Improvement of Traffic Performance at Intersections on Cak Doko Street, Kupang City, Indonesia

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Keywords: Intersection, Traffic, Volume, V/C Ratio.

Abstract: The increase in the vehicle population along with the lack of infrastructure capacity will cause social problems. Cak Doko Street is located in a commercial area in the busy city center of Kupang. At unsigned intersections, various turning movements will form many conflict points which will result in decreased traffic performance at this point. The purpose of this study is to measure traffic performance at the intersection on Cak Doko Street, especially at the meeting with the Nangka and Pemuda roads in the existing conditions and conditions for the next 10 years and provide long-term handling directions to improve traffic performance at the intersection without adding road infrastructure. The results show that the traffic conditions in the next 10 years will result in the v/c ratio for both intersections passing 1, after traffic regulation the v/c ratio will decrease below 0.9. It can be concluded that the traffic regulation proposed in this study has succeeded in improving the performance of the intersection on Cak Doko Street.

1 INTRODUCTION

Urban transportation is the main lifeblood of the urban economy. Meanwhile, rapid economic development does require smooth traffic flow. Thus, the organization of level crossings is very important in traffic control (J. Zhang *et al*., 2015). Traffic flow data at intersections is very important in the design of intersection configurations, canalization, and signal control. Therefore, it is necessary to forecast current and future traffic flows from the intersection approach (Q. Fang *et al*., 2011).

At present, urban arterial road traffic is increasingly congested, which eventually causes social problems. At present, road conditions cannot be fundamentally adjusted or engineered in the short term, and traffic management tools such as junction traffic canalization and traffic signal control technologies are basically universally applied. Thus, how to fully utilize and optimize limited road resources and allocate traffic control resources, how to better meet and serve road user demands, improve arterial road traffic efficiency, and reduce traffic congestion have become the subject of urgent research (L. L. Dai *et al*., 2013).

The city of Kupang itself is the capital of the province of East Nusa Tenggara (NTT) which is the busiest city in the province of NTT. Based on data from the Central Agency of Statistics for the City of Kupang within the City of Kupang in 2020 figures, the number of motorized vehicles in the City of Kupang continues to increase every year, with a percentage increase of 7.09% per year. This means that this will result in an increase in traffic movement which will burden the existing road network. The growth of motorized vehicles will have serious implications for road infrastructure, road safety, urban parking, traffic management (F. I. Ukonze *et al*., 2020).

The cak doko road section is located in a commercial area in the very dense city center of Kupang, there are shop houses lined up and there is also a Subasuka Factory Outlet shopping center. Traffic flow on this section is often jammed, especially in the late afternoon. at unsigned intersections, various turns form multiple points of conflict. The number of conflict points increases dramatically as the number of paths increases (P. Ouyang *et al*., 2018). The most congested points on the Cak Doko road are at 2 unsignalized intersections, namely at the confluence of the Cak Doko road with the Nangka road and the Pemuda road. These two T-junctions are close so that there are often conflicts over traffic movements here. No one relents and the squabbling between road users further adds to the congestion on this segment. If not taken seriously,

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this congestion problem will have an impact on various sectors, such as the economic sector, namely the increasing transportation costs, quality-of-life: namely the deterioration of the quality of life in a community due to the increased emotional level due to travel (Y. Yao *et al.,* 2020).

Given that this location is already crowded and there is no more empty space to increase the width of the road or intersection, the purpose of this study is to determine the appropriate handling steps in the form of controlling traffic flow by optimizing the use of existing infrastructure to improve traffic flow performance at the location. This is in order to provide convenience to traffic efficiently in the use of road space and to expedite the movement system without changing the geometry of intersections and segments (A. Wadu *et al.,* 2019). These countermeasures will be carried out with traffic engineering simulations based on the 2014 Indonesian road capacity guidelines (PKJI, 2014).

2 RESEARCH METHODS

The research stages start from literature study, data collection, data analysis, until the results are in the form of conclusions and recommendations for handling. It was started with a literature study which then identified problems that caused traffic jams on the Cak Doko street, especially at the intersection with Nangka street and Pemuda street. This stage is carried out to find out the real root problems that occur in the study area. At this stage, the concentration points of the study area and the scope of the problems to be discussed are also carried out. The analysis stage is a follow-up after data processing is completed. The purpose of this stage is to understand and analyze the processing results in depth. The analysis is carried out by taking into account the traffic performance at the two intersections starting from capacity, delays and queuing opportunities that occur with considerations based on the 2014 Indonesian Road Capacity Guidelines (PKJI 2014). Then a projection of the condition of the next 10 years is carried out using data on the growth rate of motorized vehicles in Kupang City to anticipate the possibilities that occur in depth in the future so that the handling of congestion problems can be carried out efficiently for the long term.

