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The Evaluation of New Roundabout Performance: A Case Study of *Barelang* Roundabout Development

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Abstract
Smooth traffic conditions can improve population mobility services and other supporting resources for economic growth. However, traffic jams often occur in a densely populated city like Batam, which stress road users, improve economic speed, and waste much time. Therefore, it is necessary to check the steering performance. The purpose of this study is to determine whether the Barelang junction roundabout is effective in the traffic situation prevailing in the area. In this study, a traffic survey was conducted on the Barelang Junction Batam road to determine the number of vehicles passing through Barelang Junction. The reference used in this research is the Indonesian Highway Capacity Manual (IHCM) 1997, where road capacity, traffic density, and saturation level are analyzed. The results obtained from SP Plaza to the road to Muka Kuning have a saturation value of 0.72. The saturation level of the route from Muka Kuning to SP Plaza is 0.57. Based on IHCM 1997, it was determined that the value of the saturation level of a road section should not be more than 0.75, so it can be concluded that the two roads located at the Barelang T-junction are classified as efficient. The results of this study can be used as a benchmark to improve transportation performance.

Keywords: Development, Performance, Roundabout.

1. Introduction

Roundabouts are a type of intersection control system that is commonly used in urban and non-urban areas (Isradi & Pratama, 2020). A roundabout traffic system is designed so that traffic already at the roundabout has road space, so vehicles entering the roundabout must first yield to traffic already at the roundabout (Muchlisin, M.Wijayanti, & Amanda, 2021). The purpose of roundabouts is to eliminate traffic jams on certain road sections. Therefore, the bigger the traffic at the intersection, the bigger the roundabout needed to reduce traffic congestion (Shaker & Bigdeli Rad, 2018).

Roundabout traffic capacity under outdoor traffic conditions is determined based on the relationship between all ground motions and conditions (Andika, Rifai, Isradi, & Prasetijo, 2022) . The Barelang Junction Roundabout, located in Batu Aji, Batam City, Riau Archipelago, is a government project to improve traffic infrastructure (Anthony, Ginting, & Wibowo, 2022). This is due to the increasing number of residents and vehicles in the city of Batam. The population growth of the city of Batam itself was 1,076,009 people in 2019, according to the Batam Central Statistics Agency. Then in the 2020 Batam city population census, it increased to 1,196,296 people (Sama, et al., 202).

The IHCM 1997 can be used as a method, which is the result of empirical studies conducted in several places, which can describe the state of traffic characteristics in the Indonesian region. (Saputra, Wiratno, Istardi, & Koto, 2018). IHCM 1997 is a guideline for the analysis, planning, design, and operation of road transportation facilities issued by the Department of Public Works (Mufhidin, Karimah, Isradi, & Rifai, 2022) . Previous studies identified roundabout performance analysis in various cities in Indonesia (Sun, Oh, & Ong, 2021). This shows that this method can also be used to analyze the performance of the Simpang Barelang road in Batam City.

Transportation is a significant means to support the success of development, primarily to support urban entrepreneurship. Smooth traffic conditions can improve population mobility services and other resources that support economic growth (Azizi, Kumar, & Toll, 2021). In addition, smooth traffic reflects the order and regularity of road users (Nasution & P., 2022). However, in different contexts and realities, there is a tendency for traffic problems that often accompany urban development. A typical transportation problem is traffic jams (Wardhani & Alfiansyah, 2022).

The cause of traffic jams is that the capacity of the freeway is not proportional to the number of vehicles passing, the accumulation of vehicles is often caused by people who prefer to use private vehicles for public transportation, and also the lack of adequate traffic infrastructure (Efendi & Anwar, 2019). Traffic jams can cause stress to road users, the economy slows down, and much time is wasted (Isradi, Dwiatmoko, Setiawan, & Supriyatno, 2020). One of the steps that can be taken in overcoming the problem of congestion is to identify road capacity, which includes road capacity, traffic frequency, and degree of saturation. Of course, specific methods are used to determine the path so that the results obtained are more accurate and precise (Muppidi & Klein, 2020). This research aims to determine whether the Barelang roundabout is effective in the traffic situation in the area. A traffic survey is conducted to determine the number of vehicles passing through the road.

