, this regulation is often violated. To identify what are the reasons behind a large number of accidents, research needs to be carried out. Lack of crossing facilities may lead to a pedestrian crossing the road irresponsibly. This research compares pedestrian risk in different conditions. Pedestrians are observed crossing the road individually and in the group, at the road equipped with and without zebra cross. Pedestrian Risk Index (PRI) is a conflict indicator compared in this research to see which condition has the least risk. This study will show what factors have a significant impact on pedestrian risk.

A study in Banyumas showed a larger number in a traffic accident at road segment instead of the intersection. This isn't theoretically correct since the intersection has more conflict point [3]. The study in Poland showed that about 30% of accidents happened on marked crosswalks where theoretically pedestrians should be protected and the most significant factor in pedestrian risk is lighting, this is also related to pedestrian visibility [4].

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Other study showed that higher flow in pedestrian and vehicle leads to lower the risk of the traffic accident, this might be due to slower moving pace and better visibility of the pedestrian [5]. A study needs to be carried out to see whether the same condition would happen in Indonesia, specifically in big cities.

2 Methodology

A study was carried out at one of Jl. Raya Citayam – Jl. Boulevard Raya Grand Depok City intersection legs. This intersection not equipped with any traffic lights. One lane is equipped with a zebra cross while the other doesn't. This place was chosen so that pedestrian risk comparison between two conditions can be generated. Data collection was held at the off-peak hour that is 13.00-15.30. In this time, the driver's behavior is assumed to be normal.



Fig. 1. Survey location.

Observation showed that other factors might affect the level of pedestrian risk:

1. Zebra cross observed in this study is not up to standard, i.e., no stopping line [6].
2. Zebra cross observed in this study is, i.e., faded color.
3. Physical objects exist in the area disturbing pedestrian visibility [7].
4. No traffic sign that indicates the existence of the pedestrian crossing [8].
5. No traffic lights to manage the traffic.
6. Road users were disobeying the traffic regulations, e.g., pedestrian crossing at random points without crossing facility, vehicle doing U-turn in a forbidden area.

Two surveyors were trained to be able to estimate vehicle speed with the help of speed gun. Once the estimation is mostly similar to the result speed gun generates, the data collection may start. Each surveyor had to stand in a different side of the lane to collect the data. To make data collection easier, ten persons were asked to cross the road. Each person had to cross the road individually four times and as a group twenty times. The pedestrian group consists of more than one pedestrian that moves together [9]. Ten persons were divided into a group of six and four. In the end, there are forty data for an individual, twenty data for each group of six and four data for each direction.

3 Results and discussion

PRI can only be calculated with data considered as conflict. Conflict is an event involving more than one road user that may lead to a collision if there's no emergency maneuver done. If an emergency maneuver fails, an accident arises [10]. Conflict time is defined in $TTZ_{duration}$ ($TTC_p < TTC_v < Ts$). $TTZ_{duration}$ is considered as potential conflict time, data outside the interval are not considered as traffic conflict [11].

Table 1. Number of conflict and non-conflict in different condition.

Pedestrian group size	Zebra cross existence	Conflict	Non-conflict
Single	None	32	8
	Yes	27	13
Group	None	24	16
	Yes	26	14

About 109 out of 160 data analyzed are identified as conflict, where about 48% of the conflict happened in the road with zebra cross. This finding is in line with the previous study conducted in Poland. Both shows contrast to theory where marked crosswalks should protect the pedestrian from the traffic accident. We can roughly conclude that this crossing is dangerous from the number. To identify which condition has the least risk and to know how significant the differences between conditions affect the PRI value, a Student t-test was carried out. If the P-value is less than 0.05 we can consider the difference in the mean value of PRI for the different condition as significant statistically and vice versa.

Table 2. Student T-test for means difference in different comparison.