2.1 Road Geometric

The collection of road geometric data using the manual method is carried out directly at the survey location by measuring the width of the road, the width of the sidewalk, and the parking layout, as well as other data about the roads related to this research by using a meter.

2.2 Traffic

The survey conducted in this study is a classified volume survey using the manual traffic counts method. The survey is carried out by placing the surveyor at a fixed point on the side of the road, so that it can clearly observe passing vehicles at the specified point. Data recording is filled in on the survey form according to the vehicle classification that has been determined. The implementation period starts from 06.00 to 18.00 for 7 days.

2.3 Level of Service

Road service level analysis was conducted based on the PKJI 2014 Indonesian road capacity guidelines. The level of road service to passing traffic is usually measured by the v/c ratio or commonly referred to as the degree of saturation. The degree of saturation (Ds) is the ratio between the traffic volume (V) and the road capacity (C), the magnitude of which is theoretically between 0 - 1, which means that if the value is close to 1 then the road condition is close to saturation.

$$Ds = \frac{Q}{C}$$

Where

Ds = Degree Of Saturation

Q = Traffic flow (pcu/hour)

C = Capacity (pcu/hour)

3 RESULTS AND DISCUSSION

3.1 Intersection Profile Existing Condition

The intersection of Cak Doko Street – Pemuda Street and Cak Doko Street –Nangka Street are types of 3-arm unsignalized intersection that is passed by vehicles from Cak Doko Street, Pemuda Street, and Nangka Street. The three roads are successively identified as approaches A1, B1 and A2 as shown in Figure 1. The characteristics of each of these approaches can be seen in PKJI 2014. Based on this classification, the closest type of intersection is determined for the intersection of Cak Doko Street –

Pemuda Street and Cak Doko Street –Nangka Street, namely intersection 322 which means 3-arm intersection with 2 lanes of minor roads and 2 lanes of major roads

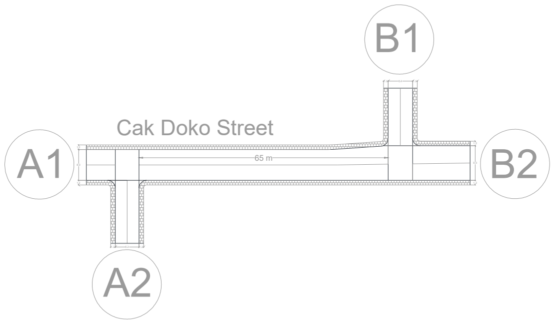

Figure 1: Overview of the intersection location.

The location of this intersection is in a commercial environment, which is an environment that surrounds many shops, shopping centers, banks, workshops. And not far from the intersection there are several schools. Pemuda Street also connects Cak Doko Street and Kuanino Market, while Nangka Street connects Cak Doko and Bhayangkara Hospital and Oeba Market. Furthermore, in this discussion, the Cak Doko Street and Nangka Street will be called the intersection A, while the Cak Doko Street and Pemuda Street intersections will be called the intersection B.

3.2 Existing Traffic Flow

Traffic counting passing through the intersection of Cak Doko Street – Pemuda Street and Cak Doko Street – Nangka Street was observed for 1 week of observation. The results obtained for the calculation of traffic volume are shown in Figure 2. Peak hours occur on Saturdays between 17:00 – 18:00 with a traffic volume of 1471 pcu/hour at the Cak Doko Street - Pemuda Street intersection and 1610 pcu/hour at the intersection. the intersection of Cak Doko Street – Nangka Street.

From the peak hour data obtained from Figure 2 and Figure 3, then an analysis of the capacity of intersection A and intersection B is carried out to obtain traffic performance at both intersections, both from the degree of saturation, intersection delays and opportunities for queues. The geometric data for intersection A is shown in figure 4 with the traffic composition shown in table 1, while the geometric data for intersection B is shown in figure 5 with the traffic composition shown in table 2.

