Pedestrian Safety Studies at Crossing Locations in Bandung

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Abstract: Walking is a fundamental form of transportation. This paper examines the pedestrian safety at crossing locations, both at intersections and midblocks; and provides recommendations for improving pedestrian safety in Bandung. Pedestrian safety is assessed through Pedestrian Intersection Safety Index (Ped ISI), for intersections and Pedestrian Midblock Level of Service (LOS), for midblocks. Analysis is conducted by ranking the pedestrian crossing locations based on the accumulation of total score which describes the relationship between the value of pedestrian safety (Ped ISI and LOS) to the pedestrian crashes data. The result shows that a comparison of Ped ISI and LOS to the total score indicates a similar trend, although in some locations the trend changes as it is influenced by the crash fatality rate which affects the score significantly. Overall, the existing pedestrian safety assessment model is, in general, able to describe the condition of pedestrian safety in Bandung.

Keywords: pedestrian, safety, crash, Pedestrian Intersection Safety Index (Ped ISI), Pedestrian Midblock Level of Service (LOS)

1. INTRODUCTION

Pedestrian is one of Non-Motorized Transport (NMT) in addition to bicycling. In the context of Sustainable Urban Transport, the pedestrian is a determining factor in the success of the urban transportation system. Along with the development technology that led to the presence of various motor vehicles, the role of walking activity is no longer dominant. In Bandung, the growth of motor vehicles increased quite dramatically each year. Increasing the number of vehicles trigger a variety of transportation problems due to the expansion of road (1.29% per year) is not proportional to the increase in the number of vehicles (9.34% per year) (Bandung Urban Mobility Project, 2014). The problem increases when the function of the road increasingly diverse, such as a parking lot, street vendor, service station, and others.

The poor quality and facilities of public transport are contributing to the increase in number of vehicles. The inconvenience gained from the use of public transport led to high use of private vehicles. Finally, the streets will be filled with the vehicle that is no longer comfortable space available to interact. It is then impacts to the pedestrians, with deprivation of the rights of pedestrians as a result of transfer function of the sidewalk into the parking lot or street vendor. Moreover, not a few of motorcyclists who use the sidewalk to pass. These circumstances would further worsen the traffic and may harm the safety of pedestrians.

Globally, pedestrian contributes as much as 22% of the total deaths on the road, and in some countries this proportion reached 67% (WHO, 2013). Based on the Global Status Report on Road Safety which released by WHO in 2015, pedestrian crashes in Indonesia reached 21% and was ranked as the third in the road traffic crash after riders motorized 2- or 3- wheelers by 36% as the first and drivers/passengers buses by 35% as the second. Thus, the above description shows the importance of pedestrian safety studies in Bandung to reduce the crash fatality rate and provide recommendations for pedestrian safety improvement.

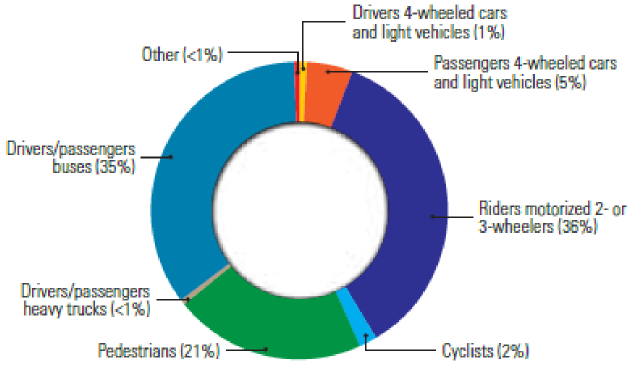
2. THE IMPORTANCE OF PEDESTRIAN SAFETY

Walking has well established health and environmental benefits such as increasing physical activity that may lead to reduced cardiovascular and obesity related diseases, and many countries have begun to implement policies to encourage walking as an important mode of transport. Unfortunately, in some situations increased walking can lead to increased risk of road traffic crashes and injury. Due to the dramatic growth in the number of motor vehicles and the frequency of their use around the world, as well as the general neglect of pedestrian needs in roadway design and land use planning, pedestrians are increasingly susceptible to road traffic injury. Pedestrian vulnerability is further heightened in settings where traffic laws are inadequately enforced.

Reduction or elimination of the risks faced by pedestrians is an important and achievable policy goal. Pedestrian collisions, like other road traffic crashes, should not be accepted as inevitable because they are in fact both predictable and preventable. There is a close association between the walking environment and pedestrian safety. Walking in an environment that lacks pedestrian infrastructure and that permits use of high speed vehicles increases the risk of pedestrian injury. The risk of a motor vehicle colliding with a pedestrian increases in proportion to the number of motor vehicles interacting with pedestrians.

3. RISK FACTORS FOR PEDESTRIAN TRAFFIC INJURY

Based on estimated global road traffic fatalities, about 273.000 pedestrians were killed in road traffic crashes in 2010. This represents around 22% of all road traffic deaths. With the exception of the Eastern Mediterranean and Western Pacific Regions, pedestrians tend to account for a much greater proportion of road traffic injury deaths in low- and middle-income countries than in high income countries. Based on the Global Status Report on Road Safety which released by WHO in 2015, pedestrian crashes in Indonesia reached 21%.



Source: WHO, 2013

Figure 1. Deaths by road user category in Indonesia

The key factors that influence the risk of pedestrian traffic injury as listed below:

1) Speed
The speed at which a car is travelling influences both crash risk and crash consequences. The effect on crash risk comes mainly via the relationship between speed and stopping distance. Research in the 1990s showed that pedestrians had a 90% chance of surviving car crashes at speeds of 30 km/h or lower, but less than a 50% chance of surviving impacts at 45 km/h.
2) Alcohol
Impairment by alcohol is an important factor influencing both the risk of a road traffic crash as well as the severity and outcome of injuries that result from it. Alcohol consumptions results in impairment, which increases the likelihood of a crash because it produces poor judgement, increases reaction time, lowers vigilance and decreases visual acuity.
3) Lack of pedestrian facilities in roadway design and land-use planning
Pedestrian risk is increased when roadway design and land-use planning fail to plan for and provide facilities such as sidewalks, or adequate consideration of pedestrian access at intersections.
4) Inadequate visibility of pedestrians
Inadequate visibility of pedestrians arises from lack of roadway lighting; vehicles and bicycles not equipped with lights; pedestrians not wearing reflective accessories or brightly coloured clothes; especially at night and at dawn or dusk; and pedestrians sharing road space with fast moving vehicles.
5) Other risk factors
Several other factors that contribute to pedestrian injury include: inadequate enforcement of traffic laws; unsafe driving practices; driver distraction, including mobile phone use; driver fatigue; pedestrian – vehicle conflict at pedestrian crossing points, etc.

Zeeger et al (2002) developed 13 crash groupings (12 specific types and 1 miscellaneous type) that are most useful for identifying safety problems and corresponding countermeasures as listed below:

1) Midblock: Dart/Dash
2) Multiple threat
3) Mailbox or other midblock
4) Failure to yield at unsignalized location
5) Bus-related
6) Turning vehicle
7) Through vehicle at signalized location
8) Walking along roadway
9) Working/playing in road
10) Non-roadway
11) Backing vehicle
12) Crossing expressway
13) Miscellaneous

Several engineering and behavioral interventions have been evaluated and found to be effective in improving pedestrian safety, such as reducing pedestrian exposure to vehicular traffic; reducing vehicle speeds; improving the visibility of pedestrians; improving pedestrian and motorist safety awareness and behavior; improving vehicle design for pedestrian protection, providing care for injured pedestrians

4. PEDESTRIAN SAFETY ASSESSMENT

4.1 Pedestrian Intersection Safety Index (Ped ISI)

Pedestrian safety issues have been approached by analyzing crash trends in police report and making improvements rooted in statistical measures. Pedestrian Intersection Safety Index (Ped ISI) was developed by Federal Highway Administration (FHWA) that would allow engineers, planners, and other practitioners to use known intersection characteristics to proactively prioritize crosswalks and intersection approaches with respect to pedestrian safety. Using variables that indicate a higher probability of risk and pedestrian, the Ped ISI can be used to identify which crosswalks and intersection approaches have the highest priority for pedestrian safety improvements within a particular jurisdiction. Once high-priority sites are identified, practitioners may conduct an in-depth evaluation at each site to determine which specific countermeasures would be appropriate to address any safety problems (Zeeger *et al*, 2002).

The Ped ISI was developed using a method in which expert survey ratings and behavioral data were used primarily to determine areas for more in depth pedestrian safety evaluations. The study involved collecting data on pedestrian crashes, conflicts, avoidance maneuvers, and subjective ratings of intersection video clips by pedestrian experts. There were a total of 68 intersection crosswalks selected for the pedestrian analysis from the cities of Philadelphia, PA; San Jose, CA; and Miami-Dade County, FL. Indicative variables included in the pedestrian safety index model included type of intersection control (signal or stop sign), number of through lanes, 85th percentile vehicle speed, main street traffic volume, and area type.

Three types of safety measures were collected for use in the development of the Ped ISI, such as crashes, behavioral data (conflicts and avoidance maneuvers), and subjective intersection ratings. Of these measures, models were developed for ratings and behavioral data. The small amount of crashes precluded any model development on crash data. Models based on ratings were developed using multiple linear regression, since the ratings generally followed a normal distribution. Models based on behavioral data were developed using a generalized linear model, since the behavioral data generally followed a Poisson distribution. The fact that these models predict a safety rating for a site on a scale of 1 to 6 conveniently leads to the development of a safety index. However, since the goal of the Ped ISI is to prioritize sites according to pedestrian safety, it is important for the tool to reflect factors that indicate where safety improvement efforts should be focused.

$$\text{Ped ISI} = 2.372 - 1.867\mathbf{SIGNAL} - 1.807\mathbf{STOP} + 0.335\mathbf{THRULNS} + 0.018\mathbf{SPEED} + 0.006\,(\mathbf{MAINADT*SIGNAL}) + 0.238\mathbf{COMM} \quad (1)$$

where,

SIGNAL	: traffic signal-controlled crossing (0 = no, 1 = yes)
STOP	: stop sign-controlled crossing (0 = no, 1 = yes)
THRULNS	: number of through lanes on street being crossed (both directions) (1,2,3,….)
SPEED	: 85^{th} percentile speed of street being crossed (mi/h)
MAINADT	: traffic volume on street being crossed (ADT in thousands)
COMM	: predominant land use on surrounding area is commercial development (i.e. retail, restaurants, etc) (0 = not predominantly commercial area, 1 = predominantly commercial area)

4.2 Pedestrian Midblock Level of Service (LOS)

In general, pedestrian safety assessment at midblock can be approached through model of Pedestrian Midblock Level of Service (LOS) which developed by The Florida Department of Transportation (FDOT). The objective of this study was to develop a pedestrian level of service methodology for street crossing at midblock locations. It should be capable of providing a measure of effectiveness that indicates pedestrians’ perceived quality of service in crossing roads at midblock locations. This measure of effectiveness could then be converted to a level of service designation. The study will attempt to determine what variables are correlated with pedestrians’ perceived quality of service for midblock crossing. This will be done through a statistical calibration and validation process involving collecting actual site characteristics and stated levels of quality of service by a sample of persons at a sample of sites (Baltes & X., 2002).

Based on a comprehensive statistical analysis of the data as collected from Hillsborough and Pinellas Counties, the following model of perceived pedestrian midblock crossing was developed:

$$\begin{aligned} LOS = &- 2.4478 + 0.4937\mathbf{PED} + 0.0758\mathbf{ADT} + 0.0016\mathbf{TURNMOVE} + 0.0107\mathbf{SPEED} \\ &+ 0.0195\mathbf{CROSSWIDTH} - 0.0661\mathbf{RESTRMED} + 0.0712\mathbf{PAINTMED} \\ &- 0.2762\mathbf{CROSSWALK} - 0.4930\mathbf{PEDSIGNAL} + 0.0284\mathbf{AVGCYCLE} \\ &+ 0.0007\mathbf{SIGNALSPACE} \end{aligned} \quad (2)$$

where,

PED	: share of pedestrians age 65 or older (percentage)
ADT	: total traffic volume (1,000 vehicles per hour)
TURNMOVE	: turning movements (vehicles per hour)
SPEED	: traffic speed (mph)
CROSSWIDTH	: crossing distance (feet)
RESTRMED	: restrictive medians (feet)
PAINTMED	: non-restrictive medians (feet)
CROSSWALK	: crosswalks (0 = no, 1 = yes)
PEDSIGNAL	: pedestrian signals (0 = no, 1 = yes)
AVGCYCLE	: signal cycle (seconds)
SIGNALSPACE	: signal spacing (feet)

The variables listed in the above equation, which measure the pedestrians’ sensitivities to the varying elements of mid-block crossing, combine to determine mid-block pedestrian level of service. By applying actual values to each, a numerical result is obtained that will correspond to one of the designations listed in the LOS breakdown chart. The designations rate level of service (i.e., A is best, F is worst) is shown below.

Table 1. LOS Breakdown

LOS	If Value
A	<= 1.5
B	> 1.5 and < 2.5
C	> 2.5 and <= 3.5
D	> 3.5 and <= 4.5
E	> 4.5 and <= 5.5
F	> 5.5

Source: Baltes & X., 2002

5. RESEARCH METHODOLOGY

The purpose of this study is to investigate pedestrian safety qualitatively and quantitatively at the crossing locations, both at intersections and midblocks; and provide recommendations for pedestrian safety improvement in Bandung in Bandung City. This chapter describes the methods used in this study, which includes a determination of sites survey, an explanation of the data collection procedures and the method used to prioritize sites for improvement as determination the recommendation.

