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Pedestrian Facilities as a Part of Road Infrastructure Resilience in Large Cities in Indonesia

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***Abstract*— Road infrastructure resilience is critical to reach disaster resilience. Disaster not only occurs and impacts the location outside cities, but also in an area with a large number of the population, like cities. In large cities, pedestrian facilities are the important road infrastructure facilities besides roadway infrastructure, both in the normal daily condition and during evacuation if there is a disaster. Unfortunately, pedestrian facilities in the city are not yet seriously taken into account. The aim of this paper is, first, identification of the availability of pedestrian facilities, second, fulfillment of the facilities based on the regulation in Indonesia, and third, recommendation to implement items of pedestrian facilities based on pedestrians' opinion. Case study is carried out on two major roads in a large city, Bandung, Indonesia, with a high number of pedestrians because there are various activities happening along the streets, for example, working, studying, shopping, and sightseeing. The method used is an interview, questionnaire, and essential performance analysis, with 18 pedestrian facility indicators — seven hundred and eighty-two pedestrians as respondents involved in this paper. The analysis is done based on respondent demographics and based on significant rate and priority rate of respondents' opinion. Results indicated that not all of the pedestrian facilities had been implemented according to regulation in Indonesia. Furthermore. based on respondents' opinion, the most important and priority items of pedestrian facilities to be applied as soon as possible are street lighting, pedestrian ramps for disabled persons, CCTV, and trash bins. Fulfillment of all pedestrian facilities will enhance road infrastructure resilience through reduction of casualty if no disaster occurs and through reduction of risk during evacuation if disaster occurs.**

***Keywords*— pedestrian facilities; road infrastructure resilience; large cities; Indonesia.**

I. Introduction

Infrastructure resilience is the ability to resist and reduce the impact and the risk of disaster by a system, including losses of home, working area, and infrastructure, so that society can recover as soon as possible economically, effectively, systematically, and continuously [1]–[4]. Road as an important part of the infrastructure, consisting of roadway and pedestrian way. Unfortunately, pedestrian facilities have had less attention to be implemented. Whereas, if there is disaster happened, not only the roadway is used as a facility for evacuation and rescue, but pedestrian ways as well. Therefore, pedestrian way with standard facility indicators is also important to be considered. The aim of this paper is, first, identification of the availability of pedestrian facilities, second, fulfillment of the facilities based on the regulation in Indonesia, and third, recommendation to implement indicators of pedestrian facilities based on pedestrians' opinion to support road infrastructure resilience. Fulfillment of all pedestrian facilities will reduce casualty risk in normal conditions and will reduce disaster risk during evacuation and reconstruction if a disaster occurs. Case study is carried out on two major roads with a high number of pedestrians in a large city, Bandung, Indonesia. There is a high number of pedestrian on the selected roads because of many social activities taking place along the road, i.e. working, studying, shopping, and sightseeing.

II. Material and Method

A. Pedestrian Facilities

Walking activity is healthy, easy, and not expensive. Unfortunately, in large cities in developing countries, for example, Indonesia, pedestrian facilities are not always available and, furthermore, pedestrians are not the highest priority among road users. Therefore, pedestrians have to walk on the roadway, a condition that is hazardous for them. On the other hand, there is a regulation about pedestrian in

Indonesia that has to be obeyed. Regulation number 22 year 2009 regarding traffic and road transport, article number 131 says that pedestrians have a right of availability of standard sidewalk, crossway, and road furniture, and the highest priority should be provided to the pedestrian [5]. This regulation requires safe, convenient, secure, and comfortable urban pedestrian facilities as a part of the transportation system during normal condition and for evacuation, rescue, and reconstruction process if a disaster happens.

Pedestrian facilities in the urban area are very important for pedestrians to access their destination, especially one that cannot be reached by other mode of transportation. The location of the destination could be an office, school, mall, hospital, or public transportation stops. The effectiveness of public transportation depends on the willingness of people to walk to the public transportation stops. Public transportation stops that can be reached in walking distance will be a sustainable public transportation mode [6], [7].

Indonesian Ministry of Public Works, regulation number 03/RPT/PM/2014 about guideline of planning, design, and using urban pedestrian infrastructure network says that pedestrian trip patterns consist of pedestrian who only walk to the location of their destination, pedestrians who walk to and from the public transportation stops, and pedestrians who walk to and from the parking facilities, after using their vehicle [8]. This condition indicates that walking is an important part of the transportation system. In more detail, there is a standard regarding effective sidewalk width, as presented in Table I.