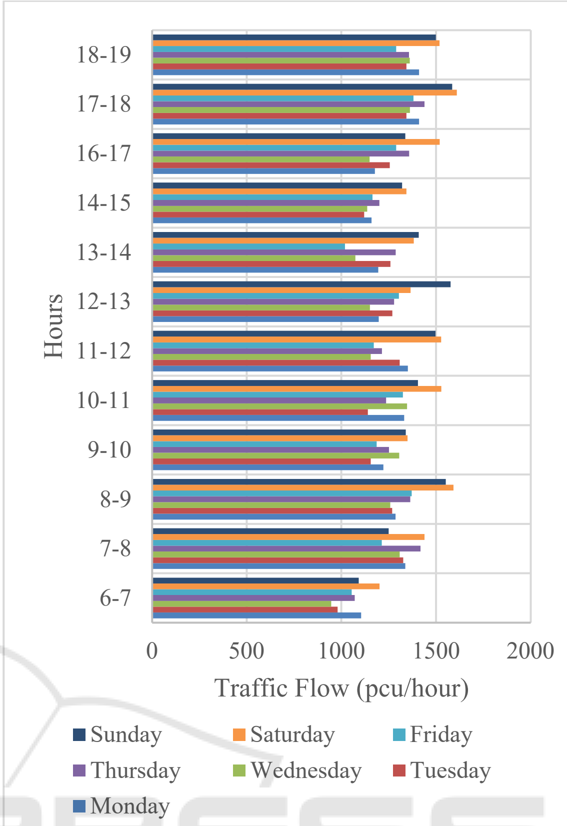

Figure 2: Traffic Flow in Intersection A.

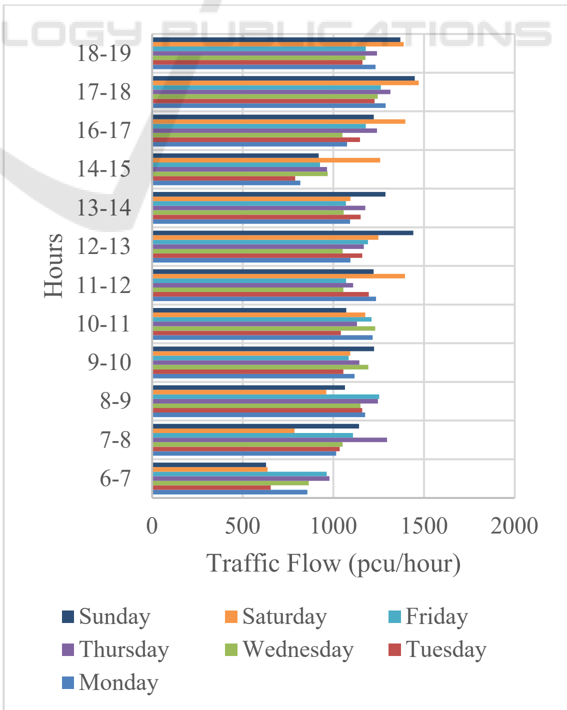

Figure 3: Traffic Flow in Intersection B.

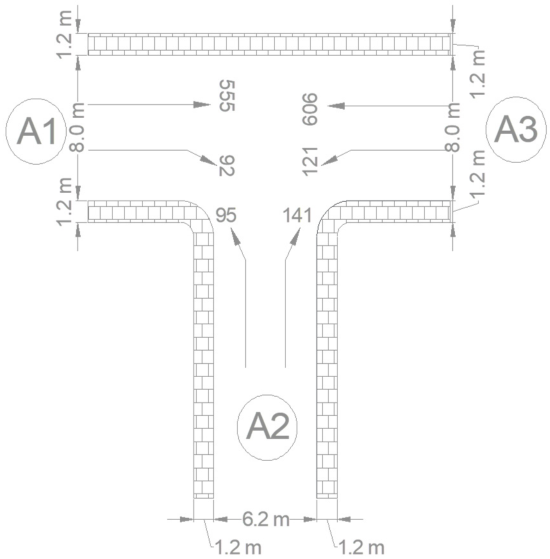

Figure 4: Geometric of Intersection A.

