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Study on Increasing the Capacity Management and Engineering of Junction Roundabout Plus Underpass: A Case Study on Intersection of Jl. Perintis Kemerdekaan and Sultan Hasanuddin Airport

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Abstract

The condition of movement in Makassar continued to increase so that the high density of vehicles that weigh on the road impacted on the declining performance of the road network, especially in theprimary and secondary arteries road network in Makassar mainly at the intersection of Jl. Perintis Kemerdekaan-Jl. Poros Maros–Jl. Tol Sutami–Jl.Sultan Hasanuddin Airport. To solve the matter, at the intersection of Jl. Perintis Kemerdekaan-Jl. Poros Maros–Jl. Tol Sutami–Jl.Sultan Hasanuddin Airport, it is required pattern of management and engineering with roundabouts plus underpass as an alternative way to improve services at the intersection. The study lasted for two years in which the first year it is focused on designing operational functions traffic lightassociated with cycle times setting and the optimum number of phases to further increase the capacity of simultaneously measuring the performance of the services of the Traffic Light Application. While in the second year, it is focused on designing roundabouts plus underpass as the main element in the analysis of that work integrated with the traffic light in determining the performance and service level technically /traffic engineering by measuring the Vehicle Operating Cost savings (VOC), the efficiency of the value of time and the delay and the difference in travel time for perspective use until 2025.
The level of saturation that occurs on this intersection between 0.31 to 1.0 is in low performance on the level of service F with a high frequency of traffic jams. Obtained optimum phase number of cycles is 153 seconds of green light each time nearly on north south west and east is 28 seconds, 36 seconds, 38 seconds and 44 seconds. This value is expected to address the queues of 6-160 vehicles and delays by 18 seconds up to 54 seconds per vehicle while waiting for the construction of the undepass and roundabout resolved.

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Keywords: Intersection, Traffic Light, Roundabout, Underpass, delay, VOC

1. Introduction

Makassar city is the fourth largest city in Indonesia and known as the largest in eastern Indonesia which lies between 119°24'17'38"East longitude and 5°8'6'19" South latitude and in the North and East bordering with Maros, and in the South bordering with Gowa regencywhile in the West by the Strait of Makassar [1].

Makassar city is administratively as the capital city of South Sulawesi Province with the total area of 175.77 km² covering 14 districts.It lies at an altitude of 0-700 meters above sea level. In the 2012 BPS Makassar's data, the total population of Makassar city was 1,352,136 with the rate of population growthwas 1.56% per year. In the mean time, the number of vehicles in South Sulawesi were 2.2 million units in which 1.4 million were of motorcyclesand the rest were cars.Meanwhile the growth of vehicles in South Sulawesi was 8% to 10% for cars per year and 13% to 14% for

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motorcycles per year. As for the city of Makassar, the number of vehicles reached 700 thousand units.

The tendency of the increasing number of vehicles inthe highway use continues to increase up to 16% per year, so it is feared for the future road network development which is relatively very low even below 1% per year will be no longer able to accommodate the society movement, goods and services [2]. The high demand of movement will push the trend of transportation facilities and infrastructure needs.

Condition of vehicle movement in Makassar which continue to increase has been implicated in the high density of vehicles that overload on the road network. These conditions also impact the declining performance of the road network, especially the primary and secondary arterial network [2] as strategic networks in Makassar, such as Jl.PerintisKemerdekaan, pivotal road to Maros (Poros Maros), Toll Reformasi and Sultan Hasanuddin Airport.

Visually, condition node (intersection) of the network, it has experienced a significant decline in performance, there is a long queue of vehicles with high frequency [3]. Intersection with the systems used today are no longer effectively regulate the flow of traffic volume which is high enough.The indicator can be seen from the cycle time of the Traffic Light that cannot regulate the movement of traffic coming from several directions. So that, this might impact on the occurrence of a long enough queue of vehicles [4], especially from the direction of Jl.PerintisKemerdekaan, pivotal road to Maros (Poros Maros), Toll Reformasi and Sultan Hasanuddin Airport.

Basically, a variety of alternative treatment has been carried out, for examplechange in the direction of movement and in shape of the intersection, which is certainly expected to increase the capacity of the intersection.But these alternativesarejust temporal and do not provide a significant contribution to the increasing of the intersection capacity [5, 6].