TABLE I
EFFECTIVE SIDEWALK WIDTH ACCORDING TO THE LAND USE [8]

Land use	**Effective sidewalk width (m)**	
	Minimum width (m)	**Recommended width (m)**
Residential	1.6	2.75
Office	2.0	3.0
Industry	2.0	3.0
School	2.0	3.0
Terminal/ public transportation stop	2.0	3.0
Shopping area	2.0	4.0
Bridge/ tunnel	1.0	1.0

B. Methodology

The research methodology consists of a systematic process to reach the aim of the paper and provide a recommendation to implement indicators of pedestrian facilities based on pedestrians' opinion to support road infrastructure resilience. Furthermore, the implementation of all pedestrian facilities will increase pedestrian safety during normal condition and increase road infrastructure resilience during evacuation and reconstruction if a disaster occurs.

Preliminary study is carried out to determine the major roads that have a high number of pedestrians walking along the road. Diponegoro Street and Suria Sumantri Street in Bandung, Indonesia, are chosen as the locations of the case studies because of the land use. There are offices, campus, malls, department stores, restaurants, and a museum, so there are many social activities, i.e. working, studying, shopping, and sightseeing happening along the road.

A preliminary study indicated that there are 14,680 pedestrians per week walking on the two major roads. Using Slovin formula and α=5% [9], [10], 758 pedestrians as a minimum number of respondents are needed in this paper. Furthermore, 782 pedestrians as respondents who completed the questionnaire are involved in this paper, as presented in Table II, while the research methodology is presented in Figure 1.

TABLE III
NUMBER OF PEDESTRIANS AS RESPONDENTS, NEEDED ON THE TWO MAJOR ROADS IN BANDUNG, INDONESIA

Name of the street	**Number of pedestrians per week during the preliminary study**	**The minimum number of pedestrians needed with α=5% [9], [10]**	**Number of pedestrians involved in the paper**
Diponegoro Street	6,210 persons	$n = \frac{N}{1 + N(\alpha)^2}$ $n = \frac{6{,}210}{1 + 6{,}210(5\%)^2}$ n = 376 persons	377 persons
Suria Sumantri Street	8,470 people	$n = \frac{N}{1 + N(\alpha)^2}$ $n = \frac{8{,}470}{1 + 8{,}470(5\%)^2}$ n = 382 persons	405 persons
Total number of pedestrians involved in this paper			**782** persons

C. Data Collection

Primary data were collected in November 2017. First primary data is existing condition of pedestrian facilities on the two major roads, i.e. Diponegoro Street. 800m long, and Suria Sumantri Street, 820m long, as the location of case studies in a large city, Bandung, Indonesia. Location of the streets is presented in Figure 2. Furthermore, the existing condition of pedestrian facilities on the two major roads in Bandung, Indonesia, according to the regulation in Indonesia, is presented in Table III and Figure 3. Second primary data are the characteristics of all 782 pedestrians as respondents. The respondent's characteristics are presented in Table IV. Third primary data are the pedestrians' answers as respondents to 18 indicators according to the existing condition of pedestrian facilities. Indonesian Ministry of Public Works regulation number 03/RPT/PM/2014 [7] is used as guideline regarding 18 pedestrian indicators that have to be available and implemented.

III. RESULTS AND DISCUSSION

A. Data Analysis

The Likert scale [9], [10] is used in this study. For the Importance Rate, the Likert scale is very important, important, fair, not important, and very not important. For the Priority Rate, Likert scale is very priority, priority, fair, not priority, and very not priority. Quantification and data transformation are presented in Table V. Furthermore, based on respondents' opinion, average values of Importance Rate (IR) and Priority Rate (PR) are presented in Table VI. Moreover, average value data of Importance Rate (IR) and Priority Rate (PR) are presented in Figure 4 using Important Performance Analysis as the method [12]. In more detail, Importance Rate and Priority Rate according to opinion of all respondent' demographics are presented in Table VII.