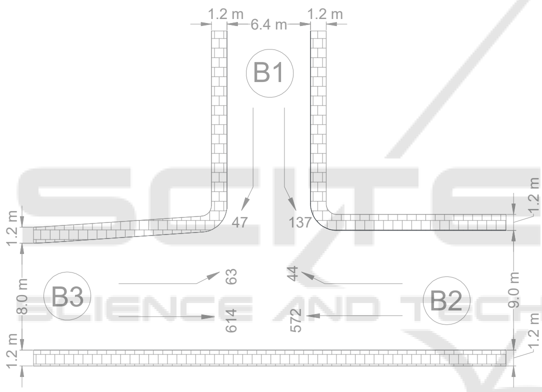

Figure 5: Geometric of Intersection B.

The traffic flow data in figure 4 is in Passenger car equivalent (pcu) units, while the traffic flow data in table 1 is in vehicles/hour units for each type of vehicle with Motorcycle (MC), Light Vehicle (LV), Heavy vehicle (HV) , and Uninsured motorist (UM) and for the direction of each vehicle is Left Turn (LT), Right Turn (RT), straight through (ST).

Table 1: Traffic flow at the peak of Intersection A.

Vehicle Type	Approach					
	A1		A2		A3	
	RT	ST	RT	LT	LT	ST
MC	206	1097	292	180	309	969
LV	47	325	77	55	56	365
HV	2	6	3	2	2	26
UM	0	1	0	0	0	4

Table 2: Traffic flow at the peak of Intersection B.

Vehicle Type	Approach					
	B3		B1		B2	
	LT	ST	LT	RT	ST	RT
MC	171	1179	110	315	1047	125
LV	26	370	19	69	330	19
HV	2	6	0	4	25	0
UM	0	2	0	0	1	0

Table 1 and Table 2 show that the type of motorcycle vehicle is the most common type of vehicle crossing intersection A and intersection B. While the type of heavy vehicle is the least crossing intersection A and intersection B. As for the Uninsured motorist, it is very little even at several legs Uninsured motorist found.

3.3 Existing Traffic Performance

The ratio between peak traffic flow (q) for one hour to capacity (C) which is determined based on the surrounding environmental conditions and the existing infrastructure at intersection A and intersection B.

$$D_S(A) = \frac{1610}{2670} = 0,603$$

$$D_S(B) = \frac{1471}{2500} = 0,588$$

The additional travel time used by the driver to pass through Intersection A and Intersection B when compared to the route without the Intersection. T consists of Traffic Delay (TLL) and Geometric Delay (TG). TLL is the waiting time caused by the interaction of traffic with opposite traffic movements. TG is the additional travel time caused by the deceleration and acceleration of vehicles turning at the intersection. Because the degree of saturation of intersection A is more than 0.6 then the average traffic delay for all motorized vehicles entering Intersection A from all directions is

$$T_{LL}(A) = \frac{1,0504}{(0,2742 - 0,2042 \times D_J)} - (1 - D_J)^2$$

$$= \frac{1,0504}{(0,2742 - 0,2042 \times 0,603)} - (1 - 0,603)^2 = 6,79$$

While the degree of saturation from intersection B is less than 0.6 then the average traffic delay for all motorized vehicles entering Intersection B from all directions is

$$T_{LL}(B) = 2 + 8,2078 \times D_J - (1 - D_J)^2$$
$$= 2 + 8,2078 \times 0,588 - (1 - 0,588)^2 = 6,66$$

The average traffic delay for all motorized vehicles entering Simpang A from Cak Doko Street is

$$T_{LLma}(A) = \frac{1,0503}{(0,3460 - 2460 \times D_J)} - (1 - D_J)^{1,8}$$
$$= \frac{1,0503}{(0,3460 - 2460 \times 0,603)} - (1 - 0,603)^{1,8} = 4,5$$

Meanwhile, the average traffic delay for all motorized vehicles entering Simpang B from Cak Doko Street is

$$T_{LLma}(B) = 1,8000 + 5,8234 \times D_J - (1 - D_J)^{1,8}$$
$$= 1,8000 + 5,8234 \times 0,588 - (1 - 0,588)^{1,8} = 5,02$$

The average traffic delay for all motorized vehicles entering Simpang A from Nangka Street is

$$T_{LLmi} = \frac{q_{TOT} \times T_{LL} - q_{ma} \times T_{LLma}}{q_{mi}}$$
$$T_{LLmi}(A) = \frac{1610 \times 6,79 - 1374 \times 4,5}{235} = 19,92$$

The average traffic delay for all motorized vehicles entering Simpang B from Pemuda Street is

$$T_{LLmi} = \frac{q_{TOT} \times T_{LL} - q_{ma} \times T_{LLma}}{q_{mi}}$$
$$T_{LLmi}(B) = \frac{1471 \times 6,66 - 1292 \times 5,02}{178} = 18,52$$

So the waiting time caused by traffic interaction with opposite traffic movements at Cak Doko Street intersection A is 4.5 seconds/pcu and for intersection B is 5.02 seconds/pcu. Meanwhile, the average traffic delay for Nangka Street is 19.92 seconds/pcu and for Pemuda Street is 18.52 seconds/pcu.