Comparison		N	Mean	Standard Deviation	t-value	p-value
Crossing Facility	Without Zebra Cross	56	61.9890	83.96379	-0.967	0.336
	With Zebra Cross	53	75.5426	59.61192		
Without Zebra Cross	Single	32	87.5256	101.54313	2.785	0.003
	Group	24	27.9402	29.05230		
With Zebra Cross	Single	27	78.6174	46.88395	0.377	0.706
	Group	26	72.3496	71.30642		
With and without Zebra Cross	Single	59	83.4489	80.72453	2.354	0.02
	Group	50	51.0331	59.09884		
Single pedestrian walking direction	From East	31	86.7267	87.20015	0.273	0.786
	From West	30	81.1039	72.88444		
Group pedestrian walking direction	From East	30	44.6563	57.22361	-0.825	0.413
	From West	22	58.2277	60.42412		
Group pedestrian	6 People	26	58.8957	72.96605	0.979	0.323
	4 People	24	42.5153	38.83704		

Significant differences are shown in the colored cells. The mean value of PRI for single pedestrian are higher than those in Group. It can be concluded that crossing the road in the group is safer compared to crossing alone. This result may be due to several possibilities. Crossing in the group might be safer because of higher visibility, pedestrians tend to move at the slower pace and more alert when crossing the road. These findings are parallel to the previous study conducted in Sukoharjo [12].

Binary logistic regression was also conducted to determine traffic risk chances in mathematical equations. Binary logistic regression was chosen because there is two independent variable that is dichotomous/binary and to show the probability of pedestrian is at risk [13]. The categorical variable was represented with “0” for single pedestrian and road not occupied with zebra cross and “1” for pedestrian group and road occupied with zebra cross. Vehicle deceleration used in the calculation is 3.4 m/s² [14] and pedestrian speed of 5.5 feet/second [15].

The result obtained from the regression is a natural logarithm equation. By doing differentiation to the equation, we can see how independent variables affect the chance for pedestrian risk to occur. The equation obtained is as follows.

$$\ln\left(\frac{p}{1-p}\right) = -0,489x_1 - 1,324x_2 - 0,246x_3 + 0,676x_4 - 0,347x_5 + 0,384x_6 + 0,740 \quad (1)$$

Thus, the probability for pedestrian risk to occur (P) can be obtained using Eq. 2:

$$p = \frac{e^{-0,489x_1 - 1,324x_2 - 0,246x_3 + 0,676x_4 - 0,347x_5 + 0,384x_6 + 0,740}}{1 + e^{-0,489x_1 - 1,324x_2 - 0,246x_3 + 0,676x_4 - 0,347x_5 + 0,384x_6 + 0,740}} \quad (2)$$

where p = probability of pedestrian is at risk, x₁ = number of pedestrian (0 for single, 1 for group), x₂ = zebra cross existence (0 for none, 1 for exist), x₃ = longitudinal distance between vehicle and the crossing (m), x₄ = vehicle speed (m/s), x₅ = lateral vehicle distance (m), x₆ = pedestrian position on crossing (m).

If p > 0.5 then the pedestrian is considered at risk and vice versa. Results generated from statistical software shows independent variables that significantly affect the probability for pedestrian risk to occur. Variables can be considered as significant if the significance value is no more than 0.05. Independent variables that are significant affects p consists of zebra cross existence (0.16), the longitudinal distance between the vehicle and the crossing (0.19), and vehicle speed (0.01).

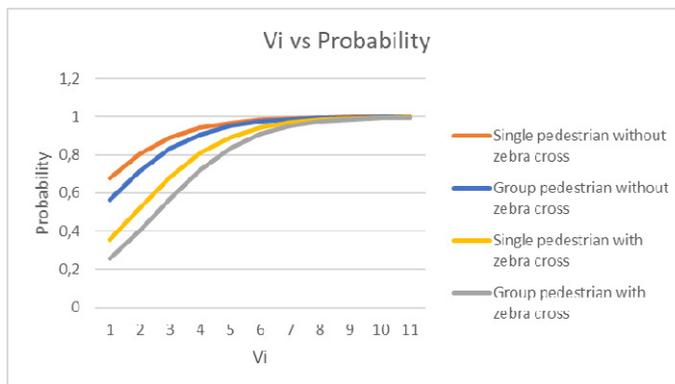


Fig. 2. Relationship between Vi or vehicle speed (m/s) and probability of pedestrian is at risk.

By substituting the binary independent variables, it can be concluded that the probability of pedestrian is at risk is decreased by 0.318 by crossing a road with zebra cross

and decreased by 0.114 by crossing as a group. That being said, data input for the group size are the combination of four and six people. The researcher needs to pay attention to this issue for the more accurate result in the future.

The probability of pedestrian is at risk is increased as the vehicle speed increases (Fig. 2) and decreased as the distance of the vehicle to the conflict area increases (Fig. 3).