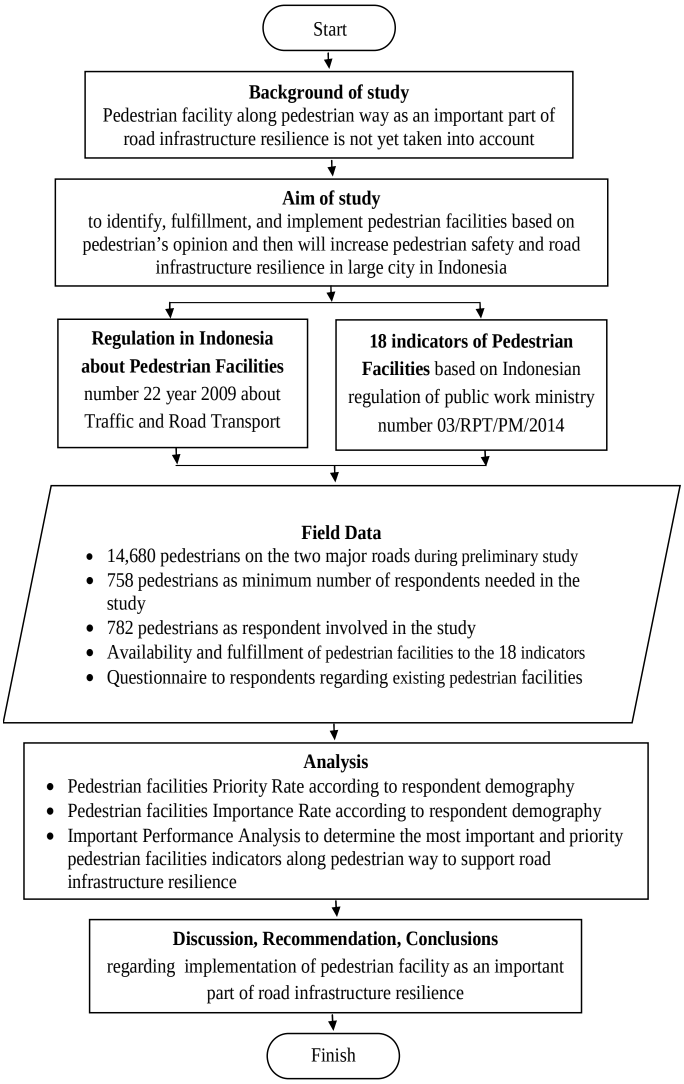

Fig. 1 Methodology of research to provide a recommendation to implement indicators of pedestrian facilities and increase road infrastructure resilience

B. Discussion

Based on the existing condition of availability of pedestrian facilities, fulfillment of the regulation in Indonesia regarding pedestrian facilities, and the respondent's opinion, specific discussion is as follows.

Fig. 2 Examples of pedestrian facilities condition on the two major roads in Bandung, Indonesia