The mean geometrical delay of the entire intersection

$$T_G(A) = 2,48$$
$$(1 - 0,603) \times \{6 \times 0,28 + 3 \times (1 - 0,28)\} + 4 \times 0,603$$

$$T_G(B) = 3,83$$
$$(1 - 0,588) \times \{6 \times 0,19 + 3 \times (1 - 0,19)\} + 4 \times 0,588$$

So the additional travel time caused by the deceleration and acceleration of vehicles turning at intersection A and intersection B or what is called the geometric delay is 2.48 seconds/pcu for intersection A and 3.83 seconds/pcu for intersection B.

So, the total delay of intersection A and intersection B is

$$T = T_{LL} + T_G$$
$$T(A) = 6,79 + 2,48 = 9,27$$
$$T(B) = 6,66 + 3,83 = 10,49$$

The additional travel time used by the driver to go through intersection A when compared to a track without an intersection is 9.27 seconds/skr, while for intersection B it is 10.49 seconds/pcu

The probability that a queue will occur at each approach at intersection A is

$$P_A =$$
$$47,71 \times 0,603 - 24,68 \times 0,603^2 + 56,47 \times 0,603^3 = 15\%$$
$$P_A =$$
$$9,02 \times 0,603 + 20,66 \times 0,603^2 + 10,49 \times 0,603^3 = 32\%$$

While the probability of a queue at each approach at intersection B is

$$P_A =$$
$$47,71 \times 0,588 - 24,68 \times 0,588^2 + 56,47 \times 0,588^3 = 15\%$$
$$P_A =$$
$$9,02 \times 0,588 + 20,66 \times 0,588^2 + 10,49 \times 0,588^3 = 31\%$$

Based on the results of the analysis, the probability of queuing vehicles at intersection A is 15-32% while at intersection B is 15-31%.

3.4 Traffic Conditions for the Next 10 Years

Traffic projections in the next 10 years in the city of Kupang is based on the growth rate of motor vehicle obtained from the Central Statistics Agency of Kupang City (Badan Pusat Statistik Kota Kupang, 2018) City (Badan Pusat Statistik Kota Kupang, 2014) can be seen in Figure 6 and Table 3

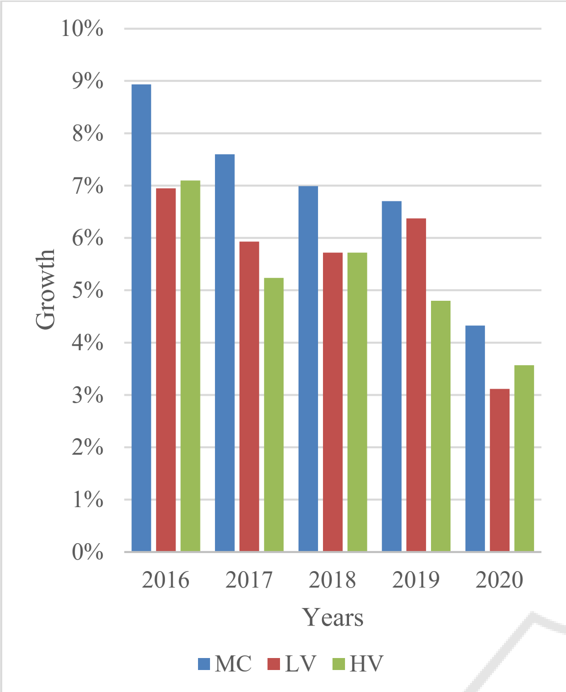

Figure 6: Growth in the Number of Vehicles in Kupang City.

Table 3: Average Growth in the Number of Vehicles in Kupang City.