2. Literature Review

A roundabout is a type of traffic control at an intersection without the use of traffic lights (although, in practice, traffic lights are sometimes also installed) in the form of a roundabout and vehicles passing through it must turn in the same direction following the roundabout before exiting at the desired intersection arm. Roundabouts are usually slightly elevated from the traffic lane but are sometimes marked with paint on the pavement surface, as in England's mini-roundabouts (Riccardi et al., 2022). Roundabouts are designed for consistent, low-speed traffic. This type of traffic control with roundabouts is prevalent in England and adopted by many countries worldwide.

The primary key to traffic safety with this roundabout is to reduce the number of conflict points and reduce the degree of the central conflict (crossing) to secondary conflict in the form of joining and weaving vehicles. (Zhan, Song, Zhang, & Wang2022). Not everything that turns around on the road is called a "roundabout." For example, there is an intersection that has a roundabout in the middle but does not function as a roundabout in traffic management. The attached sign shows the difference between an intersection with a roundabout and an intersection without a roundabout. The roundabout is symbolized by Three Circular Arrows Chasing Each Other.

For the safety of road users, it is recommended that the center point of the circle is exactly where the axes of each approach arm intersect. However, because traffic in Indonesia runs on the left, shifting the circle's center point slightly to the left of the road axis can still be accepted by making a note that a traffic guide arch is made. Furthermore, a dividing island must be provided at each foot of the approach, which functions to direct traffic and as a protector or temporary stop for pedestrians crossing.

The main advantage of using a roundabout as a traffic controller is safety. Based on data in the USA shows that the use of roundabouts at intersections can reduce the accident rate to half from before the roundabout was installed (Poudel & Singleton, 2021). This is due to the need to reduce speed due to roundabouts and reduced points. Reducing vehicle speed also reduces the chance of a pedestrian being hit by a vehicle and dying from 85% at 65km/h to 15% at 32km/h (Department of Transport, 1995). In addition, roundabouts can reduce delays when operating at design capacity because vehicles do not have to stop before entering the roundabout.

In addition, roundabouts can reduce environmental pollution because vehicles do not experience delays or stop like at traffic-lighted intersections. Roundabout maintenance costs are relatively cheaper because no equipment requires electricity, light bulbs, or other tools that require high maintenance costs. When viewed from a non-traffic function, roundabouts aesthetically, if appropriately designed, can have a stimulating effect. However, of course, the roundabout also has weaknesses. Although there are many advantages, traffic management with roundabouts also has a weakness. Namely, it requires a wider area than other types of intersection arrangements. At intersections controlled by coordinated traffic light settings, roundabouts can disrupt the smooth movement of vehicle groups (platoons), thereby disrupting the

function of the coordinated traffic light settings. Roundabouts can cause delays if the traffic volume on each approach is not balanced.

3. Methodology

This research is located in Tembesi Village, Batu Aji District, Batam, Riau Islands, with the coordinates of 1°02'21"N103°59'55"E East. The object of this study is the roundabout traffic intersection, as shown in Figure 1. precisely on the road from SP Plaza to Muka Kuning and from Muka Kuning to SP Plaza. This research uses the method of literature study and data collection. Data is one of the fundamental forces in constructing modeling and scientific research (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015) . The process of systematic scientific research must also begin by identifying the correct problems (Rifai, Hadiwardoyo, Correia, & Pereira, 2016). Data collection was carried out by surveying the SP Plaza road leading to Muka Kuning and vice versa during peak hours, namely 17.00 – 18.00, to obtain primary data on the number of vehicles passing. Data collection on road specifications was also carried out at the research location. At the same time, secondary data in the form of the population of the city of Batam was obtained from the Central Bureau of Statistics (Recky, 2021).

This study uses a calculation method based on the Indonesian Road Capacity Manual. The analysis carried out in this study includes road capacity, traffic volume, and degree of saturation. Road capacity analysis is used to determine the ability of roads to accommodate traffic volume. In comparison, an analysis of traffic volume is used to determine the level of traffic expressed in units of pcu/hour. From the capacity and traffic volume data, an analysis of the degree of saturation can be carried out to determine the degree of saturation of the roads studied. So from the analysis of the degree of saturation, it can be determined whether the road segment is influential.

4. Result and Discussion

The analysis carried out in this study is to calculate the volume of traffic flow on the SP plaza traffic flow towards the yellow face and the yellow face traffic flow towards the SP plaza. So from this analysis will get the degree of saturation (DS). Road capacity calculation Road capacity is used to determine the ability of a road segment to accommodate traffic flow or volume. The capacity of the road from SP Plaza that leads to the yellow face with two lanes is 1630.23, with a total road capacity of 3260.46 pcu/hour. The calculated value shows that the road leading to the yellow face is effective based on ICHM 1997.