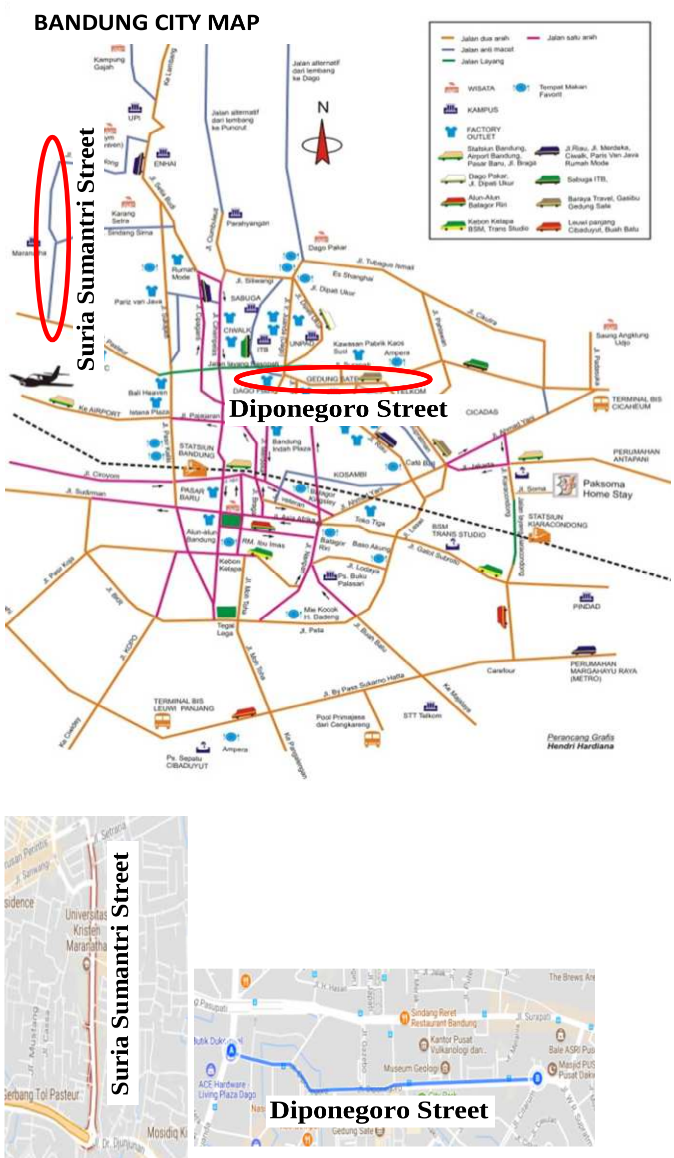

Fig. 3 Location of case studies, the two major roads in Bandung, Indonesia [11]

As can be seen in Table 3, only 72 percent of pedestrian facilities indicators is fulfilled along Diponegoro Street and only 33 percent of those along Suria Sumantri Street. The indicators not fulfilled on the two major roads are street lighting every 10m, safety fence with 0.9m height, public telephone in walking distance, pedestrian bridge, and ramp for the disabled. This condition cannot be expected to support pedestrian road resilience. Great effort by local government is needed to meet the standard required.

TABLE IIIII
EXISTING CONDITION OF PEDESTRIAN FACILITIES ON THE TWO MAJOR ROADS IN BANDUNG, INDONESIA, ACCORDING TO THE REGULATION IN INDONESIA [8]

Indicators of Pedestrian Facilities		Availability of Pedestrian Facilities			
		Diponegoro Street		Suria Sumantri Street	
		Yes	No	Yes	No
1	≥ 2.0m sidewalk width ≥2.5m vertical clearance ≤ 8% longitudinal grade	V		V	
2	≥ 0.6m road furniture width	V			V
3	≥ 0.75m lane width in front of the building	V		V	
4	≥ 1.5m green lane width	V		V	
5	Street lighting every 10m with 4m pole height		V		V
6	Seat with a size of 1.5m x 0.4m every distance of 10m	V			V
7	Safety fence with a 0.9m height		V		V
8	Trash bin every 20m length	V			V
9	Signage	V		V	
10	A bus shelter in walking distance	V		V	
11	Public phone in walking distance		V		V
12	Crosswalk at grade	V		V	
13	Pedestrian bridge		V		V
14	Ramp for disability		V		V
15	Guiding block for disability	V			V
16	CCTV	V			V
17	Bicycle lane	V			V
18	Bike racks	V			V

TABLE IV
LIKERT SCALE, QUANTIFICATION, AND DATA TRANSFORMATION OF RESPONDENTS' OPINION

Likert Scale	Quantification/ Data Transformation
Importance Rate or Priority Rate	
Very important	1
Important	2
Fair	3
Not important	4
Very not important	5