Vehicle Type	Average
Motorcycle (MC)	6.91%
Light Vehicle (LV)	5.62%
Heavy vehicle (HV)	5.28%

From Figure 6 it can be seen that the highest growth of motorized vehicles occurred in 2016 in the type of motorcycle vehicle with a growth rate of 8.93%, while the lowest growth rate occurred in 2020 in the type of light vehicle which was 3.11%. From table 3, it is found that the average growth of each type of vehicle over the last 5 years is 6.91% for motorcycles, 5.62% for light vehicles, and 5.28% for heavy vehicles. From the average growth rate for each type of vehicle, this is then used to project traffic conditions in the next 10 years.

Traffic flow in the next 10 years as shown in Figure 7 and Figure 8 is then analyzed using PKJI 2014 to obtain traffic behavior and traffic performance without handling or in other words no improvements have been made, traffic management is still as it is today as shown in table 4.

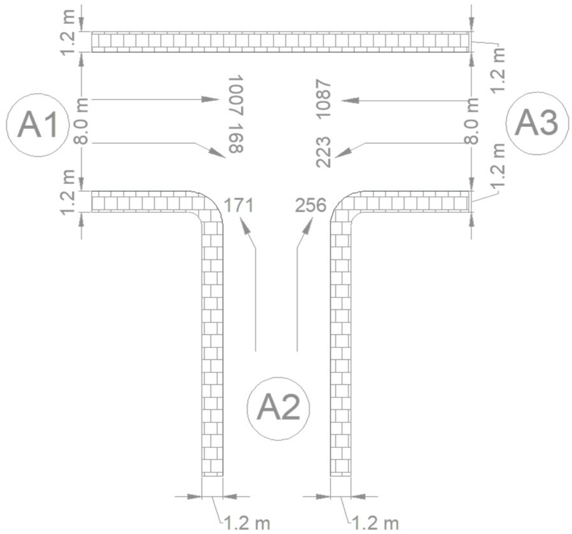

Figure 7: Traffic flow conditions in the next 10 years on Intersection A.

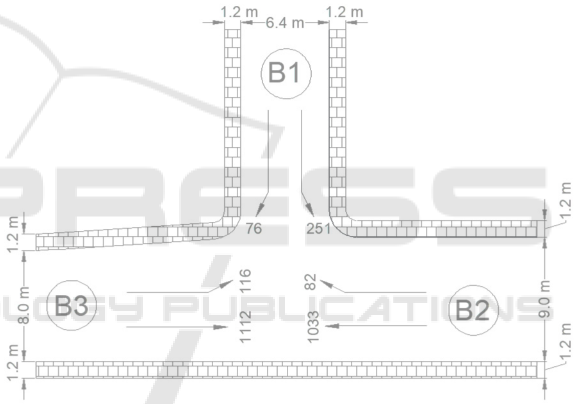

Figure 8: Traffic flow conditions in the next 10 years on Intersection B.

Table 4: Intersection Performance Conditions for the Next 10 Years.

Parameter	Intersecton A	Intersecton B
Total Traffic Flow, pcu/hour	2912	2669
Degree of saturation	1,090	1,068
Intersection traffic delay, sec/pcu	20,34	18,71
Intersection geometric delay, sec/pcu	4,00	4,00
Total Intersection delay, sec/pcu	24,34	22,71
Queue Opportunity, %	48 - 96	46 - 82

It can be seen from table 4 that there will be a decline in the performance of the intersection in the next 10 years, with increasing traffic flow, in year 0 the traffic flow only reached 1610 pcu/hour at intersection A, increasing to 2912 pcu/hour, while at intersection B the traffic flow traffic in year 0 was 1471 increasing to 2669 pcu/hour. As a result of the increase in traffic flow then the impact on the degree of saturation which in the 10th year at intersections A and B only reached 0.603 and 0.588 increased to 1.090 and 1.068, respectively. This increase in v/c ratio also has an impact on the total delay of intersections A and B, which initially only reached 9.27 sec/pcu in year 0 and 10.49 sec/pcu, in the 10th year it increased to 22.71 sec/pcu. pcu and 24.34 sec/pcu with queuing probability for intersection A is 48%-96% and for intersection B is 46%-92%.

3.5 Intersection Performance Improvement

One of the ways to improve intersection performance with traffic management is to regulate the movement of traffic flow by prohibiting each leg of the intersection to turn right (E. S. Prassas *et al*., 2020) (S. R. Srinivasula *et al*., 2020). This is the most economical step without adding infrastructure or overhauling existing infrastructure (J. Goyani, P, *et al*., 2019). The analysis is carried out using traffic conditions in the next 10 years with infrastructure conditions that are still the same as in year 0 with the arrangement of traffic movements not turning right as shown in Figure 9 and Figure 10.