5.1 Sites Survey

The sites survey is distinguished between intersections and midblocks. At intersections, the point of review only applies to the signalized intersection with a coverage area includes the entire city of Bandung. There are 78 intersections consist of 3-arm and 4-arm signalized intersections. At midblocks, the sample point of review is limited to the function of Primary Arterial and Secondary Collector. The total number of sites survey for each of these functions are 4 sites.

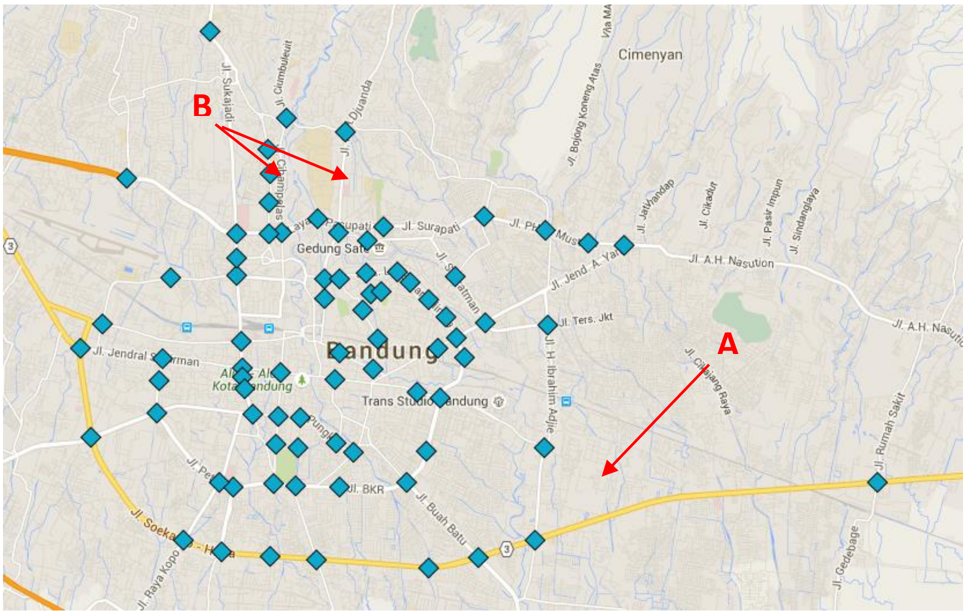


Figure 2. Sites survey at intersections

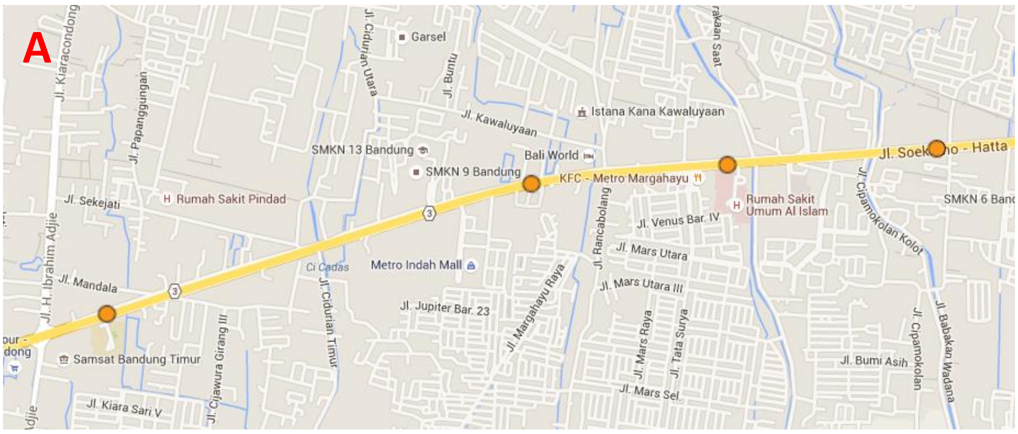


Figure 3. Sites survey of Primary Arterial at midblocks

Figure 4. Sites survey of Secondary Collector at midblocks

5.2 Data Collection

Data needs for this study consists of primary and secondary data. The secondary data is pedestrian crashes data which obtained from Bandung Traffic Police, while traffic volume at intersection is obtained through software of EMME/4 using matrix trips data in 2013 (Hafiandi, 2014). Moreover, the primary data is obtained by surveying the sites at midblocks directly, such as traffic volume by traffic counting, vehicle speed by spot speed and pedestrian-vehicle conflict. Some other supporting data such as the presence of crossing facilities, crossing distance and others as needed is obtained through observation at the sites.

The pedestrian-vehicles conflict data was only observed at midblocks and summarized for each crossing location and total number of pedestrians and vehicles for each movement were calculated. Pedestrian behaviors were totaled per location to provide three interaction totals: no interaction, normal interaction, and abnormal interaction. In each conflict data summary, the total number of abnormal interactions was calculated (called $N_{conflict}$). A conflict percentage was also calculated, which represents the percent of potentially dangerous pedestrian-vehicle interactions per total interactions at given location (Dobbs, 2009).

$$\text{Conflict }\% = \frac{\text{Abnormal Interactions}}{\text{Normal Interactions} + \text{Abnormal Interactions}} \tag{3}$$

5.3 Determination the Recommendation

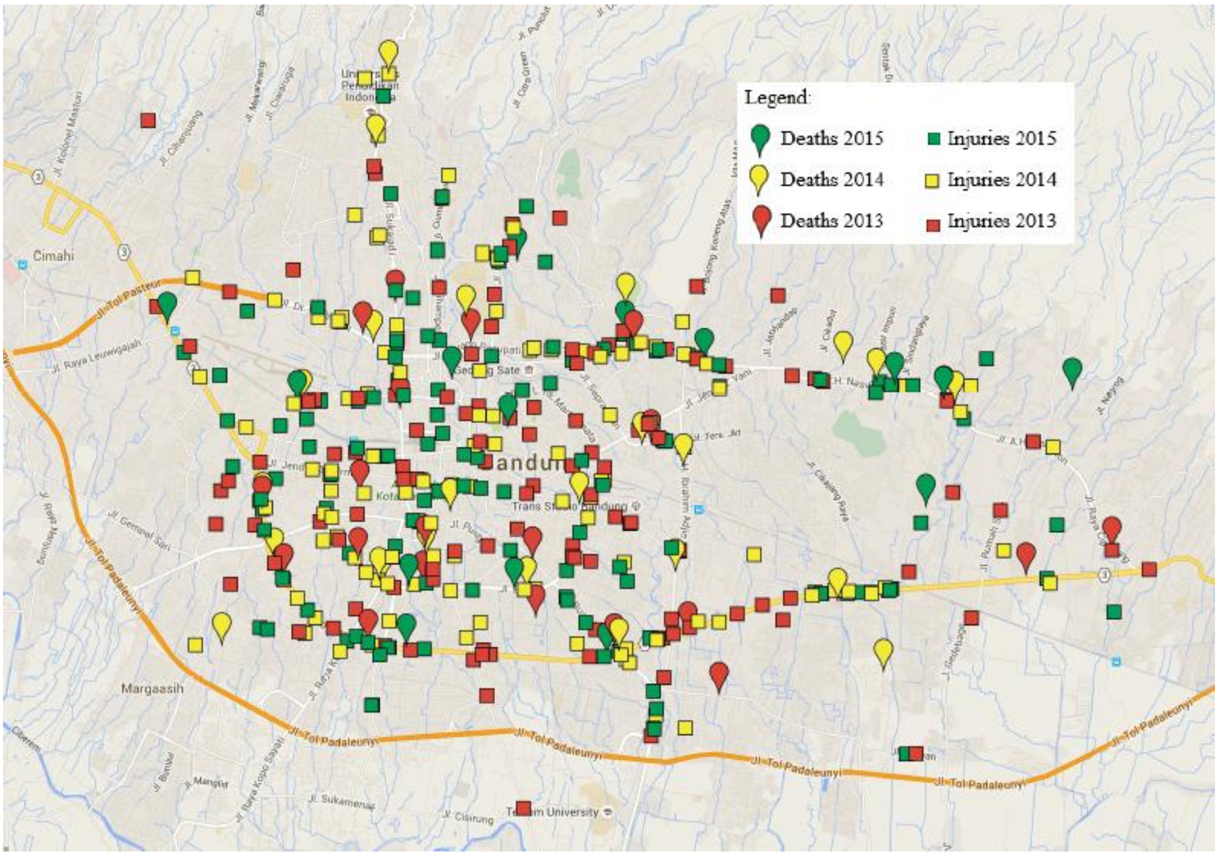
Determination the recommendation begins by ranking the sites who have the highest priority to improve the pedestrian safety. The ranking process are sorted based on the accumulated total score from the highest to the lowest of several assessment criteria. Total score calculation can describe the relationship between the value of pedestrian safety (Ped ISI and LOS) to the pedestrian crashes data, therefore the prioritization of the site can be done comprehensively. In addition, the parameters of conflict percentage and P/V Ratio that is only found at midblocks can be used as an additional aspect to see the magnitude of the crash risk to pedestrian safety.

After the determination of sites that have priority to improvements completed, the next step is provide recommendations for improving pedestrian safety. The appropriate method for determining this is using the software of PEDSAFE. PEDSAFE is a software prepared by The Federal Highway Administration in 2013, created by David L. Harkey and Charles V. Zegeer. This system provides users with information on how to improve pedestrian safety and mobility. PEDSAFE also contains information on understanding pedestrian crashes, implementing countermeasures, and creating a pedestrian environment.

6. DATA PRESENTATION AND ANALYSES

6.1 Data Presentation

Pedestrian crashes data is a secondary data which obtained from Bandung Traffic Police for 3 latest years, 2013 to 2015. Those data was collected in an integrated system data collecting, named Integrated Road Safety Management System (IRSMS).



Source: IRSMS, 2013 - 2015

Figure 5. Pedestrian Crashes Data 2013 – 2015 in Bandung

Traffic volume data are used for both location, intersections and midblocks. Traffic volume at intersections are obtained based on the secondary data (Hafiandi, 2014) which modeled through software EMME/4 using matrix trips data in 2013. Moreover, the traffic volume data at midblocks are obtained by traffic counting.

6.2 Data Analyses

6.2.1 Pedestrian Safety at Intersections

Pedestrian safety at intersections will be assessed using the Pedestrian Intersection Safety Index (Ped ISI) model. The calculation of Ped ISI for each crossing location aided in the prioritization of the crossing locations for improvement. Only 78 sites had available data to enable calculation of indices, and the analyses will be divided into 14 type of intersections based on the following road function as listed in Table 2 and Figure 6.

Table 2. Number of signalized intersections

No	Road Functions	Number of Intersections
1	Primary Arterial – Primary Arterial	3
2	Primary Arterial – Primary Collector	9
3	Primary Arterial – Secondary Arterial	6
4	Primary Arterial – Secondary Collector	5
5	Primary Arterial – Local	4
6	Primary Collector - Primary Collector	9
7	Primary Collector – Secondary Arterial	8
8	Primary Collector – Secondary Collector	2
9	Primary Collector – Local	1
10	Secondary Arterial – Secondary Arterial	5
11	Secondary Arterial – Secondary Collector	3
12	Secondary Arterial – Local	1
13	Secondary Collector - Secondary Collector	16
14	Secondary Collector – Local	6
	Total of Intersections	78

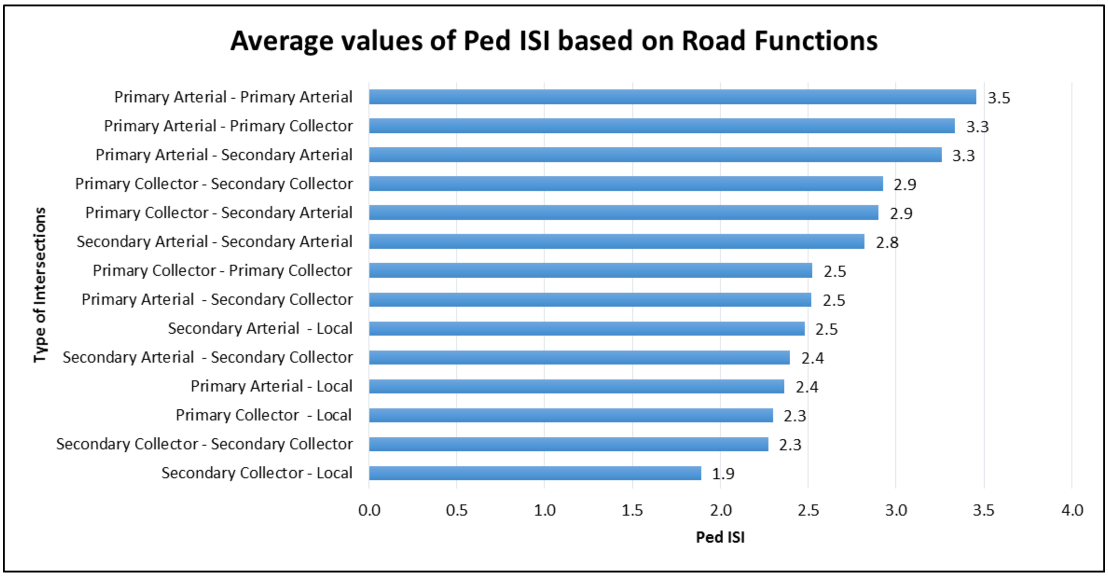


Figure 6. Average values of Ped ISI based on road function

Based on the analysis above, the average value of Ped ISI by road function was ranged from 1.9 – 3.5 with standard deviation of 0.5. However, the average value of Ped ISI in Bandung is 2.7. Maximum value of Ped ISI is at intersection of Primary Arterial – Primary Arterial, while the minimum value of Ped ISI is at intersection of Secondary Collector – Local. Therefore, it can be concluded that the higher level of road function which intersected at the other intersection will increase the value of Ped ISI and vice versa.