TABLE V
CHARACTERISTICS OF ALL 782 PEDESTRIANS AS RESPONDENTS

	Characteristic	Diponegoro Street	Suria Sumantri Street	Average
		Number (%)	Number (%)	Number (%)
1	**Gender**			
	Male	246 (65%)	200 (49%)	**446 (57%)**
	Female	131 (35%)	205 (51%)	336 (43%)
2	**Age** (year)			
	< 25	212 (56%)	353 (87%)	**565 (72%)**
	26-35	87 (23%)	30 (8%)	117 (15%)
	36-45	36 (10%)	13 (3%)	49 (6%)
	46-55	23 (6%)	9 (2%)	32 (4%)
	> 55	19 (5%)	0 (0%)	19 (3%)
3	**Occupation**			
	Student	139 (37%)	318 (79%)	**457 (58%)**
	Employee	100 (27%)	56 (14%)	156 (20%)
	Employer	77 (20%)	22 (5%)	99 (13%)
	Others	61 (16%)	9 (2%)	70 (9%)
4	**Education**			
	< High School	18 (5%)	16 (4%)	34 (4%)
	High School	185 (49%)	311 (77%)	**496 (64%)**
	Undergraduate/ Graduate	174 (46%)	78 (19%)	252 (32%)
5	Income/month (Rp)			
	< 2,500,000	225 (60%)	324 (80%)	**549 (70%)**
	2,500,000-5,000,000	106 (28%)	66 (16%)	172 (22%)
	> 5,000,000	46 (12%)	15 (4%)	61 (8%)
6	**Walking Purpose**			
	Working	23 (6%)	45 (11%)	68 (9%)
	Studying	24 (6%)	159 (39%)	183 (23%)
	Exercise	247 (66%)	89 (22%)	**336 (43%)**
	Shopping	47 (12%)	28 (7%)	75 (10%)
	Others	36 (10%)	84 (21%)	120 (15%)
7	**Reason of Walking**			
	Faster	21 (6%)	98 (24%)	119 (15%)
	Cheaper	70 (18%)	111 (27%)	181 (22%)
	More convenient	106 (28%)	31 (8%)	137 (18%)
	More secure	17 (5%)	11 (3%)	28 (4%)
	Have no vehicle	26 (7%)	34 (8%)	60 (8%)
	No other choice	137 (36%)	120 (30%)	**257 (33%)**
8	**Frequency of Walking/ Week**			
	1-2	183 (49%)	60 (15%)	**243 (31%)**
	3-4	123 (32%)	82 (20%)	205 (26%)
	5-6	30 (8%)	141 (35%)	171 (21%)
	7	41 (11%)	122 (30%)	163 (22%)
9	**Walking Pattern**			
	Walking Only	85 (23%)	153 (38%)	238 (30%)
	Walking to/ from parking area	114 (30%)	106 (26%)	220 (28%)
	Walking to/ from car and public transportation stops	178 (47%)	146 (36%)	**324 (42%)**

Table 4 regarding characteristics of all respondents indicated that, on average, number of male and female as a pedestrian is similar. Most of them are under 25 years old (72%); have occupation as student (58%); high school education (64%); have less than Rp.2,500,000 as monthly income (70%); have exercise (43%) and study (23%) as walking purposes; said no other choice (33%) and cheaper (22%) as the reason of walking; 1-2 times (31%) and 3-4 times (26%) as frequency of walking per week; and their walking patterns are walking to/ from car and public transportation stops (42%) and walking only (30%). These characteristics of respondents present that most pedestrians are young people, students, having high school education level, have low income per month; walking purposes are exercise and studying. Some others being pedestrians because there is no other choice and it is cheaper to reach the destination, walking 1-4 times per week to their destination, and walking to/from car and public transportation stops, and walking only as the walking pattern.

Characteristics of respondents influence the Importance Rate (IR) value and Priority Rate (PR) value. It can be seen in Table VI that, based on respondents' opinion, IR values and PR values of most indicators are more than 3.5 out of 5.0, except one indicator, i.e. public phone in walking distance with IR value is 2.83 and PR value of 2.65. This condition shows that most respondents are satisfied with the existing pedestrian facilities condition, although some indicators are not yet implemented as required in the regulation.

TABLE VI
IMPORTANCE RATE AND PRIORITY RATE OF PEDESTRIAN FACILITIES ON THE TWO MAJOR ROADS IN BANDUNG, INDONESIA

Indicators of Pedestrian Facilities		Average Value of Importance Rate (IR) and Priority rate (PR)			
		Diponegoro Street		Suria Sumantri Street	
		IR	PR	IR	PR
1	≥ 2.0m sidewalk width ≥2.5m vertical clearance ≤ 8% longitudinal grade	3.94	3.92	4.05	3.89
2	≥ 0.6m road furniture width	3.78	3.68	3.95	3.72
3	≥ 0.75m lane width in front of a building	3.57	3.54	3.71	3.57
4	≥ 1.5m green lane width	4.00	3.93	4.23	4.03
5	Street lighting every 10m with 4m pole height	4.14	4.12	4.36	4.30
6	Seat with a size of 1.5m x 0.4m every distance of 10m	3.63	3.55	3.65	3.61
7	Safety fence with a 0.9m height	3.66	3.60	3.75	3.60
8	Trash bin every 20m length	4.08	4.03	4.17	4.10
9	Signage	4.07	4.06	4.21	4.12
10	A bus shelter in walking distance	3.68	3.54	3.78	3.67
11	Public phone in walking distance	2.88	2.65	2.78	2.64
12	Crosswalk at grade	4.08	4.07	4.25	4.21
13	Pedestrian bridge	3.53	3.31	3.81	3.65
14	Ramp for disability	3.99	3.81	4.24	4.13
15	Guiding block for disability	4.06	3.79	4.22	4.15
16	CCTV	4.12	4.03	4.28	4.16
17	Bicycle lane	3.88	3.75	4.11	3.89
18	Bike racks	3.54	3.30	3.79	3.55

