THE EFFECTS OF SIDE FRICTION REDUCTION TO THE PERFORMANCE OF UNSIGNALIZED INTERSECTION (CASE STUDY IN BANDUNG, INDONESIA)

by A. Caroline Sutandi[a] and Novaliya[b]

ABSTRACT

Unsignalized intersections, which are locations, with high potential traffic congestion, are the largest number of intersections in large cities in developing country such as Indonesia. Moreover, a number of side frictions worsen traffic congestion and then decrease performance of intersection. Some Regulator traffic signs have been installed to reduce traffic congestion at these locations. However, road users especially angkot (local public transportation mode) drivers ignored the signs. The purpose of this paper is to analyze the effects of side friction reduction to the performance of the intersection. Unsignalized intersection at Rajawali-Dadali in Bandung, Indonesia was used as a case study. Results of this paper showed that at the intersection with capacity of around 4000 pcu/hour, degree of saturation of 0.91 and delay of 15.3 second/pcu, traffic signs alone were not effective. The presence of police officer increased 8.46 percent of capacity, decreased 2.72 percent of degree of saturation, and decreased 4.93 percent of delay at the intersection. However, since the presence of police officers are not always available even during peak hours, it is recommended that the unsignalized intersections with high degree of congestions be changed into signalized intersections.

KEYWORDS: *angkot drivers; performance of unsignalized intersection; side friction reduction; traffic congestion; unsignalized intersection.*

INTRODUCTION

Bandung is the capital city of West Java Province and it lies 180 km from Jakarta, the capital city of Indonesia. Bandung is a city with the third largest population in Indonesia, after Jakarta and Surabaya. The area of Bandung is 16,730 ha and population of 2,364,312 million with 1.06 percent annual growth rate.[1] The road infrastructure density of Bandung is only 3 percent of the city area and has to serve 1,207,455 vehicles excluding 2,253,379 motorcycles.[2]

In addition to signalized intersections, most of intersections in Bandung are unsignalized intersections. With this condition, traffic congestion occurs at many intersections, especially at unsignalized intersections. Rajawali-Dadali is one of unsignalized intersections in Bandung that is usually congested. One of reasons that cause traffic congestion at intersection is side friction, due to for examples: parking activities near intersection and activities of angkot (local public transportation mode) drivers who are usually picking up and dropping off passengers near intersection.

The condition reflects poor adherence of the drivers to the traffic regulation.[3]

It is hoped that reduction of side frictions may reduce traffic congestion and then increase the performance of the intersection. This is the main purpose of the study. In order to reach the purpose, identification of existing side frictions at intersection, how to reduce the side friction, and evaluation of performance of the intersection before and after side friction reduction are crucial to discuss. Afterwards, recommendation for improvement to increase the performance of intersection is given.

RESEARCH SIGNIFICANCE

Unsignalized intersections are the largest number of intersections in large city in developing country such as Indonesia. Since these locations have high potential traffic congestion, efforts to reduce the traffic congestion and increase the performance of intersection are crucial. If regulatory traffic signs and presence of police officers cannot reduce traffic congestion, it is recommended to change this kind of intersections into signalized intersections. The results of this study is belief not only beneficial to unsignalized intersections in Bandung, but also to other large cities in Indonesia or in other developing countries with similar traffic conditions.

LITERATURE REVIEW

Intersection can be defined as the public area where two or more roads join or cross, including the roadway and roadside facilities for traffic movement. Because intersection has to be shared by everybody using it, intersection needs to be designed with great care, taking into consideration efficiency, safety, speed, cost of operation, and capacity.[4-6] In general, there are three types of intersections: (1) at grade intersection, (2) grade separation intersection without ramps, and (3) interchanges. Intersection at grade can be classified into two types i.e. signalized intersection and unsignalized intersection.[7] The unsignalized intersection is the focus of this study.

[a]Lecturer, Department of Civil Engineering, Faculty of Engineering, Parahyangan Catholic University, Ciumbuleuit 94 Bandung 40141 Indonesia

[b]Student, Department of Civil Engineering, Faculty of Engineering, Parahyangan Catholic University, Ciumbuleuit 94 Bandung 40141 Indonesia

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Controls at Unsignalized Intersection

Traffic control devices include marking, signs, and signal. Each of this can be used alone or in combination if necessary. They are primary means of regulating, warning, or guiding traffic on all streets or highways. Traffic control devices are designed to provide safe and efficient functioning of intersections by separating conflicting vehicle streams by time.[8] At unsignalized intersections, marking, roundabouts, and traffic signs are used, for examples yield or stop signs assign priority to particular traffic streams relative to other streams at the same intersection. Specifically, marking and traffic signs fulfilll the following purposes: the regulation of traffic (e.g. speed limit), turn prohibition, stop prohibition, alerting drivers and pedestrians regarding roadway conditions, and guiding traffic along appropriate routes to reach trip destinations through signs and markings.[3,9]