The mapping of Ped ISI values in Bandung can be seen in Figure 8 as follows.

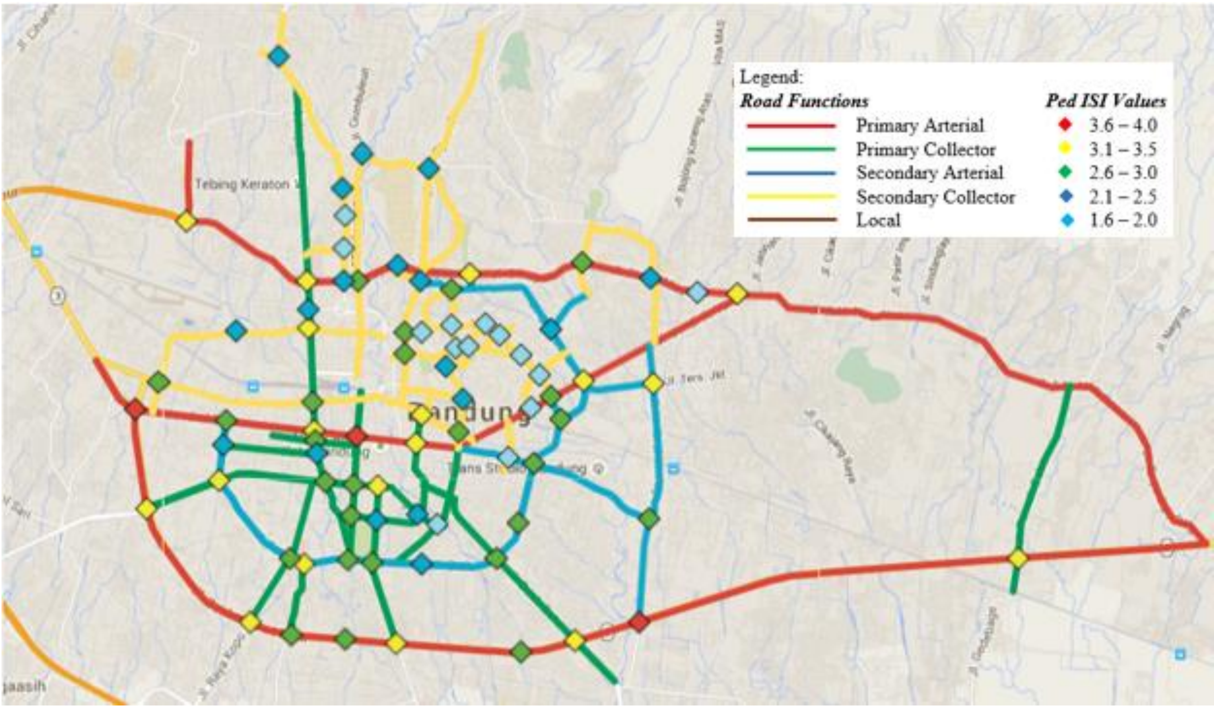


Figure 7. Mapping of Ped ISI values in Bandung

6.2.2 Pedestrian Safety at Midblocks

Analyses of pedestrian safety at midblocks includes analysis of pedestrians-vehicles conflict, vehicular volume and speed, and application the model of Pedestrian Midblock Level of Service (LOS). Only 8 sites was chosen to this research, the analyses will be divided based on the road functions, in this case only for Primary Arterial and Secondary Collector. The characteristics of each location will be differentiated by the presence of pedestrian facilities, side friction and land use.

In terms of knowing the presence of vehicle in pedestrian area and to illustrate the magnitude of interactions between pedestrians and vehicles, the traffic volume is compared to pedestrian volume per hour, which will produce P/V Ratio. Here is the summary of pedestrians and vehicles ratio (P/V Ratio).

Table 3. Pedestrians and vehicles ratio (P/V Ratio)

No	Code	Locations	Veh. Vol (pcu/hr)	Ped. Vol (person/hr)	P/V Ratio
Primary Arterial 2-way					
1	SHT-01-F	In front of UNINUS	3023	76	0.025
2	SHT-02-F	Opposite of UNINUS	2833	76	0.027
3	SHT-03-NF	In front of TELKOMSEL	3345	24	0.007
4	SHT-04-NF	Opposite of TELKOMSEL	3633	24	0.007
5	SHT-05-F	In front of RS AL-ISLAM	3580	90	0.025
6	SHT-06-F	Opposite of RS AL-ISLAM	3427	90	0.026
7	SHT-07-NF	In front of SUZUKI	2218	78	0.035
8	SHT-08-NF	Opposite of SUZUKI	2296	78	0.034

No	Code	Locations	Veh. Vol (pcu/hr)*	Ped. Vol (person/hr)	P/V Ratio
Secondary Collector 1-way					
9	CIH-01-NF	Cihampelas Walk	1463	770	0.526
10	CIP-10-NF	Cipaganti Mosque	2208	215	0.097
Secondary Collector 2-way					
11	DGO-11-NF	FO Dago (Blossom)	1427	108	0.076
12	DGO-12-NF	FO Dago (Cheap Outlet)	1384	108	0.078
13	DGO-13-F	In front of SMAN 1	1611	123	0.076
14	DGO-14-F	Opposite of SMAN 1	1881	123	0.065

*pcu = passenger car unit

Vehicle speed which has been obtained from the survey results then classified into 3 (three) vehicles speed range, such as below 30 km/hr, 30-65 km/hr, and above 65 km/hr. The vehicle speed range is useful to predict the possibility of crash that will happen to pedestrian. The first range, 30-65 km/hr indicates the possibility of an injury crash if the vehicle collided with a pedestrian. The second range, 65 km/hr and above indicates the possibility of a fatal pedestrian crash if a hit by a vehicle in this range. Particular research has shown that pedestrians who are struck by vehicles moving slower than 20 mph (32.2 km/hr) do not typically suffer injury, where as pedestrians struck at speeds greater than 20 mph are likely to sustain severe injury if not death. Vehicles travelling at speeds 40 mph (64.4 km/hr) or greater will cause a pedestrian fatality 85 percent of the time a collision occurs (AASHT0, 2004).

Table 4. Pedestrians and vehicles ratio (P/V Ratio)

No	Code	Locations	$V_{planned}$ (km/hr)	$V_{85percentile}$ (km/hr)	Potential of Injury
Primary Arterial 2-way					
1	SHT-01-F	In front of UNINUS	60	32.82	Serious
2	SHT-02-F	Opposite of UNINUS	60	50.00	Serious
3	SHT-03-NF	In front of TELKOMSEL	60	42.51	Serious
4	SHT-04-NF	Opposite of TELKOMSEL	60	45.95	Serious
5	SHT-05-F	In front of RS AL-ISLAM	60	23.14	Minor
6	SHT-06-F	Opposite of RS AL-ISLAM	60	56.25	Serious
7	SHT-07-NF	In front of SUZUKI	60	40.00	Serious
8	SHT-08-NF	Opposite of SUZUKI	60	37.50	Serious
Secondary Collector 1-way					
9	CIH-01-NF	Cihampelas Walk	20	24.76	Minor
10	CIP-10-NF	Cipaganti Mosque	20	33.23	Serious
Secondary Collector 2-way					
11	DGO-11-NF	FO Dago (Blossom)	20	35.07	Serious
12	DGO-12-NF	FO Dago (Cheap Outlet)	20	32.63	Serious
13	DGO-13-F	In front of SMAN 1	20	52.29	Serious
14	DGO-14-F	Opposite of SMAN 1	20	32.86	Serious

The calculation results for Pedestrian Midblock Level of Service (LOS) is shown as follows.

Table 5. Pedestrians and vehicles ratio (P/V Ratio)

No	Code	Locations	Score	LOS
Primary Arterial 2-way				
1	SHT-01-F	In front of UNINUS	2.88	C
2	SHT-02-F	Opposite of UNINUS	2.99	C
3	SHT-03-NF	In front of TELKOMSEL	8.13	F
4	SHT-04-NF	Opposite of TELKOMSEL	7.71	F
5	SHT-05-F	In front of RS AL-ISLAM	7.72	F
6	SHT-06-F	Opposite of RS AL-ISLAM	7.61	F
7	SHT-07-NF	In front of SUZUKI	5.60	F
8	SHT-08-NF	Opposite of SUZUKI	5.60	F
Secondary Collector 1-way				
9	CIH-01-NF	Cihampelas Walk	2.07	B
10	CIP-10-NF	Cipaganti Mosque	0.95	A
Secondary Collector 2-way				
11	DGO-11-NF	FO Dago (Blossom)	4.51	E
12	DGO-12-NF	FO Dago (Cheap Outlet)	4.46	D
13	DGO-13-F	In front of SMAN 1	3.52	D
14	DGO-14-F	Opposite of SMAN 1	3.30	C

Overall, the calculation results for LOS at midblocks is shown in the following figure.

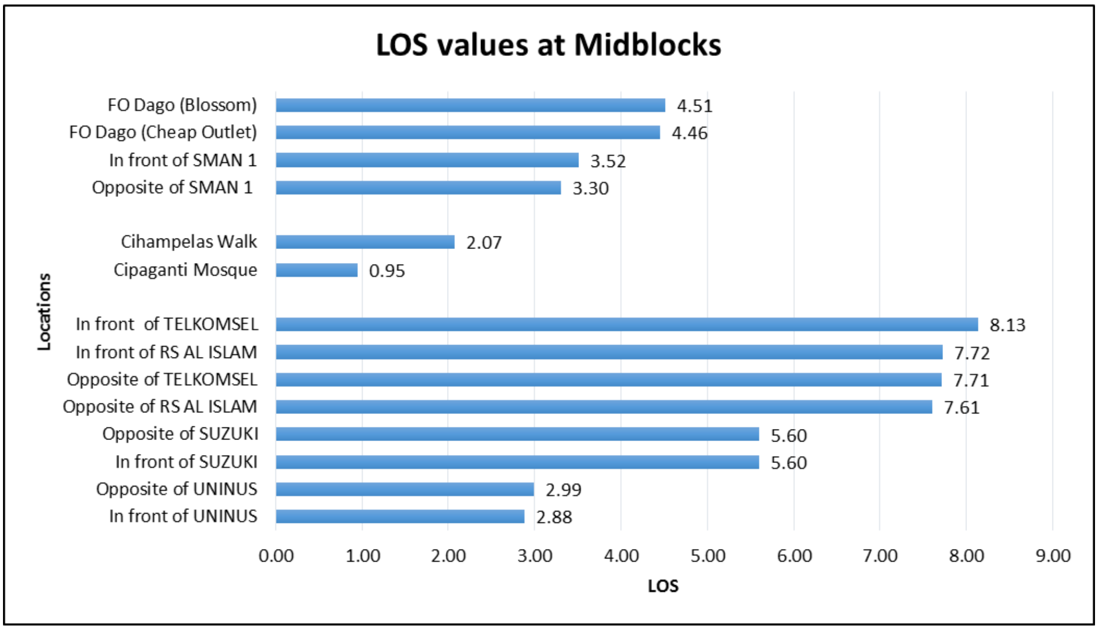


Figure 8. LOS values at midblocks

6.2.3 Recommendations for Improving Pedestrian Safety

Determination the recommendations in order to improve pedestrian safety is based on ranking the sites to the value of pedestrian safety of the calculation results using the existing models, such as Pedestrian Intersection Safety Index (Ped ISI) and Pedestrian Midblock Level of Service (LOS) and also the other influential factors like history of pedestrian crashes, pedestrians-vehicles conflict percentage and P/V Ratio. The calculation results of the Total Score is based on number of crashes in each location, number of victims and the value of pedestrian safety using the existing models (Ped ISI and LOS) for all locations that have the history of pedestrian crashes. The ranking will be based on the accumulation total score which is calculated using the standardized assessment with a range from 0 to 1, where value of "1" corresponding to the worst site. The alternative recommendation will be provided to location that has a history of pedestrian crashes using PEDSAFE Software. The comparison between Ped ISI and LOS to the Total Score based on pedestrian crashes is shown below.