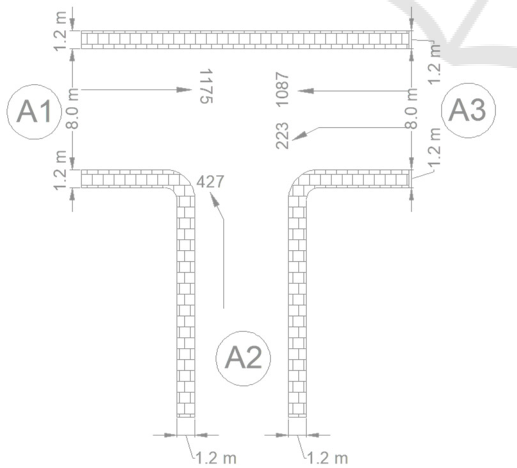

Figure 9: Arrangement of intersection A traffic movement.

Seen in Figure 9 and Figure 10, the traffic flow at intersection A and intersection B if a right turn prohibition is applied, so there is no conflict at the intersection. Traffic flow on this movement is then analyzed based on the PKJI 2014.

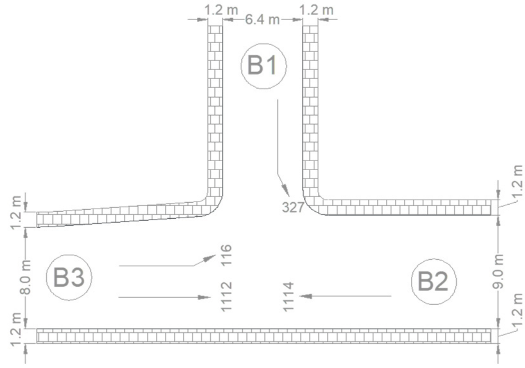

Figure 10: Arrangement of intersection B traffic movement.

Table 5: Traffic Performance After Traffic Arrangements.

Parameter	Intersection A	Intersection B
Total Traffic Flow, pcu/hour	2912	2669
Degree of saturation	0.843	0.825
Intersection traffic delay, sec/pcu	10.27	9.90
Major Road Traffic Delay, sec/pcu	6.1	6.56
Minor Road Traffic Delay, sec/pcu	34.76	33.87
Intersection geometric delay, sec/pcu	1.10	3.91
Total Intersection delay, sec/pcu	11.37	13.81
Queue Opportunity, %	29 - 57	27 - 54

It can be seen in table 5, that there was an increase in traffic performance at both intersections due to the regulation of traffic movement at the intersection. The traffic flow in the 10th year at intersection A and intersection B, namely 2912 pcu/hour and 2669 pcu/hour turned out to produce a degree of saturation of 0.843 and 0.825, which decreased the v/c ratio from before treatment was 1.090 and 1.068. Meanwhile, the total delay at the intersection after adjusting the traffic movement resulted in a delay of 11.37 sec/pcu for intersection A and 13.81 sec/pcu for intersection B, this decreased from the previous which reached 24.34 sec/pcu for intersection A and 22.71 sec/pcu for intersection B. Chances of queues are also decreasing due to traffic movement regulation, which only reached 29%-57% for intersection A and 27%-54% for intersection B, this is better than before the regulation namely reaching 48%-96% for intersection A and 46%-82% for intersection B.

Based on the results of the analysis in table 5, the performance of intersection A and intersection B is still sufficient for the next 10 years, with no need for additional infrastructure, it is only enough to rearrange traffic movements at both intersections by prohibiting vehicles to turn right at both intersections.

4 CONCLUSIONS

Based on the results and discussion, The analysis of the condition of intersection A and intersection B in 10 years will cause traffic jams, the capacity of the intersection will not be able to accommodate traffic flows that have exceeded capacity, this can be seen from the v/c ratio of intersection A which reaches 1.090 and intersection B reaches 1.068. Traffic regulation in the form of a right turn prohibition for each leg of the intersection will improve the performance of the intersection, this can be seen from the capacity of the intersection that will be able to accommodate traffic flow with a v/c ratio for intersection A 0.843 and intersection B 0.825.

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