In this case,it is necessary to manage the intersection with the system of Roundabout plus Underpass as an alternative to increase the capacity of the intersection and at the same time it can improve service at the intersection. As a turn result, it is expected to contribute to the increasing mobility and productivity of society that would positively correlated with economic growth of Makassar in South Sulawesi both in particular and in general [7, 8]. This intersection is also expected to be an icon entrance of Makassar city, South Sulawesi from the Sultan Hasanuddin International Airport and the entire vehicles movement from the north of Makassar.

The main problem is focused on the analysis of the Roundabouts plus Underpass design at the intersection, in addition to optimizing the existing traffic light. The main problem in this research is measured on the following matters:

1. To what extent the increasing capacity on the use of Roundabout plus Underpass toward the intersection performance.

2. What level of technical feasibility and traffic management using several criteria and the analysis of the material such as, increasing the capacity of the intersection, vehicles operating cost savings (VOC), the efficiency of the time value, queue and the difference of travel time.

3. How to determine the timing of operational and traffic light cycle times are optimized in each side of the intersection.

This research aims to carry out analysis of the influence on the design of Roundabouts plus Underpass at the intersection of Sultan Hasanuddin Airport follows the road network surrounding the transportation movement performanceat the intersection as well as the effect pertaining to the use of traffic light.

2. Research Method

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This research was conducted in Makassar city for two (2) years, started from the design stage, the needed data survey (either primary or secondary data) and map the macro from the relevant authorities in Makassar:

a. The research was conducted in Makassar on the Roundabout plus Underpass at Airport intersection. The approach used in this research is descriptive and explanatory research.

b. This research design was used primary and secondary data collection. In addition, this research was supported by the theories and the previous related research results, as well as methods of analysis that was used to answer the problem.

c. The first year of the research was to develop the design of the traffic light system at Sultan Hasanuddin Airport intersection as theresearch object.

To find out how the increasing of capacity and service levels are, the decrease in the degree of saturation and the number of queues and queue opportunities occur at the intersection, including a reduction in travel time and delay.

The stages in the implementation of the research and analysis process were outlined below:

2.1. Research Area Restrictions

Research area was in Makassar, it coveredthe area of Jl.PerintisKemerdekaan, pivotal road to Maros (Poros Maros), Toll Reformasi and Sultan Hasanuddin Airport approximately 100 meters on each side of the intersection

2.2. Implementation of the survey

A better picture of the characteristics of the researched object was obtained from the relevant information with the intent and purpose of research. Further information be obtained by field observation and interviews.

The method used to obtain the necessary data were, as follows [9]:

- Observation, which was done through observation and systematic statement of the symptoms or the observed phenomenon based on direct observation.
- Interviews with relevant parties in this case the manager of the operational management of transport services, and the vehicle drivers.
- Documentation, by using documentation in the form of photographs and field note related to the research.

2.3. Data Analysis

This research was conducted by performing the formulation and identification of problems related to the implementation of road traffic policy, a policy that has been done. In line with it, itwas done a study toward the theory and other related library research [10]. The questionnaire, it was a data collection techniques by providing a series of questions given to the respondents, in this case road users from various communities proportionally [11, 12].

3. The Research Results

3.1. Analysis of Roads Characteristics

The biggest vehicle flow is occurred on Monday (as a busy day), therefore the direct field observations conducted by collecting data related to the characteristics of the traffic are traffic

volume, vehicle speed, the effective width of the road and then conducted by the processing and analysis. Collecting data from each type of vehicle groupcalculated through the total of the vehicles in each period of observation that is inthe period of time in 15 minutes for 1 hour, then it was taken the highest volume of each road [13].

3.2. Volume of Traffic

The survey result of the traffic volume on the roads around pivotal road to all directions in 2014 are presented in Table 1.