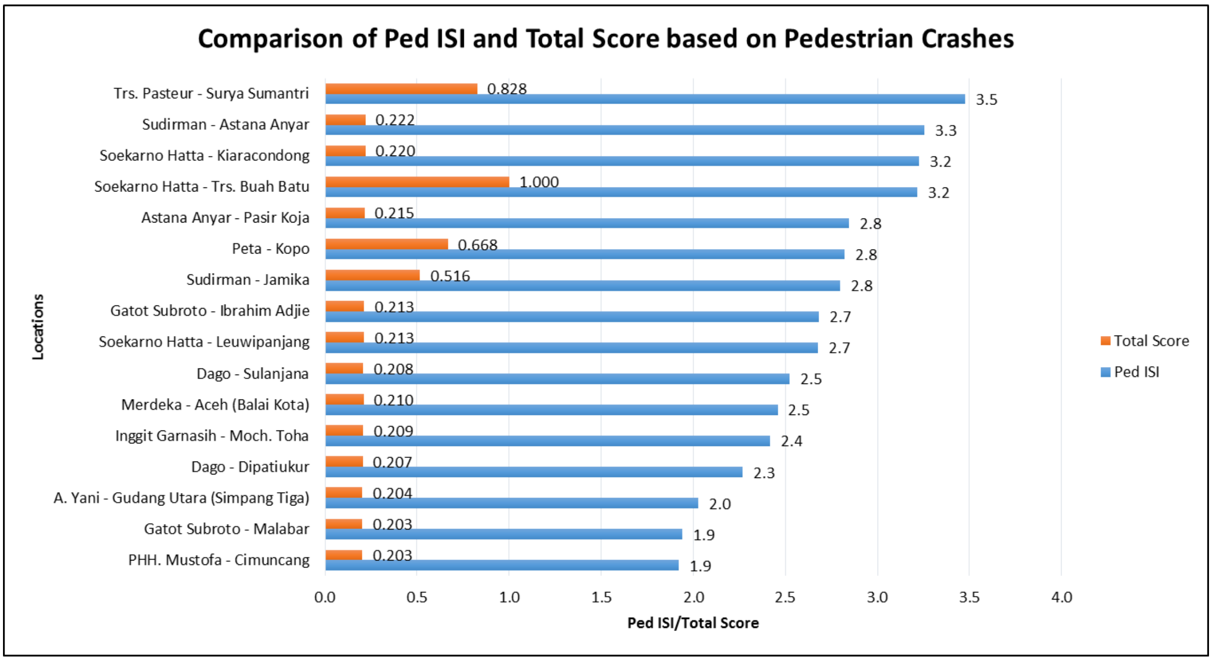


Figure 9. Comparison of Ped ISI and Total Score

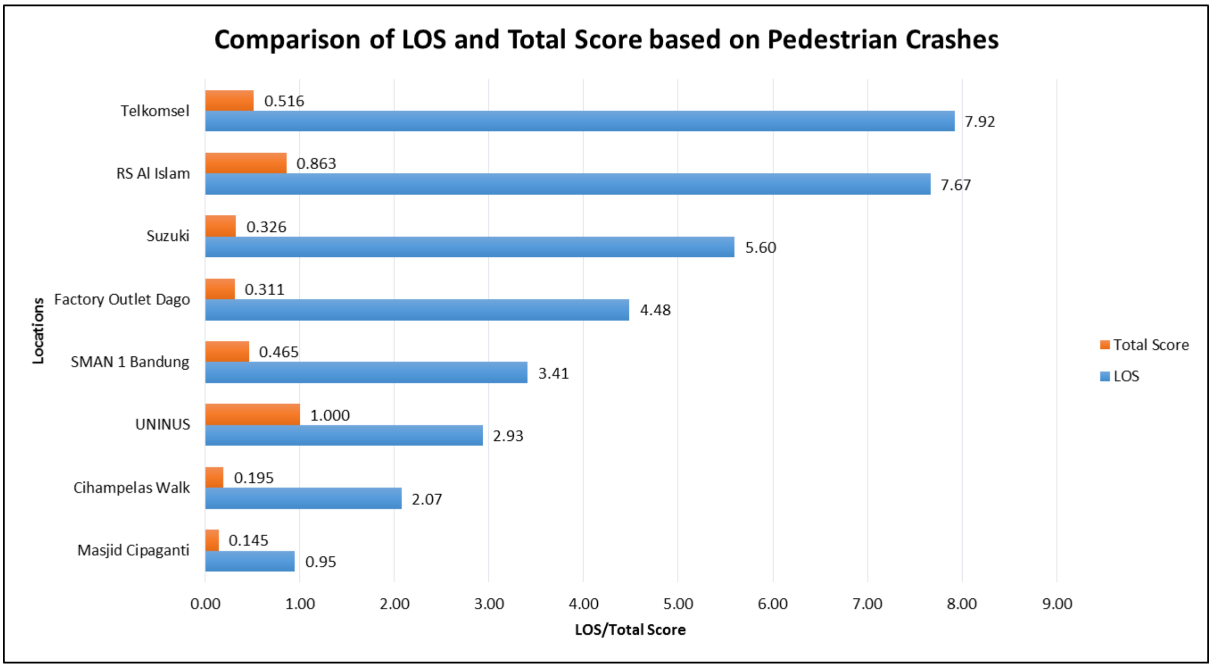


Figure 10. Comparison of Ped ISI and Total Score

Visually, the sites which include in the analyses above is shown in the following figure, the most priority sites is described alphabetically.

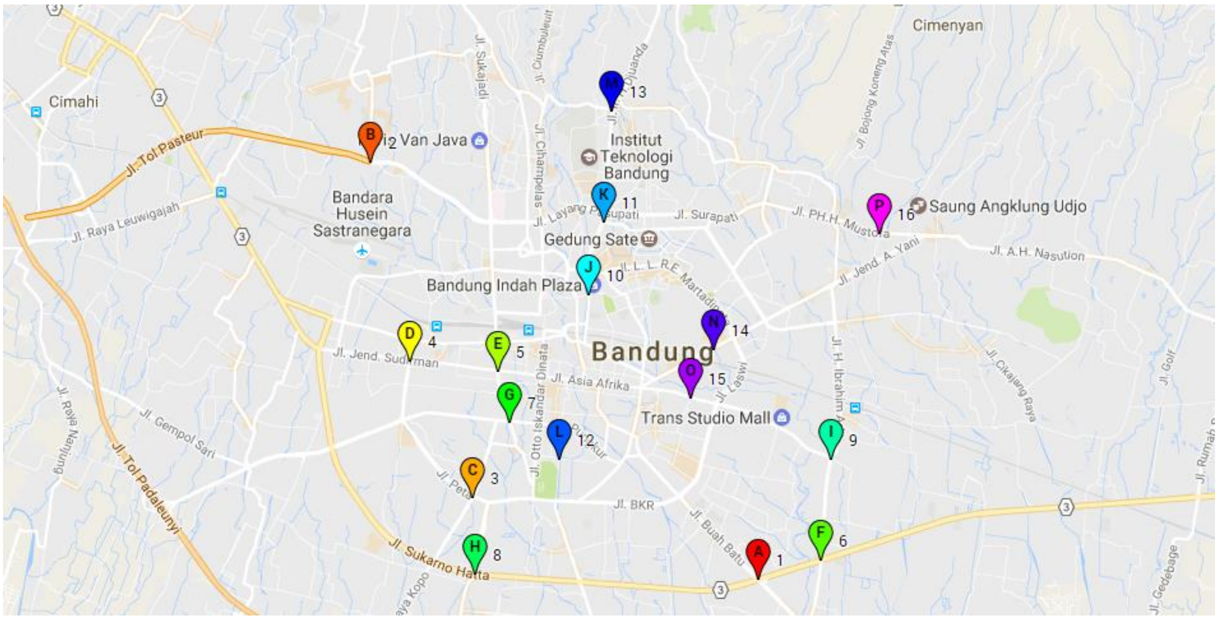


Figure 11. The priority sites at intersections

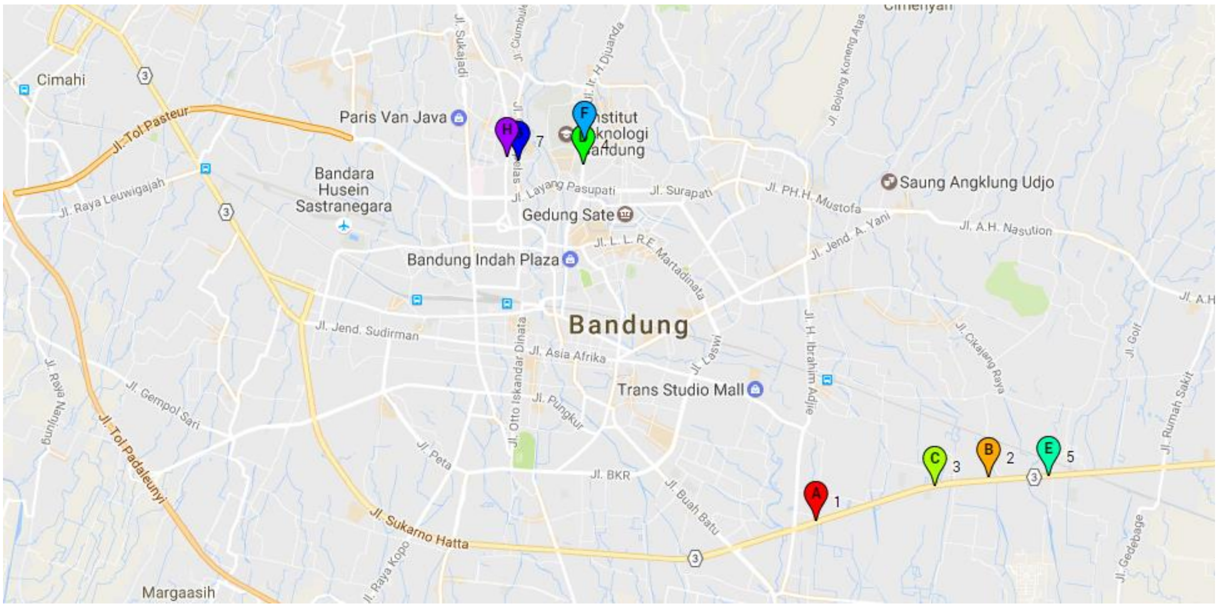


Figure 12. The priority sites at midblocks

The comparison of Ped ISI and LOS to Total Score above has a similar patterns to the value of Ped ISI or LOS, although in some sites have the higher Ped ISI and LOS but the Total Score is still low. The main influence is caused by the number of victims that varied for each categories (i.e deaths, severe injuries, minor injuries). The death victims has the higher crash weight in value than the injuries (Pd T-09-2004-B), therefore if the site which has high Ped ISI or LOS but the victims is low or the crash is not fatal, then the total score will be low. Some of the recommendations that can be implemented in Bandung based on PEDSAFE Software includes raised pedestrian crossing, pedestrian crossing island and installation speed humps.

7. CONCLUSIONS

Based on the pedestrian crashes data in Bandung since 2013 to 2015, the number of pedestrian crashes tend to be the same every year and even decrease but the number of victims is dramatically increasing. Overall, pedestrian safety assessment using the existing models, either Pedestrian Intersection Safety Index (Ped ISI) or Pedestrian Midblock Level of Service (LOS) is able to describe the condition of pedestrian safety in Bandung generally. However, it is necessary to do some modifications of the variables in accordance with the conditions of Bandung, so that the model can be applied more accurately.

An overall ranking score was calculated for each of sites survey both at intersections and midblocks; and the locations were prioritized. The overall ranking score ranges from 0 to 1, with a value of 1 being the greatest priority in the scheme. The list of the top 3 priority at intersections are Soekarno Hatta – Trs. Buah Batu, Trs. Pasteur – Surya Sumantri, and Peta – Kopo, while at midblocks are UNINUS, RS Al Islam and Telkomsel. Some of the recommendations that can be implemented in Bandung includes raised pedestrian crossing, pedestrian crossing island and installation speed humps.

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Pedestrian Safety Studies at the Crossing Locations in Bandung

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Abstract: Walking is a fundamental form of transportation. This paper examines the pedestrian safety at the crossing locations, both at intersections and midblocks; and provide recommendations for pedestrian safety improvement in Bandung. Pedestrian safety is assessed through an existing models, namely Pedestrian Intersection Safety Index (Ped ISI) for intersections and Pedestrian Midblock Level of Service (LOS) for midblocks. Determination the recommendation is conducted by ranking the pedestrian crossing locations based on the accumulation of total score which describes the relationship between the value of pedestrian safety (Ped ISI and LOS) to the pedestrian crashes data. The result shows that a comparison of Ped ISI and LOS to the total score indicates a similar trend, although in some locations the trend changes as it is influenced by the crash fatality rate which affects the score significantly. Overall, the existing pedestrian safety assessment model is able to describe the condition of pedestrian safety in Bandung generally.

Keywords: pedestrian, safety, crash, Pedestrian Intersection Safety Index (Ped ISI), Pedestrian Midblock Level of Service (LOS)

1. INTRODUCTION

Pedestrian is one of Non-Motorized Transport (NMT) in addition to bicycling. In the context of Sustainable Urban Transport, the pedestrian is a determining factor in the success of the urban transportation system. Along with the development technology that led to the presence of various motor vehicles, the role of walking activity is no longer dominant. In Bandung, the growth of motor vehicles increased quite dramatically each year. Increasing the number of vehicles trigger a variety of transportation problems due to the expansion of road (1.29% per year) is not proportional to the increase in the number of vehicles (9.34% per year) (Bandung Urban Mobility Project, 2014). The problem increases when the function of the road increasingly diverse, such as a parking lot, street vendor, service station, and others.

The poor quality and facilities of public transport are contributing to the increase in number of vehicles. The inconvenience gained from the use of public transport led to high use of private vehicles. Finally, the streets will be filled with the vehicle that is no longer comfortable space available to interact. It is then impacts to the pedestrians, with deprivation of the rights of pedestrians as a result of transfer function of the sidewalk into the parking lot or street vendor. Moreover, not a few of motorcyclists who use the sidewalk to pass. These circumstances would further worsen the traffic and may harm the safety of pedestrians.

Globally, pedestrian contributes as much as 22% of the total deaths on the road, and in some countries this proportion reached 67% (WHO, 2013). Based on the Global Status Report on Road Safety which released by WHO in 2015, pedestrian crashes in Indonesia reached 21% and was ranked as the third in the road traffic crash after riders motorized 2- or 3- wheelers by 36% as the first and drivers/passengers buses by 35% as the second. Thus, the above description shows the importance of pedestrian safety studies in Bandung to reduce the crash fatality rate and provide recommendations for pedestrian safety improvement.