TABLE VII
IMPORTANCE RATE AND PRIORITY RATE ACCORDING TO ALL RESPONDENTS' DEMOGRAPHICS

Characteristic		Pedestrian Facilities Indicator	
		Importance Rate	Priority Rate
1	**Gender**		
	Male	Street lighting	Street lighting
	Female	Signage, CCTV, Crosswalk	Signage
2	**Age** (year)		
	< 25	Street lighting	Street lighting
	26-35	Crosswalk, CCTV	Crosswalk
	36-45	Crosswalk	Crosswalk
	46-55	Green lane	Green lane
	> 55	Trash bin	Trash bin
3	**Occupation**		
	Student	Street lighting	Street lighting
	Employee	Crosswalk	Crosswalk
	Employer	Crosswalk, trash bin	Crosswalk
	Others	Street lighting, Crosswalk, CCTV Guiding block	Street lighting, CCTV Guiding block
4	**Education**		
	< High School	Street lighting, Crosswalk	Street lighting, Crosswalk
	High School	Street lighting, CCTV	Street lighting
	Undergraduate/ Graduate	Street lighting, Signage, Green lane	Street lighting, Signage, Green lane
5	Income/month (Rp)		
	< 2,500,000	Street lighting, Crosswalk	Street lighting,
	2,500,000-5,000,000	Street lighting, Crosswalk	Street lighting, Crosswalk
	> 5.000.000	Signage, Green lane	Signage, Green lane
6	**Walking Purpose**		
	Working	Street lighting	Street lighting
	Studying	Street lighting, Crosswalk	Street lighting, Crosswalk
	Exercise	Street lighting	Street lighting
	Shopping	Street lighting, CCTV	Street lighting, CCTV
	Others	Street lighting, CCTV	Street lighting, CCTV
7	**Reason of Walking**		
	Faster	Street lighting, Signage	Street lighting, Signage
	Cheaper	Street lighting	Street lighting
	More convenient	Crosswalk, CCTV	Crosswalk
	More secure	Street lighting, CCTV	Street lighting, CCTV
	Have no vehicle	Street lighting, Crosswalk	Street lighting, Crosswalk
	No other choice	Street lighting, Ramp	Street lighting, Ramp
8	**The frequency of the Walking/ Week**		
	1-2	Street lighting, Crosswalk	Street lighting,
	3-4	Street lighting, Signage	Street lighting,
	5-6	Street lighting, Trash bin	Street lighting,
	7	Street lighting	Street lighting
9	**Walking Pattern**		
	Walking Only	Street lighting, CCTV	Street lighting, CCTV
	Walking to/ from parking area	Street lighting, Green lane	Street lighting, Green lane
	Walking to/ from car and public transportation stops	Street lighting Signage	Street lighting Signage

Furthermore, Figure 4 presents that indicators that have high priority rate and high importance rate are street lighting, crosswalk, signage, CCTV, trash bin, green lane, ramp and guiding block for the disabled. These indicators have to be implemented as soon as possible by local government as required in the regulation in Indonesia. Whereas indicators that have low priority rate, but high importance rate, are bicycle lane, road furniture, bus shelter in walking distance, safety fence, lane width in front of a building, pedestrian bridge, seat, and bike rack. These indicators have also to be implemented by local government because they are required in the regulation in Indonesia, but are included in the next priority to do.