Performance Measurements at Unsignalized Intersection

The performance of unsignalized intersection can be evaluated in term of how well the objectives of the treatment have been satisfied. The main measurements are capacity, degree of saturation, and delay.[3,9] Capacity is calculated as the product between a base capacity (C_0) for a set of predetermined (ideal) conditions and corrections factors (F), taking account of the influence of the capacity of the actual site conditions, usually the capacity is termed vehicles per hour or passenger car unit per hour. Degree of saturation is ratio of actual flow to maximum flow and delay is the stopped time delay per approach vehicle in seconds per vehicle. Approach is the part of an intersection leg that is used by traffic approaching the intersection.[10]

Indonesian Highway Capacity Manual (IHCM)

In this study, capacity, degree of saturation, and delay as performance measurements at unsignalized intersection in large cities in Indonesia is evaluated based on methodology in Indonesian Highway Capacity Manual 1997.[11] Capacity in pcu/h is defined as follow:

$$C = C_0 xF_W xF_M xF_{CS} xF_{RSU} xF_{LT} xF_{RT} xF_{MI} \quad (1)$$

where C_0 is basic capacity (pcu/h) and F_W, F_M, F_{CS}, F_{RSU}, F_{LT}, F_{RT}, and F_{MI} are correction factors of entry width (W), median of major road (M), city size (CS), environmental condition (RSU), side friction, and unmotorized (RSU), left turn (LT), right turn (RT), and minor road traffic flow ratio (MI), respectively.

Degree of saturation (DS) is the ratio of total flow to capacity (Q_{TOT}), therefore it can be defined as follow:

$$DS = \frac{Q_{TOT}}{C} \quad (2)$$

While unsignalized intersection delay (D) consists of traffic delay (DT) in sec/pcu and geometric delay (DG) in sec/pcu and can be defined as follow:

$$D = DT + DG \quad (3)$$

where

$$DT = 2 + 8.2078 \times DS - (1 - DS) \times 2$$

for $DS \leq 0.6$ and

$$DT = \frac{1.0504}{(0.2742 - 0.2042 \times DS)} - (1 - DS) \times 2$$

for $DS > 0.6$ and

$$DG = (1 - DS) \times (P_T \times 6 + (1 - P_T) \times 3) + DS \times 4$$

for $DS < 1.0$ and

$DG = 4$ for $DS \geq 1.0$ and PT is turning traffic flow to total traffic flow ratio

CASE STUDY

Case study was carried out at Rajawali-Dadali unsignalized intersection in Bandung, Indonesia. Figure 1 presents the location of the intersection in the city and Figure 2 presents traffic condition where "angkots" as local public transportation mode in Bandung parked near the intersection, although there is "no-stopping" sign at the intersection.

Rajawali-Dadali unsignalized intersection is chosen because this intersection is one of congested unsignalized intersections in Bandung. Survey was carried out on weekdays and weekends during morning peak hour (07:00 – 08:00 am), off peak hour (12:00 am – 01:00 pm), and afternoon peak hour (04:00 – 05:00 pm).

DATA COLLECTION

Two data sets was collected at Rajawali-Dadali unsignalized intersection.[12] Previously, identification of side frictions at intersection and evaluation of how to reduce the side frictions had been done. The first collection data set was carried out without the presence of police officers at intersection and the second was carried out with the presence of police officers. Geometric data, environmental data, traffic flow data, and side friction data will be discussed in this section. Stop watch, video camera, meter, and field data forms were used during field data collection. Police officers from Police Station of The West Bandung City assisted surveyors during field data collection.

Geometric Data

Geometric data at congested intersection Rajawali-Dadali consists of number of leg intersections, number of lanes, and lane width. Figure 3 shows the geometric data and traffic movements at the intersection.

Fig. 1. The Location of Rajawali-Dadali Unsignalized Intersection in Bandung, Indonesia (Sumber: © 2010 Google Map Data – Tele Atlas).[13]

Table 1. Environmental Data at Rajawali-Dadali Unsignalized Intersection.

Approach	Street Type	Approach Width	Environmental Type	City Size
Rajawali street	4/1 UD	7.2 m	CBD	Large
Dadali street	2/2 UD	2.0 m	Residential area	

Table 2. Traffic Flow Data at Rajawali-Dadali Unsignalized Intersection during Weekdays.