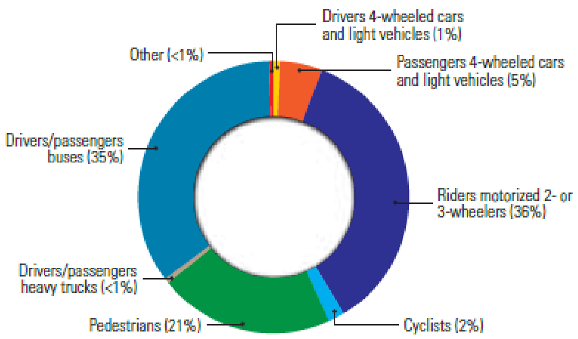
2. THE IMPORTANCE OF PEDESTRIAN SAFETY

Walking has well established health and environmental benefits such as increasing physical activity that may lead to reduced cardiovascular and obesity related diseases, and many countries have begun to implement policies to encourage walking as an important mode of transport. Unfortunately, in some situations increased walking can lead to increased risk of road traffic crashes and injury. Due to the dramatic growth in the number of motor vehicles and the frequency of their use around the world, as well as the general neglect of pedestrian needs in roadway design and land use planning, pedestrians are increasingly susceptible to road traffic injury. Pedestrian vulnerability is further heightened in settings where traffic laws are inadequately enforced.

Reduction or elimination of the risks faced by pedestrians is an important and achievable policy goal. Pedestrian collisions, like other road traffic crashes, should not be accepted as inevitable because they are in fact both predictable and preventable. There is a close association between the walking environment and pedestrian safety. Walking in an environment that lacks pedestrian infrastructure and that permits use of high speed vehicles increases the risk of pedestrian injury. The risk of a motor vehicle colliding with a pedestrian increases in proportion to the number of motor vehicles interacting with pedestrians.

3. RISK FACTORS FOR PEDESTRIAN TRAFFIC INJURY

Based on estimated global road traffic fatalities, about 273.000 pedestrians were killed in road traffic crashes in 2010. This represents around 22% of all road traffic deaths. With the exception of the Eastern Mediterranean and Western Pacific Regions, pedestrians tend to account for a much greater proportion of road traffic injury deaths in low- and middle-income countries than in high income countries. Based on the Global Status Report on Road Safety which released by WHO in 2015, pedestrian crashes in Indonesia reached 21%.



Source: WHO, 2013

Figure 1. Deaths by road user category in Indonesia

The key factors that influence the risk of pedestrian traffic injury as listed below:

1) Speed
The speed at which a car is travelling influences both crash risk and crash consequences. The effect on crash risk comes mainly via the relationship between speed and stopping distance. Research in the 1990s showed that pedestrians had a 90% chance of surviving car crashes at speeds of 30 km/h or lower, but less than a 50% chance of surviving impacts at 45 km/h.
2) Alcohol
Impairment by alcohol is an important factor influencing both the risk of a road traffic crash as well as the severity and outcome of injuries that result from it. Alcohol consumptions results in impairment, which increases the likelihood of a crash because it produces poor judgement, increases reaction time, lowers vigilance and decreases visual acuity.
3) Lack of pedestrian facilities in roadway design and land-use planning
Pedestrian risk is increased when roadway design and land-use planning fail to plan for and provide facilities such as sidewalks, or adequate consideration of pedestrian access at intersections.
4) Inadequate visibility of pedestrians
Inadequate visibility of pedestrians arises from lack of roadway lighting; vehicles and bicycles not equipped with lights; pedestrians not wearing reflective accessories or brightly coloured clothes; especially at night and at dawn or dusk; and pedestrians sharing road space with fast moving vehicles.
5) Other risk factors
Several other factors that contribute to pedestrian injury include: inadequate enforcement of traffic laws; unsafe driving practices; driver distraction, including mobile phone use; driver fatigue; pedestrian – vehicle conflict at pedestrian crossing points, etc.

Zeeger et al (2002) developed 13 crash groupings (12 specific types and 1 miscellaneous type) that are most useful for identifying safety problems and corresponding countermeasures as listed below:

1) Midblock: Dart/Dash
2) Multiple threat
3) Mailbox or other midblock
4) Failure to yield at unsignalized location
5) Bus-related
6) Turning vehicle
7) Through vehicle at signalized location
8) Walking along roadway
9) Working/playing in road
10) Non-roadway
11) Backing vehicle
12) Crossing expressway
13) Miscellaneous

Several engineering and behavioral interventions have been evaluated and found to be effective in improving pedestrian safety, such as reducing pedestrian exposure to vehicular traffic; reducing vehicle speeds; improving the visibility of pedestrians; improving pedestrian and motorist safety awareness and behavior; improving vehicle design for pedestrian protection, providing care for injured pedestrians

4. PEDESTRIAN SAFETY ASSESSMENT

4.1 Pedestrian Intersection Safety Index (Ped ISI)

Pedestrian safety issues have been approached by analyzing crash trends in police report and making improvements rooted in statistical measures. Pedestrian Intersection Safety Index (Ped ISI) was developed by Federal Highway Administration (FHWA) that would allow engineers, planners, and other practitioners to use known intersection characteristics to proactively prioritize crosswalks and intersection approaches with respect to pedestrian safety. Using variables that indicate a higher probability of risk and pedestrian, the Ped ISI can be used to identify which crosswalks and intersection approaches have the highest priority for pedestrian safety improvements within a particular jurisdiction. Once high-priority sites are identified, practitioners may conduct an in-depth evaluation at each site to determine which specific countermeasures would be appropriate to address any safety problems (Zeeger *et al*, 2002).

The Ped ISI was developed using a method in which expert survey ratings and behavioral data were used primarily to determine areas for more in depth pedestrian safety evaluations. The study involved collecting data on pedestrian crashes, conflicts, avoidance maneuvers, and subjective ratings of intersection video clips by pedestrian experts. There were a total of 68 intersection crosswalks selected for the pedestrian analysis from the cities of Philadelphia, PA; San Jose, CA; and Miami-Dade County, FL. Indicative variables included in the pedestrian safety index model included type of intersection control (signal or stop sign), number of through lanes, 85th percentile vehicle speed, main street traffic volume, and area type.

Three types of safety measures were collected for use in the development of the Ped ISI, such as crashes, behavioral data (conflicts and avoidance maneuvers), and subjective intersection ratings. Of these measures, models were developed for ratings and behavioral data. The small amount of crashes precluded any model development on crash data. Models based on ratings were developed using multiple linear regression, since the ratings generally followed a normal distribution. Models based on behavioral data were developed using a generalized linear model, since the behavioral data generally followed a Poisson distribution. The fact that these models predict a safety rating for a site on a scale of 1 to 6 conveniently leads to the development of a safety index.

Statistical models for average rating and behavioral data were developed where the pedestrian behavioral model is based on a combined group of conflicts and avoidance maneuvers. Results of these model developments are shown in tables below.

Table 1. Pedestrian rating model

Variable No	Variable Name	Estimate	T-Test	p-Value
0	Constant	2.360	9.03	<0.001
1	Stop sign on main street*	-1.821	-9.81	<0.001
2	Signal on main street*	-1.830	-11.99	<0.001
3	Number of through lanes	0.368	8.76	<0.001
4	85^{th} percentile speed	0.018	2.47	0.0162
5	Commercial area*	0.221	2.39	0.197

R^2 = 0.84; dependent variable is the average numerical site rating

*Denotes an indicator variable where a value of 1 indicates that specified condition is true

Table 2. Pedestrian behavioral model

Variable No	Variable Name	Estimate	X^2	p-Value
0	Constant	-1.69	396.78	<0.001
1	Signal on main street*	-0.689	86.75	<0.001
2	Number of through lanes	0.337	87.11	<0.001
3	Main street ADT	-0.016	12.65	0.0004
4	Median island*	-0.215	4.86	0.0274

N = 4,048 pedestrians; dependent variable is the total number of vehicle and pedestrian avoidance maneuvers and conflicts.
*Denotes an indicator variable where a value of 1 indicates that specified condition is true

All significant variables in the ratings model – signal and stop control, number of through lanes, vehicle speed, and commercial area type – were retained and included in the final Ped ISI model. The inclusion of traffic control types in the model assumes that the signal or stop sign is located according to normal traffic engineering practice (i.e., signal at multi-lane, high-volume intersections; stop sign for low-volume movements). Although the ratings model did not include the variable for traffic volume, such a variable was added to the final Ped ISI model because of its significance in the behavioral model. The traffic volume (main street ADT) is included as an interaction with signal control.

The commercial area showed up as a significant factor in the ratings model and was included in the final Ped ISI model. The surrounding area was considered commercial if the predominant land use consisted of restaurants, retail shops, gas stations, banks, etc. Although not completely intuitive by itself, this factor generally correlates with other characteristics, such as greater number of lanes, which warrant higher ratings from the evaluators. However, since the goal of the Ped ISI is to prioritize sites according to pedestrian safety, it is important for the tool to reflect factors that indicate where safety improvement efforts should be focused.

$$\text{Ped ISI} = 2.372 - 1.867\textbf{SIGNAL} - 1.807\textbf{STOP} + 0.335\textbf{THRULNS} + 0.018\textbf{SPEED} + 0.006\,(\textbf{MAINADT*SIGNAL}) + 0.238\textbf{COMM} \qquad (1)$$

where,

SIGNAL	: traffic signal-controlled crossing (0 = no, 1 = yes)
STOP	: stop sign-controlled crossing (0 = no, 1 = yes)
THRULNS	: number of through lanes on street being crossed (both directions) (1,2,3,….)
SPEED	: 85^{th} percentile speed of street being crossed (mi/h)
MAINADT	: traffic volume on street being crossed (ADT in thousands)
COMM	: predominant land use on surrounding area is commercial development (i.e. retail, restaurants, etc) (0 = not predominantly commercial area, 1 = predominantly commercial area)

4.2 Pedestrian Midblock Level of Service (LOS)

In general, pedestrian safety assessment at midblock can be approached through model of Pedestrian Midblock Level of Service (LOS) which developed by The Florida Department of Transportation (FDOT). The objective of this study was to develop a pedestrian level of service methodology for street crossing at midblock locations. It should be capable of providing a measure of effectiveness that indicates pedestrians' perceived quality of service in crossing roads at midblock locations. This measure of effectiveness could then be converted to a level of service designation. The study will attempt to determine what variables are correlated with pedestrians' perceived quality of service for midblock crossing. This will be done through a statistical calibration and validation process involving collecting actual site characteristics and stated levels of quality of service by a sample of persons at a sample of sites (Baltes & X., 2002).

The statistical analysis of the data set started with a basic model which has several features: 1) it uses all characteristics that were hypothesized to be important in the research-design process; 2) it uses directional measures for four characteristics; 3) all variables are in linear form; and 4) the full data set was used for estimation.

The R-square reflects how well the model fits the data and measures the proportion of variation in the reported level of difficulty across the sample that is explained by the explanatory variables in the model. One property of the R-square is that it increases with the number of explanatory variables. It is customary to report the adjusted R-square that accounts for the number of explanatory variables. The adjusted R-square of this model is 0.34. For ecample, Landis et al. (2001) report an unadjusted R-square value of 0.85. With adjustment, the R-square value would be still more than double what is being reported from this analysis.

Table 3. Basic model with full sample

Variables	Coefficients	Standardized Coefficients	t-statistics
Constant	-2.4778		-3.2120
(+) 65 Years or Older Dummy (0-1)	0.4937	0.0933	3.1133
(+) NS Total Volume (1000 veh/hr)	-0.1159	-0.2682	-4.1854
(+) FS Total Volume (1000 veh/hr)	0.2674	0.3957	6.8259
(+) NS Turning Movements (veh/hr)	0.0018	0.2033	3.5434
(+) FS Turning Movements (veh/hr)	0.0013	0.1244	2.5595
(+) Average Speed (miles/hr)	0.0107	0.0344	0.7618
(+) NS Crossing Width (feet)	-0.0852	-0.3846	-4.3901
(+) FS Crossing Width (feet)	0.1241	0.7015	6.1663
(-) Width of Restricted Median (feet)	-0.0661	-0.5300	-5.5726
(-) Width of Painted Median (feet)	0.0712	0.2531	7.2010
(-) Crosswalk Dummy (0-1)	-0.2762	-0.0844	-1.5645
(±) Pedestrian – Signal Dummy (0-1)	-0.4930	-0.1265	-3.1598
(±) NS Cycle Length (seconds)	-0.0326	-0.9823	-3.3957
(±) FS Cycle Length (seconds)	0.0610	1.7144	5.4797
(±) Signal Spacing (feet)	0.007	0.6464	7.6269
Adjusted R Square		0.34	
Std. Error of the Regression		1.328	
Sample		767	

Notes: "(+)" indicates that an increase in the explanatory variable would increase the level of difficulty. "(-)" indicates that an increase in the explanatory variable would decrease the level of difficulty. "(±)" indicates that the direction of the net effect of the explanatory variable is analytically unknown and needs to be empirically determined. The abbreviations "NS" and "FS" represent nearside and far side, respectively. The dummy variables take one when the characteristic as described in the name of the variable is present and zero otherwise. The standardized coefficients represents the change in the level of difficulty from a change of one standard deviation in an explanatory variable. The t-statistics assumes that the repeated observations from the same participant were statistically independent.