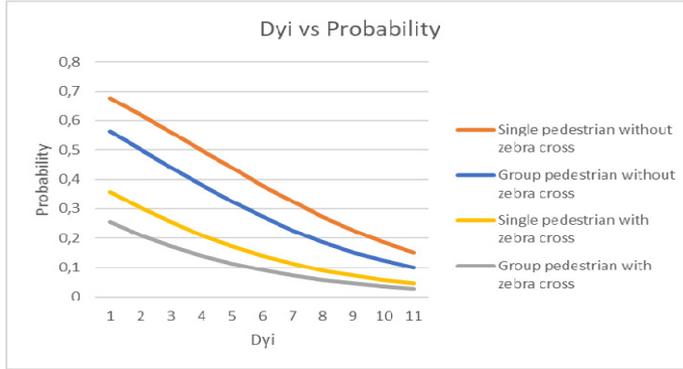


Fig. 3. Relationship between Dyi or vehicle distance to conflict area (m) and probability of pedestrian is at risk.

Both graphs show the same result was crossing the road as a group is safer compared to crossing by oneself, crossing at zebra cross correspondingly safer than a road without zebra cross. As mentioned before, p is declined more by crossing at zebra cross compared to crossing in the group.

Another binary logistic regression was done using only significant variable resulted from the first regression. The result obtained from the regression is as follows:

$$\ln\left(\frac{p}{1-p}\right) = 0,698x_1 - 0,14x_2 + 0,599x_3 - 1,435 \tag{3}$$

Thus, the probability for pedestrian risk to occur (P) can be obtained using Eq. 4:

$$p = \frac{e^{0,698x_1 - 0,14x_2 + 0,599x_3 - 1,435}}{1 + e^{0,698x_1 - 0,14x_2 + 0,599x_3 - 1,435}} \tag{4}$$

where p = probability of pedestrian is at risk, x1 = zebra cross existence (0 for none, 1 for exist), x2 = longitudinal distance between vehicle and the crossing (m), x3 = vehicle speed (m/s).

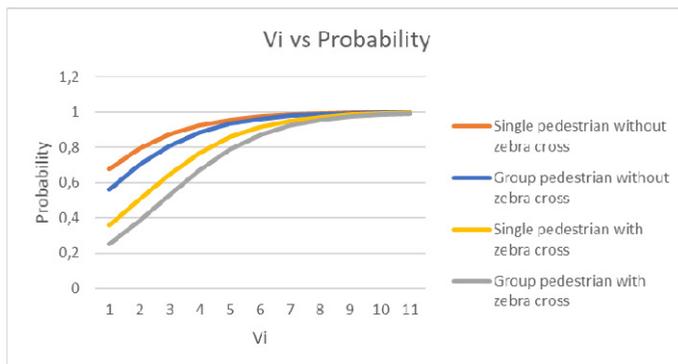


Fig. 4. Relationship between Vi or vehicle speed (m/s) and probability of pedestrian is at risk.

There's only one independent variable that significantly affects p , i.e., vehicle speed with Sig. value of 0.001. The difference between vehicle speed coefficient from the first and second regression is so small, resulting in the identical graph (Fig. 4).

4 Conclusions

Based on the conducted research, it can be concluded that the number of conflicts for the single pedestrian is higher compared to the group. This may be due to visibility. PRI value for a single pedestrian is higher than the group, and the difference between both mean PRI value is statistically significant. Fig. 2 indicates that when vehicle speed increases, the risk probability increases. An increase of vehicle speed from 7 m/s to 10 m/s will result in a rise in pedestrian risk by 0.60% for single pedestrians where there is no crossing and 2.24% where there is a crossing. For group pedestrian, the risks increase 0.97% where there is no crossing and 3.65% if they cross at pedestrian crossings.

Distance to pedestrians also changes the pedestrian risks when crossing. From Fig. 3 it can be seen that when longer distance decreases the pedestrian risks. When the distance is increased two times from 2 m to 4 m, the single pedestrian risk is decreased 27.85% where there is no crossing and 47.39% where there is crossing. For group pedestrian, the risks decreased 35.59% where there is no crossing and 52.56% where there is crossing.

Equation produced from binary logistic regression shows three variables have a significant impact on the probability of pedestrian is at risk. Those variables consist of zebra cross existence, the longitudinal distance between the vehicle and the crossing, and vehicle speed. Pedestrian risk probability is increased as vehicle speed increases and the longitudinal distance between the vehicle and the crossing decreases. Moreover, zebra cross usage and crossing in the group can lead to a lower pedestrian risk probability.

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