Table 1. Traffic Volume on Each Side Intersection

No	Road	Volume (smp/hour)		
		Median	Minimum	Maximum
1	Jl. PerintisKemerdekaan	7,166	822	10,302
2	Jl. Poros Maros	8,359	6,844	10,247
3	Jl. Tol Reformasi	2,976	1,502	4,751
4	Jl. Bandara St. Hasanuddin	2,982	2,611	4,327
Average (Median) Volume		5,371	2,945	7,407
Lowest Volume		2,976	822	4,327
Highest Volume		8,359	6,844	10.302

The table shows the highest volume occurring is 8.359 pcu/hour, and the lowest volume of 2,976 pcu/hour, with a median score of 5.371 pcu/hour. Based on the maximum values, it appears that the highest volume achieved is 10.302 pcu/hour, the lowest 4.327 pcu/hour and the median score of 7.407 pcu/hour, while the value of the minimum volume of 6.844 pcu/hour, while the lowest of 822 pcu/hour and the median score of 2.945 pcu/hour.

3.3. Spot Speed

The survey results of spot speed on the roads around the intersection in this activity is presented as seen in Table 2 below

Table 2. The characteristics on Roads around Intersection

No	Roads	Free Flow of Spot Speed (Km/hour)	Road Capacity (Smp/Hour)	Degree of Saturation
1	Jl. PerintisKemerdekaan	22,54	5.880	1.22
2	Jl. PorosMaros	17.43	4.277	1.95
3	Jl. TolReformasi	28.54	3.666	0.81
4	Jl. Bandara St. Hasanuddin	16.25	5.880	0.51
Mean score		22.54	4.926	1.12

As seen in the Table 2 above, it appears that based on the free flow of Spot Speed, the highest free flow of spot speedis at 28.54 km/hour, while the lowest is at 16.25 km / h, with the median score of the speed is 22.54 km/hour.

3.4. Road Capacity

The capacity on the four roads which are obeseved in this research is presented in Table 3 above. Based on the Table 3, it is shown that the highest capacity on the roads around the Airport Intersection of 5,880 pcu/hour and the lowest capacity of 3666 pcu/hour, with the median score of the capacity is 4926 pcu/hour

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3.5. Saturation Degree of Traffic

The degree of saturation describes the level of traffic density in an intersection, in which this value is the ratio of the roads capacity on the intersection.It can be presented in the Table 3 above. From the Table 3, it appears that the highest degree of saturation is occurring at 1.04, and the lowest degree of saturation is at 0:38, with the median score of the degree of saturation is at 0.76

3.6. Road Service Level

The results of data analysis shows the value of the service level at 4 roadsas samples in this research. The value of the service level of the four (4) roads shows that the roads which are surveyed around the Pivotal Road to Maros (PorosMaros) – Jl. PerintisKemerdekaan – Sultan Hasanuddin Airport - Toll Sutami is E in average (median), but it is found two segments of the roads showed a solid queue condition tends to saturate with the degree of saturation above the value of 1.00. When it is analyzed based on the spot speed, so that it is stated that the intersection indicates the service level in the category F on Jl. PerintisKemerdekaan, category F on Jl. MarosDaya, category B on Jl.Ir.Sutami, and category B on Jl. Sultan Hasanuddin. This is obtained from the ratio between the spot speed and the degree of saturation.

3.7. Queue Length

The number of vehicles passed through the intersection where in its movement it would have a long waiting queue for other vehicles that crossed the intersection.It is described in the calculation of the following queues

The Stop value of the four roads around the intersection was obtained by dividing the number of vehicles stopped at intersections throughout the nearest flow, so that the total flow Q around intersection is in vehicles/h [14, 15]. From the applicable equation, so that it the average value of the proportion of stopped vehicles is 0,975 stop/pcu

Table 3. The Length of Queues on the Four (4) Roads around Intersection

Code	NQ_1	NQ_2	NQ	NQ_{MAX}	QL	NS	NSV	Tot
PS	23	50	73	64	160	1.296	3151.742	6892.867
MU	4	62	66	64	142	0.860	2580.946	
TB	1	25	26	32	6	0,904	1086.969	
BT	0	6	6	9	36	0.169	73.210	

3.8. Delay

A measure of critical efficiency in the disrupted roads facilities is delay. The delay is a common measure that can be interpreted by the average number of stops. Average stopped time delay is a measure of the principle effectiveness used in evaluating the servicelevel at signalized intersections [16].