Based on a comprehensive statistical analysis of the data as collected from Hillsborough and Pinellas Counties, the following model of perceived pedestrian midblock crossing was developed:

$$\begin{aligned} LOS = & -2.4478 + 0.4937\mathbf{PED} + 0.0758\mathbf{ADT} + 0.0016\mathbf{TURNMOVE} + 0.0107\mathbf{SPEED} \\ & + 0.0195\mathbf{CROSSWIDTH} - 0.0661\mathbf{RESTRMED} + 0.0712\mathbf{PAINTMED} \\ & - 0.2762\mathbf{CROSSWALK} - 0.4930\mathbf{PEDSIGNAL} + 0.0284\mathbf{AVGCYCLE} \\ & + 0.0007\mathbf{SIGNALSPACE} \end{aligned} \qquad (2)$$

where,

PED	: share of pedestrians age 65 or older (percentage)
ADT	: total traffic volume (1,000 vehicles per hour)
TURNMOVE	: turning movements (vehicles per hour)
SPEED	: traffic speed (mph)
CROSSWIDTH	: crossing distance (feet)
RESTRMED	: restrictive medians (feet)
PAINTMED	: non-restrictive medians (feet)
CROSSWALK	: crosswalks (0 = no, 1 = yes)
PEDSIGNAL	: pedestrian signals (0 = no, 1 = yes)
AVGCYCLE	: signal cycle (seconds)
SIGNALSPACE	: signal spacing (feet)

The variables listed in the above equation, which measure the pedestrians' sensitivities to the varying elements of mid-block crossing, combine to determine mid-block pedestrian level of service. By applying actual values to each, a numerical result is obtained that will correspond to one of the designations listed in the LOS breakdown chart. The designations rate level of service (i.e., A is best, F is worst) is shown below.

Table 4. LOS Breakdown

LOS	If Value
A	<= 1.5
B	> 1.5 and < 2.5
C	> 2.5 and <= 3.5
D	> 3.5 and <= 4.5
E	> 4.5 and <= 5.5
F	> 5.5

Source: Baltes & X., 2002

One approach is based on a set of pre-selected breakpoints within the range of possible quality of service values among a sample of sites. These breakpoints are used to define the various level-of-service designations. Landis et al. (1999) use this approach in determining pedestrian level of service for walking along roadway segments. In fact, 1.5, 2.5, 3.5, 4.5, and 5.5 are suggested as the breakpoints on a rating range from 1 through 6.

5. RESEARCH METHODOLOGY

The purpose of this study is to investigate pedestrian safety qualitatively and quantitatively at the crossing locations, both at intersections and midblocks; and provide recommendations for pedestrian safety improvement in Bandung in Bandung City. This chapter describes the methods used in this study, which includes a determination of sites survey, an explanation of the data collection procedures and the method used to prioritize sites for improvement as determination the recommendation.

5.1 Sites Survey

The sites survey is distinguished between intersections and midblocks. At intersections, the point of review only applies to the signalized intersection with a coverage area includes the entire city of Bandung. There are 78 intersections consist of 3-arm and 4-arm signalized intersections. At midblocks, the sample point of review is limited to the function of Primary Arterial and Secondary Collector. The total number of sites survey for each of these functions are 4 sites.

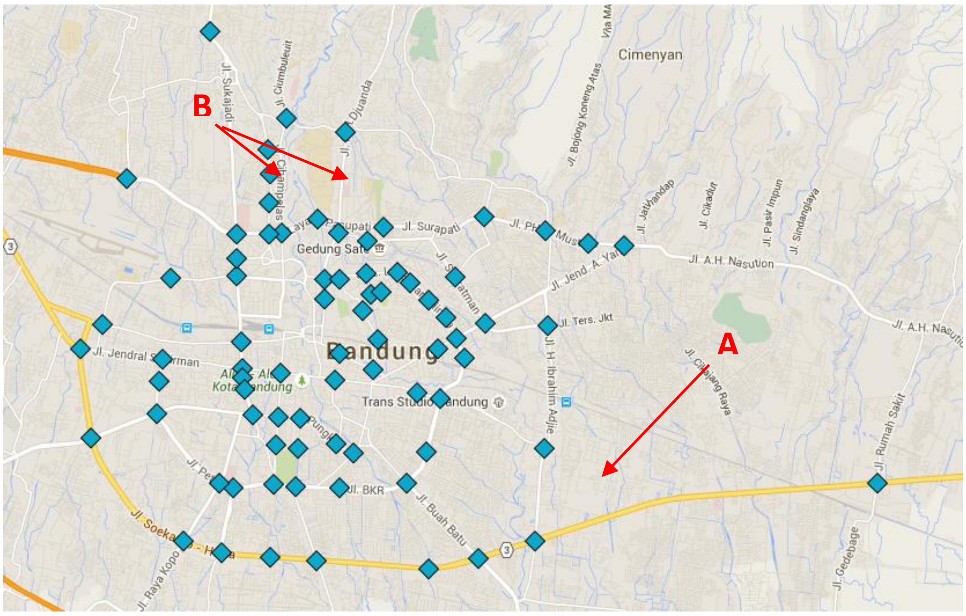


Figure 2. Sites survey at intersections

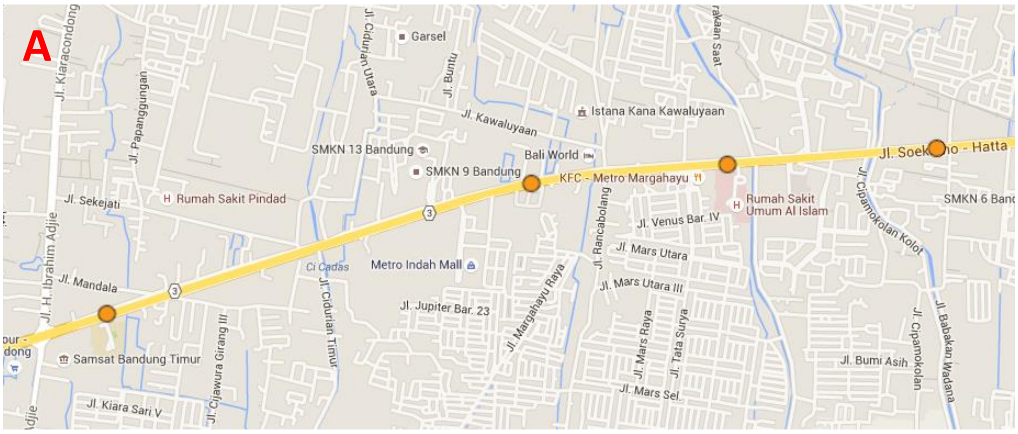


Figure 3. Sites survey of Primary Arterial at midblocks

Figure 4. Sites survey of Secondary Collector at midblocks

5.2 Data Collection

Data needs for this study consists of primary and secondary data. The secondary data is pedestrian crashes data which obtained from Bandung Traffic Police, while traffic volume at intersection is obtained through software of EMME/4 using matrix trips data in 2013 (Hafiandi, 2014). Moreover, the primary data is obtained by surveying the sites at midblocks directly, such as traffic volume by traffic counting, vehicle speed by spot speed and pedestrian-vehicle conflict. Some other supporting data such as the presence of crossing facilities, crossing distance and others as needed is obtained through observation at the sites.

The pedestrian-vehicles conflict data was only observed at midblocks and summarized for each crossing location and total number of pedestrians and vehicles for each movement were calculated. Pedestrian behaviors were totaled per location to provide three interaction totals: no interaction, normal interaction, and abnormal interaction. In each conflict data summary, the total number of abnormal interactions was calculated (called $N_{conflict}$). A conflict percentage was also calculated, which represents the percent of potentially dangerous pedestrian-vehicle interactions per total interactions at given location (Dobbs, 2009).

$$\text{Conflict \%} = \frac{\text{Abnormal Interactions}}{\text{Normal Interactions} + \text{Abnormal Interactions}} \quad (3)$$

5.3 Determination the Recommendation

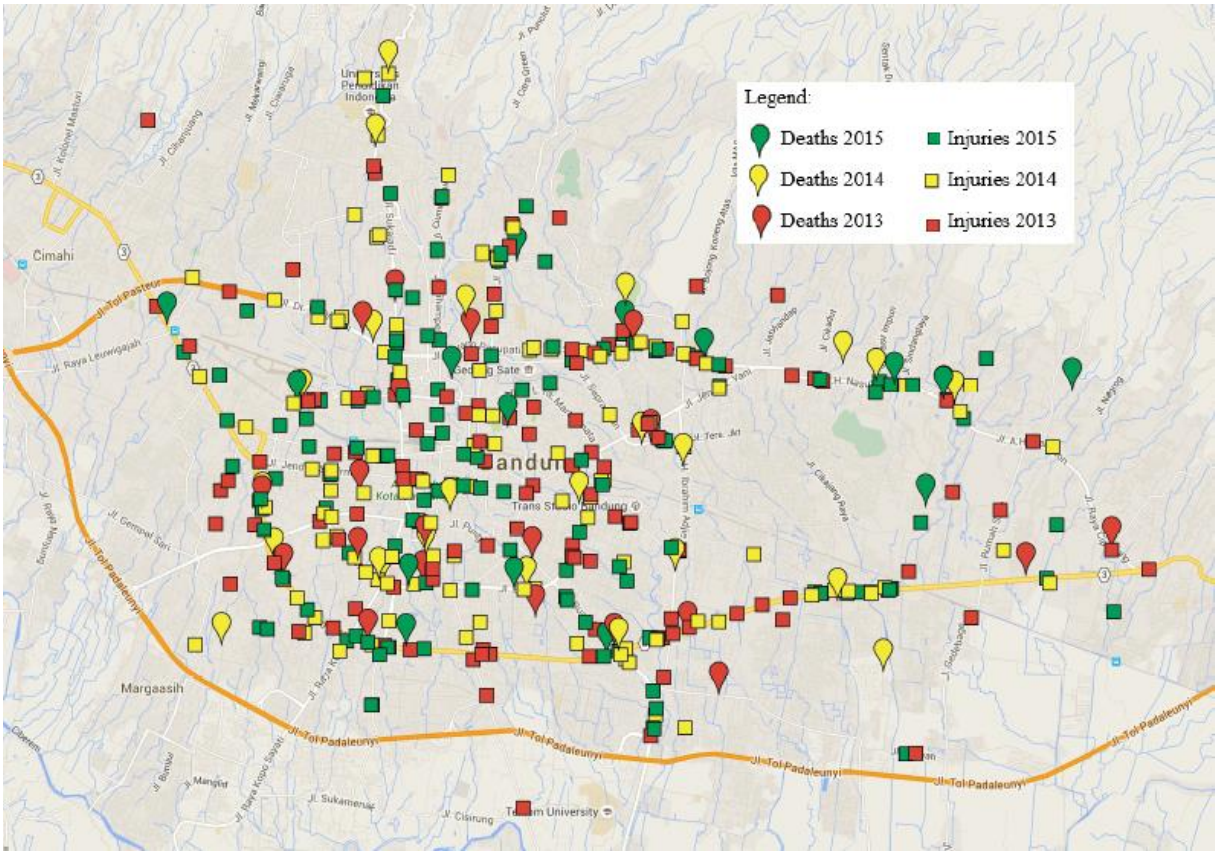
Determination the recommendation begins by ranking the sites who have the highest priority to improve the pedestrian safety. The ranking process are sorted based on the accumulated total score from the highest to the lowest of several assessment criteria. Total score calculation can describe the relationship between the value of pedestrian safety (Ped ISI and LOS) to the pedestrian crashes data, therefore the prioritization of the site can be done comprehensively. In addition, the parameters of conflict percentage and P/V Ratio that is only found at midblocks can be used as an additional aspect to see the magnitude of the crash risk to pedestrian safety.

After the determination of sites that have priority to improvements completed, the next step is provide recommendations for improving pedestrian safety. The appropriate method for determining this is using the software of PEDSAFE. PEDSAFE is a software prepared by The Federal Highway Administration in 2013, created by David L. Harkey and Charles V. Zegeer. This system provides users with information on how to improve pedestrian safety and mobility. PEDSAFE also contains information on understanding pedestrian crashes, implementing countermeasures, and creating a pedestrian environment.

6. DATA PRESENTATION AND ANALYSES

6.1 Data Presentation

Pedestrian crashes data is a secondary data which obtained from Bandung Traffic Police for 3 latest years, 2013 to 2015. Those data was collected in an integrated system data collecting, named Integrated Road Safety Management System (IRSMS).



Source: IRSMS, 2013 - 2015

Figure 5. Pedestrian Crashes Data 2013 – 2015 in Bandung

Traffic volume data are used for both location, intersections and midblocks. Traffic volume at intersections are obtained based on the secondary data (Hafiandi, 2014) which modeled through software EMME/4 using matrix trips data in 2013. Moreover, the traffic volume data at midblocks are obtained by traffic counting.

6.2 Data Analyses

6.2.1 Pedestrian Safety at Intersections

Pedestrian safety at intersections will be assessed using the Pedestrian Intersection Safety Index (Ped ISI) model. The calculation of Ped ISI for each crossing location aided in the prioritization of the crossing locations for improvement. Only 78 sites had available data to enable calculation of indices, and the analyses will be divided into 14 type of intersections based on the following road function as listed in Table 2 and Figure 6.