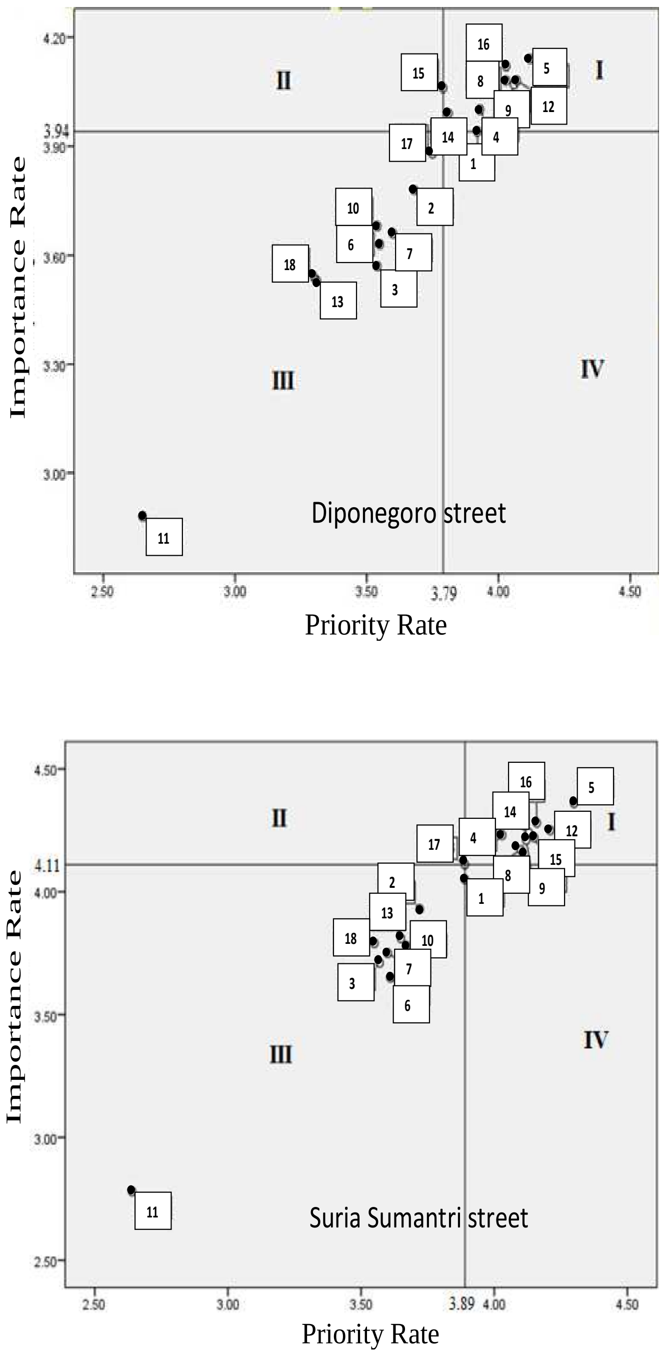

Fig. 4 Quadrant of important performance analysis between priority rate and importance rate of pedestrian facilities

Moreover, Table 7 presents that, based on respondent characteristics, the most important, and the highest priority indicators of pedestrian facilities that have to be implemented as soon as possible are street lighting, crosswalk, CCTV, signage, and pedestrian ramp for the disabled. Fulfillment of all pedestrian facilities as required in the regulation will increase road infrastructure resilience through reduction of casualty in normal condition with no disaster and reduction risk during evacuation if disaster occurs.

Based on the detailed discussion above, recommendations to fulfill the regulation and then increase the road infrastructure resilience are as follows:

- Identification of availability of pedestrian indicators/facilities as required in the regulation.
- Identification of challenges of implementation of the facilities not yet available, including financial support, the commitment of local government to implement the facilities and then maintain them continuously, the responsibility of society to always preserve the pedestrian facilities while using them.
- Dissemination of regulation to the society about pedestrian facilities that have to be available and implemented as their right as a pedestrian to be safe and secure during walking.
- Implementation the pedestrian facilities are not yet available by local government.
- An effort to make government and society realize that fulfillment of pedestrian facilities as required in the regulation will be very beneficial for people to reduce casualty risk during normal condition and reduce damage and lost life risk during evacuation and the reconstruction process if a disaster happens.

IV. CONCLUSIONS

Disaster could occur anytime and anywhere on the risk location. Up to this moment, there is no knowledge or science which can accurately determine where, when, and how large the disaster. Therefore, road infrastructure resilience as an essential part of disaster resilience is critical to implement, especially in locations where many people live, like large cities. If a disaster happened, not only roadway is used as a facility for evacuation and rescue of the people, but the pedestrian way as well. The pedestrian way that fulfills the regulation has a huge role to support road infrastructure resilience. Based on pedestrians' opinion in the large city of Bandung, Indonesia, as a case study, the most important, and the highest priority indicators that have to be implemented soon are street lighting, crosswalk, CCTV, signage, and pedestrian ramp for the disabled. The pedestrian way that fulfills all indicators as required in the regulation in Indonesia will reduce casualty risk in normal condition and increase road infrastructure resilience if there is a disaster so that the society can recover as fast as possible.

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