The volume of traffic flow is the number of vehicles that pass through a road to be studied, where the data included is the volume of traffic calculated every hour. Calculation of the volume of traffic flow is carried out on the traffic flow of SP Plaza heading towards Muka Kuning and from Muka Kuning towards SP Plaza. Traffic volume from SP Plaza heading towards can be seen in table 1.

Table 1. Traffic volume data

Time	Motorcycle	Light Vehicle	Public Transport	Heavy Vehicle
17:00-17:15	580	241	19	23
17:15-17:30	617	273	30	26
17:30-17:45	591	255	23	19
17:45-18:00	566	233	18	16
Total	2354	1002	90	84

According to IHCM, the vehicle correction factor is LV = 1, HV = 1.3, and MC = 0.5. Traffic composition affects the flow-speed relationship if flow and capacity are expressed in vehicles/hour, i.e. depending on the ratio of motorcycles or heavy vehicles in the traffic flow. If traffic and capacity are expressed in passenger car units, then traffic composition does not affect light vehicle speed and capacity (pcu/hour). (Prayitno & Veronika, 2019). In the manual, the value of traffic flow (Q) reflects the traffic composition by expressing the flow in units of passenger cars (Almaida & Purnomo, 2021). All traffic flow

values (per direction and total) are converted into passenger car units using passenger car equivalents derived empirically for the vehicle type.

The effect of non-motorized vehicles is included as a separate event in the side drag adjustment factor. The passenger car equivalent (emp) for each type of vehicle depends on the type of road and the total traffic flow expressed in vehicles/hour. The passenger car equivalent indicates different types of vehicles compared to light vehicles concerning their effect on the speed of light vehicles in a traffic stream (for passenger cars and light vehicles with parallel sides, emp = 1.0). The passenger car unit (pcu) is a unit for traffic flow where the flow of various types of vehicles is converted into the flow of light vehicles (including passenger cars) using the equivalent of passenger cars (emp) (Pratama et al., 2022). Based on the data obtained, it can be calculated traffic volume. as shown in table 2.

Table 2. Correction factor

Correction Factor	Description	Value	Result
LV (x 1)	Light vehicle	(1002 + 90) x 1	1092
HV (x 1,3)	Heavy Vehicle	84 x 1,3	109,2
MC (x 0,5)	Motorcycle	2354 x 0,5	1177
		Total	2378,2

Based on table 2 above, the traffic volume at SP Plaza towards Yellow Front is 2378.2 pcu/hour. Whereas for the opposite direction, a value of 1882.7 pcu/hour is obtained with the same calculation.

The final step is to analyze the degree of saturation (DS). It was used to determine the level of saturation of a road segment. Theoretically, the degree of saturation ranges from 0 to 1, which means that if the value is close to 1, then the road conditions are close to saturation. The degree of saturation of the road section from SP Plaza to Muka Kuning has a capacity of 3260.46 pcu/hour and a traffic flow volume of 2378.2 pcu/hour. Then it can be calculated DS of 0.72. From the calculation analysis above, the degree of saturation is 0.72. This value is below the maximum threshold set by the 1997 IHCM guidelines, namely 0.75. It is a threshold value set by IHCM 1997 based on the existing classification system in IHCM 1997, which means that the road from SP Plaza that leads to Muka Kuning is classified as adequate.

Whereas in the opposite direction DS Road Section from Muka Kuning towards SP Plaza, the capacity for the road section from Muka Kuning that leads to SP Plaza is 3260.46 pcu/hour and has a traffic flow volume of 1882.7 pcu/hour. Then it can be calculated DS of 0.57. From the analysis of these calculations, the DS is below the maximum threshold. This general description can explain that the roads around the Simpang Barang roundabout area are classified as effective for at least the next five years. This is based on data from the Batam City Statistics Center, where the growth Batam city population is relatively stable every year.

5. Conclusion

Based on the research that has been done, the results show that the road from SP Plaza that leads to Muka Kuning has a degree of saturation value of 0.72. Whereas for the road from Muka Kuning that leads to SP Plaza, the degree of saturation is 0.57. Based on the IHCM, it is determined that the degree of saturation value of a road section cannot be more than 0.75, so it can be concluded that for the two roads at the Barelang intersection, this is classified as adequate. The results of this study can be used as a reference in efforts to improve transportation performance.

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