Table 5. Number of signalized intersections

No	Road Functions	Number of Intersections
1	Primary Arterial – Primary Arterial	3
2	Primary Arterial – Primary Collector	9
3	Primary Arterial – Secondary Arterial	6
4	Primary Arterial – Secondary Collector	5
5	Primary Arterial – Local	4
6	Primary Collector - Primary Collector	9
7	Primary Collector – Secondary Arterial	8
8	Primary Collector – Secondary Collector	2
9	Primary Collector – Local	1
10	Secondary Arterial – Secondary Arterial	5
11	Secondary Arterial – Secondary Collector	3
12	Secondary Arterial – Local	1
13	Secondary Collector - Secondary Collector	16
14	Secondary Collector – Local	6
	Total of Intersections	78

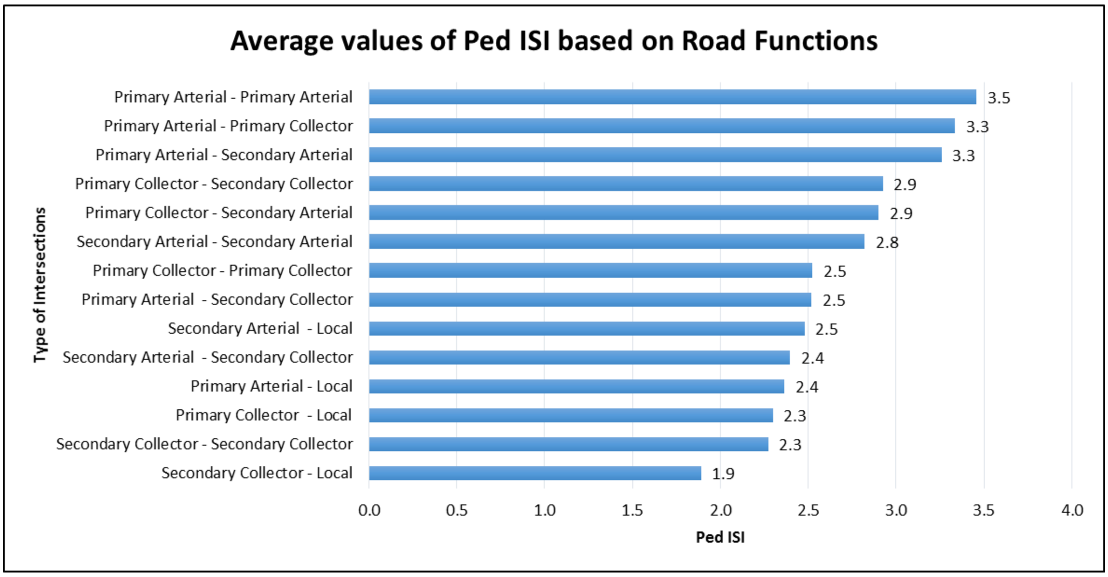


Figure 6. Average values of Ped ISI based on road function

Based on the analysis above, the average value of Ped ISI by road function was ranged from 1.9 – 3.5 with standard deviation of 0.5. However, the average value of Ped ISI in Bandung is 2.7. Maximum value of Ped ISI is at intersection of Primary Arterial – Primary Arterial, while the minimum value of Ped ISI is at intersection of Secondary Collector – Local. Therefore, it can be concluded that the higher level of road function which intersected at the other intersection will increase the value of Ped ISI and vice versa.

The mapping of Ped ISI values in Bandung can be seen in Figure 8 as follows.

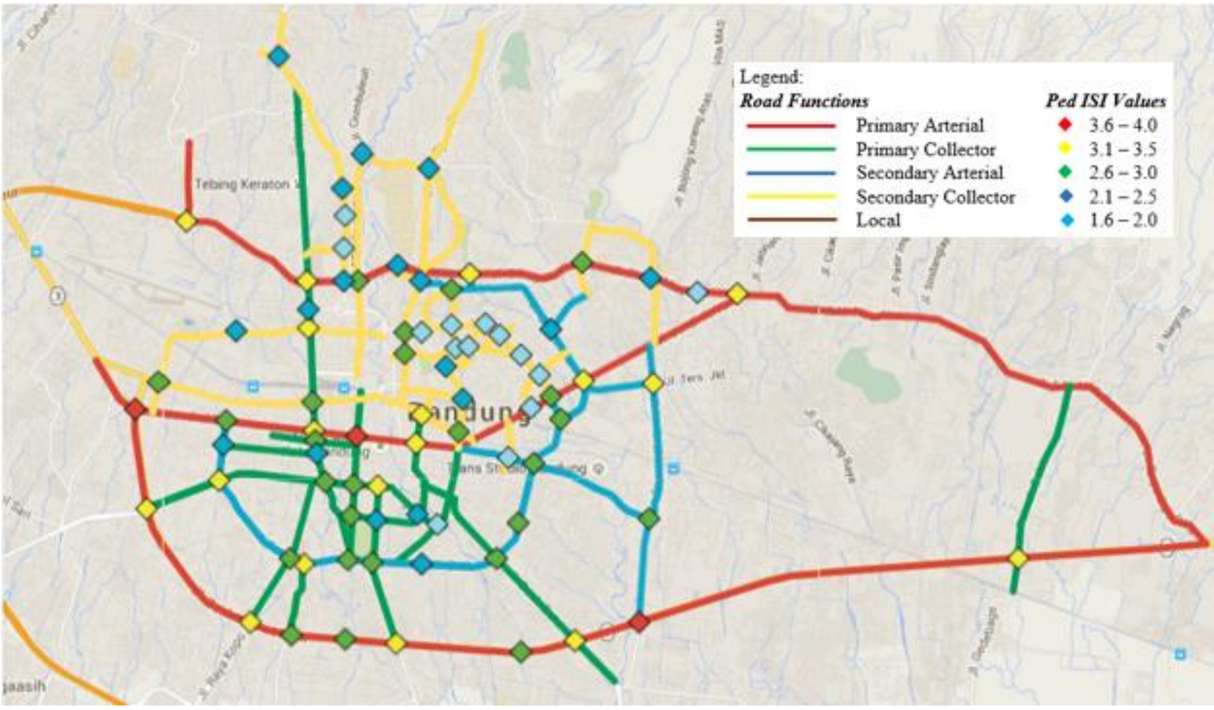


Figure 7. Mapping of Ped ISI values in Bandung

6.2.2 Pedestrian Safety at Midblocks

Analyses of pedestrian safety at midblocks includes analysis of pedestrians-vehicles conflict, vehicular volume and speed, and application the model of Pedestrian Midblock Level of Service (LOS). Only 8 sites was chosen to this research, the analyses will be divided based on the road functions, in this case only for Primary Arterial and Secondary Collector. The characteristics of each location will be differentiated by the presence of pedestrian facilities, side friction and land use.

In terms of knowing the presence of vehicle in pedestrian area and to illustrate the magnitude of interactions between pedestrians and vehicles, the traffic volume is compared to pedestrian volume per hour, which will produce P/V Ratio. Here is the summary of pedestrians and vehicles ratio (P/V Ratio).

Table 6. Pedestrians and vehicles ratio (P/V Ratio)

No	Code	Locations	Veh. Vol (pcu/hr)	Ped. Vol (person/hr)	P/V Ratio
Primary Arterial 2-way					
1	SHT-01-F	In front of UNINUS	3023	76	0.025
2	SHT-02-F	Opposite of UNINUS	2833	76	0.027
3	SHT-03-NF	In front of TELKOMSEL	3345	24	0.007
4	SHT-04-NF	Opposite of TELKOMSEL	3633	24	0.007
5	SHT-05-F	In front of RS AL-ISLAM	3580	90	0.025
6	SHT-06-F	Opposite of RS AL-ISLAM	3427	90	0.026
7	SHT-07-NF	In front of SUZUKI	2218	78	0.035
8	SHT-08-NF	Opposite of SUZUKI	2296	78	0.034

No	Code	Locations	Veh. Vol (pcu/hr)*	Ped. Vol (person/hr)	P/V Ratio
Secondary Collector 1-way					
9	CIH-01-NF	Cihampelas Walk	1463	770	0.526
10	CIP-10-NF	Cipaganti Mosque	2208	215	0.097
Secondary Collector 2-way					
11	DGO-11-NF	FO Dago (Blossom)	1427	108	0.076
12	DGO-12-NF	FO Dago (Cheap Outlet)	1384	108	0.078
13	DGO-13-F	In front of SMAN 1	1611	123	0.076
14	DGO-14-F	Opposite of SMAN 1	1881	123	0.065

*pcu = passenger car unit

Vehicle speed which has been obtained from the survey results then classified into 3 (three) vehicles speed range, such as below 30 km/hr, 30-65 km/hr, and above 65 km/hr. The vehicle speed range is useful to predict the possibility of crash that will happen to pedestrian. The first range, 30-65 km/hr indicates the possibility of an injury crash if the vehicle collided with a pedestrian. The second range, 65 km/hr and above indicates the possibility of a fatal pedestrian crash if a hit by a vehicle in this range. Particular research has shown that pedestrians who are struck by vehicles moving slower than 20 mph (32.2 km/hr) do not typically suffer injury, where as pedestrians struck at speeds greater than 20 mph are likely to sustain severe injury if not death. Vehicles travelling at speeds 40 mph (64.4 km/hr) or greater will cause a pedestrian fatality 85 percent of the time a collision occurs (AASHT0, 2004).

Table 7. Pedestrians and vehicles ratio (P/V Ratio)

No	Code	Locations	$V_{planned}$ (km/hr)	$V_{85percentile}$ (km/hr)	Potential of Injury
Primary Arterial 2-way					
1	SHT-01-F	In front of UNINUS	60	32.82	Serious
2	SHT-02-F	Opposite of UNINUS	60	50.00	Serious
3	SHT-03-NF	In front of TELKOMSEL	60	42.51	Serious
4	SHT-04-NF	Opposite of TELKOMSEL	60	45.95	Serious
5	SHT-05-F	In front of RS AL-ISLAM	60	23.14	Minor
6	SHT-06-F	Opposite of RS AL-ISLAM	60	56.25	Serious
7	SHT-07-NF	In front of SUZUKI	60	40.00	Serious
8	SHT-08-NF	Opposite of SUZUKI	60	37.50	Serious
Secondary Collector 1-way					
9	CIH-01-NF	Cihampelas Walk	20	24.76	Minor
10	CIP-10-NF	Cipaganti Mosque	20	33.23	Serious
Secondary Collector 2-way					
11	DGO-11-NF	FO Dago (Blossom)	20	35.07	Serious
12	DGO-12-NF	FO Dago (Cheap Outlet)	20	32.63	Serious
13	DGO-13-F	In front of SMAN 1	20	52.29	Serious
14	DGO-14-F	Opposite of SMAN 1	20	32.86	Serious

The calculation results for Pedestrian Midblock Level of Service (LOS) is shown as follows.

Table 8. Pedestrians and vehicles ratio (P/V Ratio)

No	Code	Locations	Score	LOS
Primary Arterial 2-way				
1	SHT-01-F	In front of UNINUS	2.88	C
2	SHT-02-F	Opposite of UNINUS	2.99	C
3	SHT-03-NF	In front of TELKOMSEL	8.13	F
4	SHT-04-NF	Opposite of TELKOMSEL	7.71	F
5	SHT-05-F	In front of RS AL-ISLAM	7.72	F
6	SHT-06-F	Opposite of RS AL-ISLAM	7.61	F
7	SHT-07-NF	In front of SUZUKI	5.60	F
8	SHT-08-NF	Opposite of SUZUKI	5.60	F
Secondary Collector 1-way				
9	CIH-01-NF	Cihampelas Walk	2.07	B
10	CIP-10-NF	Cipaganti Mosque	0.95	A
Secondary Collector 2-way				
11	DGO-11-NF	FO Dago (Blossom)	4.51	E
12	DGO-12-NF	FO Dago (Cheap Outlet)	4.46	D
13	DGO-13-F	In front of SMAN 1	3.52	D
14	DGO-14-F	Opposite of SMAN 1	3.30	C

Overall, the calculation results for LOS at midblocks is shown in the following figure.

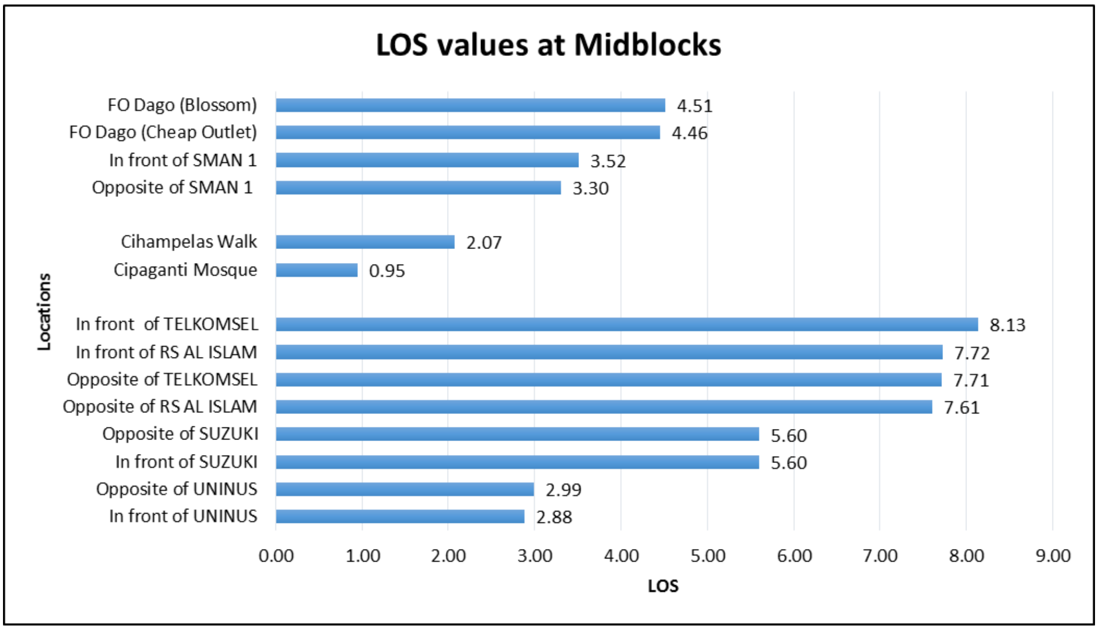


Figure 8. LOS values at midblocks

6.2.3 Recommendations for Improving Pedestrian Safety

Determination the recommendations in order to improve pedestrian safety is based on ranking the sites to the value of pedestrian safety of the calculation results using the existing models, such as Pedestrian Intersection Safety Index (Ped ISI) and Pedestrian Midblock Level of Service (LOS) and also the other influential factors like history of pedestrian crashes, pedestrians-vehicles conflict percentage and P/V Ratio. The calculation results of the Total Score is based on number of crashes in each location, number of victims and the value of pedestrian safety using the existing models (Ped ISI and LOS) for all locations that have the history of pedestrian crashes. The ranking will be based on the accumulation total score which is calculated using the standardized assessment with a range from 0 to 1, where value of “1” corresponding to the worst site. The alternative recommendation will be provided to location that has a history of pedestrian crashes using PEDSAFE Software. The comparison between Ped ISI and LOS to the Total Score based on pedestrian crashes is shown below.