The stopped time delay is the time spent by a vehicle to a stop in a queue while waiting to enter to an intersection. The average stopped time delay is the total of stopped delay experienced by all vehicles on a road or a group of rows during a specified period of time. It is then divided by the total volume of vehicles entering the intersection on road or lane group at the same period of time expressed in seconds per vehicle [17]. Traffic and geometric delays are respectively at the intersection of roads that can be seen as follows:

Table 4. Delays on Roads around Intersection

Code	DT	DG	D	D_{Tot}	Tot	Av Delay
PS	48.631	4.953	53.584	34.133	76.549	11 sec/pcu
MU	14.790	3.549	18.339	11.682		
TB	24.109	3.690	27.799	17.708		
BT	17.873	2.575	20.449	13.026		

From the various results of the analysis indicate that the total of the actual flow entering the intersection is very large and it is happened a frequent traffic jams. This is due to the traffic light performance at the intersection which is no longer effective in regulating the flow of traffic.

3.9. Traffic Light

The traffic light is a manually operated equipment, mechanical or electrical for vehicles to be ordered to stop or run [18]. In planning traffic light and phase of the signal, it can be done with a variety of alternatives to be evaluated. As the first step, it is determined by the 2-phases control. A good number of the phase is a phase that produces large capacity and lower the average delay [19]. Separation of the control on the right turn movement will usually be better and if the capacity is 200 smp / hour. This may be expected if the traffic safety becomes one consideration [20]. This situation adds to the number of phases and the time between Intergreen which resulted in the increasing cycle of time and the lost of time. When the flow of right turn of a foot towards the opponent happens to the same phase, then the flow is known as a "oppsed". While the flow of right turn is not allowed to turn right, so that it is known as "protect" [21].

By doing the analysis for the purpose of resetting the traffic light, so that the cycle of times obtained for 153 seconds. The Green time for crossing near the intersection varies between 28 seconds to 44 seconds with a time allocation that can be seen in the Table 5, as follows

Table 5. Time Signals on Roads around Intersection

No.	Phase	Time Signals (Sec)			Red in the same time (Sec)	Time Cycle (sec)
		Green	Yellow	Red		
1.	I (PS)	28	3	120	2	153
2.	II (MU)	36	3	115	2	
3.	III (TB)	38	3	113	2	
4.	IV (BT)	44	3	107	2	

3.10. Calculation Analysis of Traffic after Existence of Underpass

From the data dimensions and road conditions, it can be determined the amount of road capacity is calculated using the following equation [22]:

$$C = C_o \; x \; FC_w \; x \; FC_{sp} \; x \; FC_{sf} \; x \; FC_{cs}$$

Where: C = the capacity of roads pcu/hour ; C_o = base capacity= 6.600 pcu / hour
FC_W = factor of capacity adjustment for lane width = 0.92
FC_{sp} = factor of capacity adjustment for the separation direction = 1.00
FC_{sf} = factor of capacity adjustment for side friction = 0.95
FC_{CS} = factor of capacity adjustment for the size of the city. = 1.00

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Thus,it is believed that with the existence the underpass building, it is estimated the DS value for Jl.PerintisKemerdekaan was reduced from 1.0 to 0.31 while Jl. Maros-Daya from 0.9 to 0.38. These results illustrate the phenomenon of the increasing capacity of the intersection up to 3 times to 4 times that of from the previous.

4. Conclusion

From the analysis and calculation of traffic light performancecarried at the intersection, the conclusion can be given,as follows:

• Setting of the cycle of time of traffic light used at the intersection of Jl. Pivotal Makassar-Maros now is no longer effective in regulating the flow of the current traffic. It can be seen on the degree of saturation which approximately reached 1.0 to Jl. Perintis Kemerdekaan and 0.9 to Jl. Maros-Daya. Similarly, the high value of long delays and queues showed the 11 seconds for each vehicle reached 0.975 stop/vehicle.

• The effectiveness of the intersection services can be improved to be better by planning underpass engineering. This is expected to cause a degree of saturation that reducedfrom 1.0 to 0.31 for Jl. PerintisKemerdekaan and for Jl. MarosDaya reduced from 0.9 to 0.38

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