Veh Type	Traffic flow (veh/h)without the presence of police officers									Traffic flow (veh/h) with the presence of police officers		
	Rajawali Approach						Dadali Approach			Rajawali Approach		Dadali Approach
	MP		OP		AP		MP	OP	AP	MP		MP
	LT	ST	LT	ST	LT	ST	LT	LT	LT	LT	ST	LT
LV	231	1,505	201	1,498	228	1,518	201	166	208	263	1,520	251
HV	0	36	0	35	0	30	0	0	0	0	35	0
MC	366	2,548	320	2,492	372	2,536	262	227	271	411	2,613	280
UM	33	86	39	81	37	82	41	37	40	24	82	30

Note: MP = morning peak hour; OP = off peak hour; AP = afternoon peak hour; LT = left turn; ST = straight through; LV = light vehicle; HV = heavy vehicle; MC = motor cycle; UM = unmotorized

Fig. 2. Existing Traffic Conditions at Rajawali – Dadali Unsignalized Intersection.

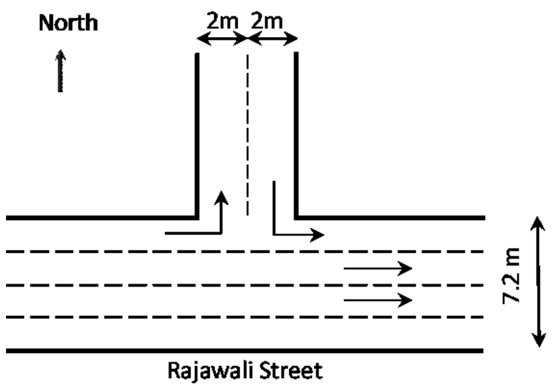

Fig. 3. Geometric and Traffic Movements Data at Rajawali - Dadali Unsignalized Intersection.

Environmental Data

Based on Indonesian Highway Capacity Manual, 1997,[11] environmental data consists of city size (small, medium, large city) and environmental type (CBD or residential area). Since population of the city of Bandung is 2,364,312 million people, therefore the city size is categorized as large (population between 1 up to 3 million people). Table 1 presents environmental data of the intersection.

Traffic Flow Data

Two data sets of traffic condition was carried out at the intersection. The first was existing traffic flow without the presence of police officers at the intersection and the second was those with the presence of police officers. The presence of police officers only during morning peak hour since during off peak hour and afternoon peak hour police officers are on duty at other intersections. The data is presented in Table 2 for traffic flow during weekdays and in Table 3 for those during weekends. Correction factors for light vehicle, heavy vehicle, and motor cycle are 1.0, 1.3, and 0.2, respectively.[11]

Side Friction Data

Side friction level is high if traffic flow at the entry and the exit is reduced by road side activities in the approach, such as public transit stops, pedestrian walking along and accros the approach, and exit and entries from and to road side properties. Whereas, side friction level is low if traffic flow at the entry and the exit is not reduced by all road side activities.[11]

Side friction at unsignalized intersection is defined based on weight frequency of every activity at road side per hour per 200 meter.[11] Regarding identification of existing side frictions, there are 4 categories of the activities, i.e. pedestrian activities, parking activities, vehicle enter to or exit from a property, and vehicle that move slowly. Side friction data at Rajawali-Dadali unsignalized intersection is presented in Table 4.

Table 3. Traffic Flow Data at Rajawali-Dadali Unsignalized Intersection during Weekends.

Veh Type	Traffic flow (veh/h)without the presence of police officers									Traffic flow (veh/h) with the presence of police officers		
	Rajawali Approach						Dadali Approach			Rajawali Approach		Dadali Approach
	MP		OP		AP		MP	OP	AP	MP		MP
	LT	ST	LT	ST	LT	ST	LT	LT	LT	LT	ST	LT
LV	234	1,498	184	1,438	233	1,451	198	179	216	266	1,541	264
HV	0	36	0	33	0	31	0	0	0	0	31	0
MC	356	2,540	329	2,401	367	2,467	260	216	258	406	2,593	301
UM	35	85	19	68	32	76	38	25	29	24	79	29

Note: MP = morning peak hour; OP = off peak hour; AP = afternoon peak hour; LT = left turn; ST = straight through; LV = light vehicle; HV = heavy vehicle; MC = motor cycle; UM = unmotorized

Table 4. Side Friction Data at Rajawali-Dadali Unsignalized Intersection.