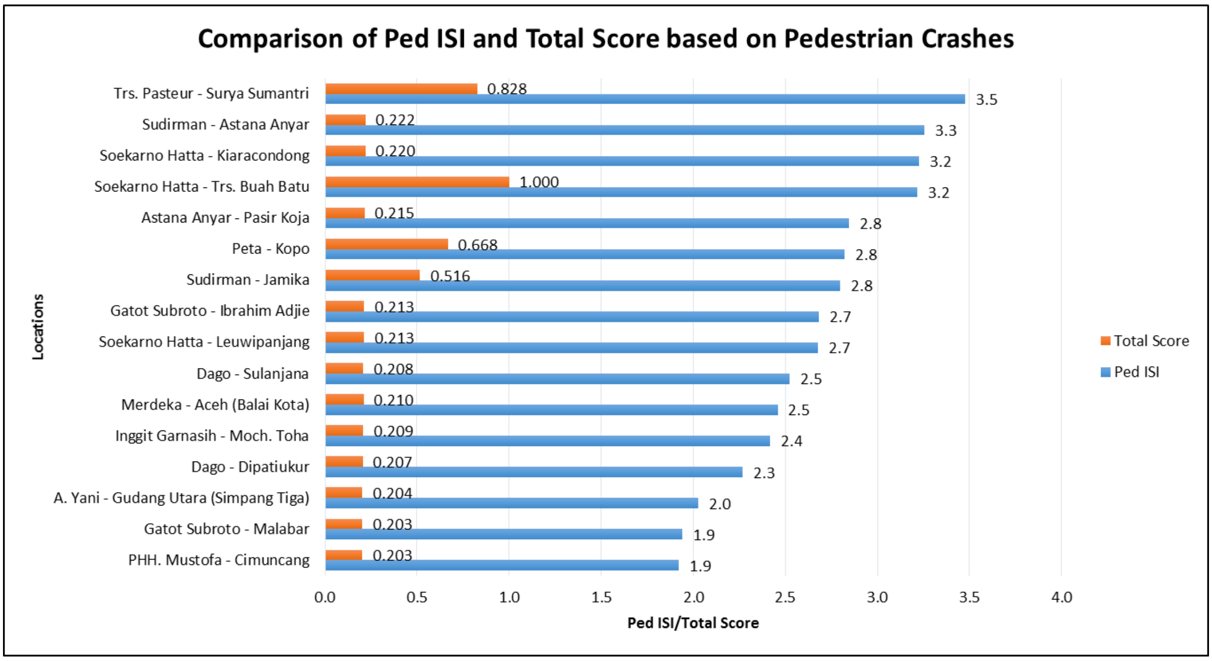


Figure 9. Comparison of Ped ISI and Total Score

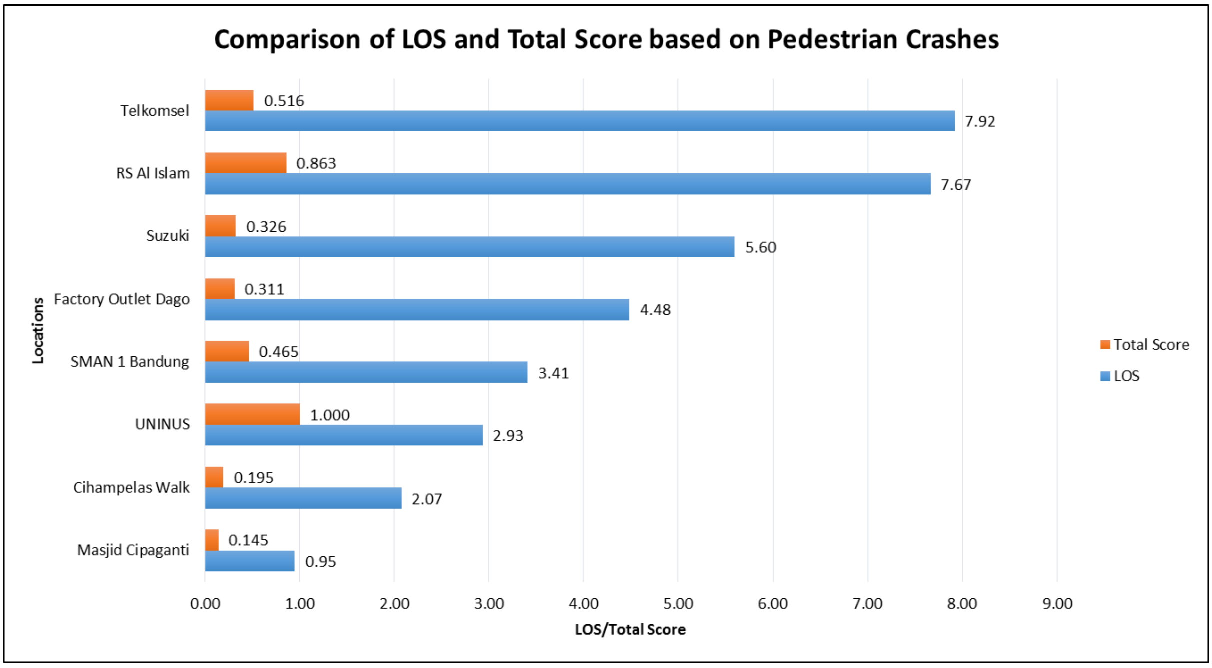


Figure 10. Comparison of LOS and Total Score

Visually, the sites which include in the analyses above is shown in the following figure, the most priority sites is described alphabetically.

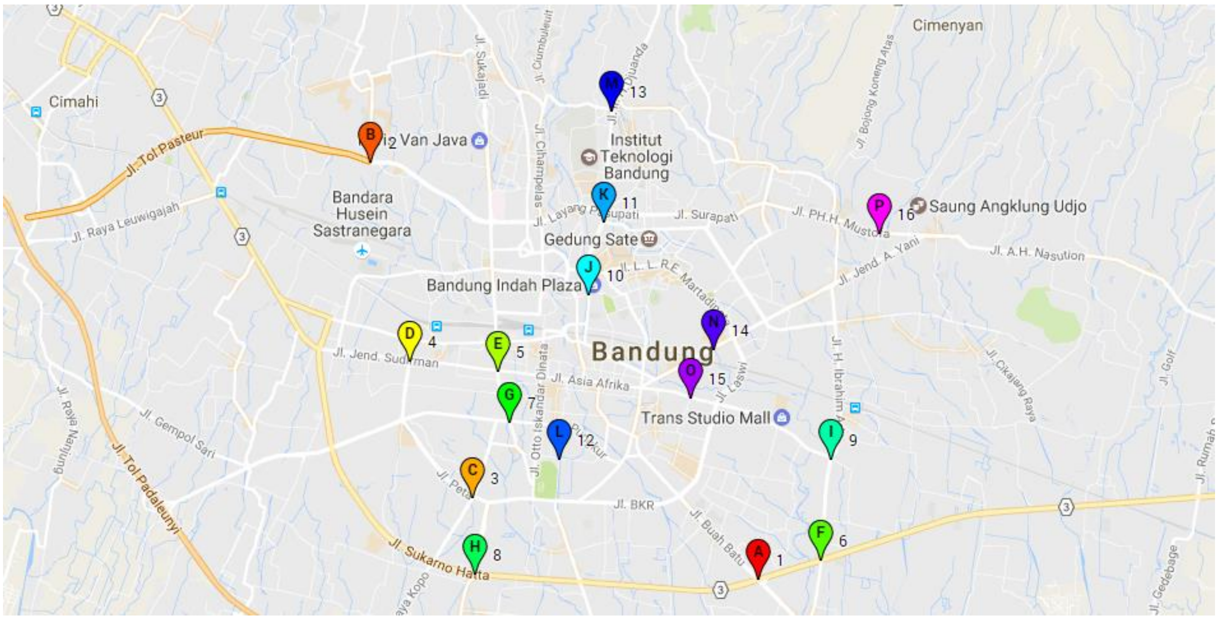


Figure 11. The priority sites at intersections

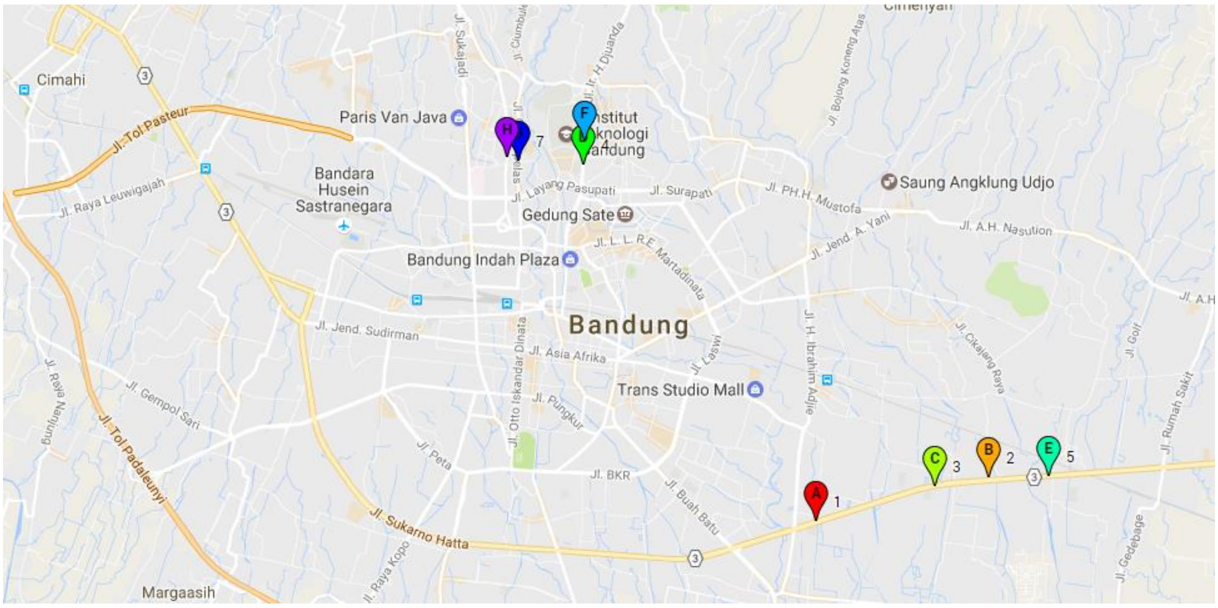


Figure 12. The priority sites at midblocks

The comparison of Ped ISI and LOS to Total Score above has a similar patterns to the value of Ped ISI or LOS, although in some sites have the higher Ped ISI and LOS but the Total Score is still low. The main influence is caused by the number of victims that varied for each categories (i.e deaths, severe injuries, minor injuries). The death victims has the higher crash weight in value than the injuries (Pd T-09-2004-B), therefore if the site which has high Ped ISI or LOS but the victims is low or the crash is not fatal, then the total score will be low. Some of the recommendations that can be implemented in Bandung based on PEDSAFE Software includes raised pedestrian crossing, pedestrian crossing island and installation speed humps.

7. CONCLUSIONS

Based on the pedestrian crashes data in Bandung since 2013 to 2015, the number of pedestrian crashes tend to be the same every year and even decrease but the number of victims is dramatically increasing. Overall, pedestrian safety assessment using the existing models, either Pedestrian Intersection Safety Index (Ped ISI) or Pedestrian Midblock Level of Service (LOS) is able to describe the condition of pedestrian safety in Bandung generally. However, it is necessary to do some modifications of the variables in accordance with the conditions of Bandung, so that the model can be applied more accurately.

An overall ranking score was calculated for each of sites survey both at intersections and midblocks; and the locations were prioritized. The overall ranking score ranges from 0 to 1, with a value of 1 being the greatest priority in the scheme. The list of the top 3 priority at intersections are Soekarno Hatta – Trs. Buah Batu, Trs. Pasteur – Surya Sumantri, and Peta – Kopo, while at midblocks are UNINUS, RS Al Islam and Telkomsel. Some of the recommendations that can be implemented in Bandung includes raised pedestrian crossing, pedestrian crossing island and installation speed humps.

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