Activity at Side Friction [2]	Weight Factor [2]	Weekdays		Weekends	
		Activity/hour per 200m	Weigh Frequency	Activity/hour per 200m	Weigh Frequency
Pedestrian (PED)	0.5	368	184	325	163
Parking /stop vehicle (PSV)	1.0	588	588	479	479
Entry/enter vehicle (EEV)	0.7	312	218	254	178
Slow vehicle (SMV)	0.4	58	23	56	22
TOTAL			1,013		842

Table 5. Results of Analyses of Capacity, Degree of Saturation, and Delay.

Performance Measurement	Period					
	Weekdays			Weekends		
	Without the presence of police officers	With the presence of police officers	Difference (%)	Without the presence of police officers	With the presence of police officers	Difference (%)
Capacity (pcu/h)	3,905	4,226	+ 8.22	3,907	4,247	+8.70
Degree of Saturation	0.904	0.881	- 2.54	0.900	0.874	- 2.89
Delay (sec/pcu)	15.255	14.731	- 3.44	15.227	14.250	- 6.42

Fig. 4. Traffic Conditions with The Presence of Police officers at Rajawali-Dadali Unsignalized Intersection.

RESULTS AND DISCUSSIONS

Based on Indonesian Highway Capacity Manual, 1997,[11] it can be seen in Table 4 that side friction level at unsignalized intersection Rajawali-Dadali was very high during weekdays (weight frequency > 900) and high during weekends (weight frequency between 500 and 800). Before all field data were analyzed, determination of how to reduce side friction at unsignalized intersection was crucial. Obviously, traffic signs at the intersection was not useful. Road users especially angkot drivers usually ignored the traffic regulation and stopped or parked near the intersection. Therefore, the presence of police officers at the intersection is needed to force road users to adhere to the traffic regulation.

Performance of unsignalized intersection can be analized based on performance measurements i.e. capacity, degree of saturation, and delay. The values of performance measurements are determined based on methodology in Indonesia Highway Capacity Manual 1997 for unsignalized intersections in large city in Indonesia.[11]

Results of analyses of capacity, degree of saturation, and delay are presented in Table 5. Table 5 shows that all performance measurements during weekdays are similar with those during weekends. Capacity of intersection was

high (around 4,000 pcu/h) with very high degree of saturation (more than 0.75). The condition influenced the value of delay and indicated that traffic condition at unsignalized intersection was very congested during weekdays and weekends.

Table 5 also shows that performance of intersection increase with the presence of police officers at intersection. In more detail, capacity increased of 8.22 percent, degree of saturation decreased of 2.54 percent, and delay decreased of 3.44 percent during weekdays. While during weekends, capacity increased of 8.70 percent, degree of saturation decreased of 2.89 percent, and delay decreased of 6.42 percent. The traffic condition occured since road users, especially angkot drivers, adhered to the traffic regulation i.e. did not stop or park near intersection. On one aspect the presence of police officers at intersection was beneficial in term of increase the performance of intersection; but on the other side, the condition did not educate road users. Road users only adhered to the traffic regulation to avoid getting traffic ticket from police officer. Moreover, police officers could not always present at unsignalized intersection because of limited number of personnel.

Therefore, for this kind of unsignalized intersection, where traffic signs is not effective and the presence of police officers cannot increase the performance of intersection significantly, it is recommended to change it into signalized intersection, especially using SCATS (Sydney Coordinated Adaptive Traffic Systems) as the advanced traffic control systems (ATCS) implemented to a number of intersections in Bandung.

FURTHER RESEARCH

Implementation of recommendation to change the unsignalized intersection into signalized intersection is needed. If the performance measurements of signalized intersection are better significantly than performance measurements of unsignalized intersection with the presence of police officers, then the recommendation can be one of problem solvings to reduce severe traffic congestion in large cities, at least in Indonesia. However, permission from Bandung Road Authority, number of surveyors, time, and financial support should be available to do the further research.

CONCLUSIONS

Unsignalized intersections are the greatest number of intersections in large city Bandung in Indonesia. The intersection is the location with high potential traffic congestion. Side friction reduction cause decrease in traffic congestion and then increase the performance of intersection. Traffic signs at intersection cannot force road users, especially angkot drivers to adhere to the traffic regulation. Therefore, the presence of police officers is needed.

The presence of police officers increase the performance of intersection in terms of capacity, degree of saturation, and delay. However, police officers cannot always present at unsignalized intersection and the condition did not educate roas users to adhere to traffic regulation. Therefore, for this kind of very congested unsignalized intersection, it is recommended to change it into signalized intersection, especially using advanced traffic control systems (ATCS) as is implemented to a number of intersections in Bandung.

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