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THE ROAD PERFORMANCE ANALYSIS OF THE TUAH MADANI ROUNDABOUT, BATAM-INDONESIA

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ABSTRACT

Roundabouts are considered to be an adequate replacement for signalized intersections and reduce congestion in urban areas. However, the increase in vehicles each year causes roundabouts to be ineffective in distributing vehicles. This paper aims to analyze road performance. The research method was carried out by means of a field survey. Data was collected from the Tuah Madani Roundabout, Batam, Indonesia. The results show that the average speed is 46 km/hour and a small degree of saturation, with a good level of service. It is stated that the roundabout is still comfortable for motorists to pass through.

INTRODUCTION

A roundabout is a one-way intersection that aims to facilitate the flow of a road. Roundabouts are self-limiting intersections, so they have many advantages over other signalized intersections. Simply reducing the vehicle's speed and the number of collision points ensures the maximum possible safety and comfort (Patnaik, Krishna, Rao, & Bhuyan, 2017). The use of roundabouts on the road must follow its rules. However, a two-lane or alternative design is required if these roundabouts cannot meet traffic engineering or geometric constraints. In recent years, the turbo gyro has become the most popular alternative design (Šarić & Lovrić, 2017). The decision to replace traffic with a roundabout which is classified as small, is a global problem. This type of intersection should not be placed on first-class roads and high-intensity roads due to the low capacity and permeability of small roundabouts (Kalašová, Skřivánek Kubíková, Čulík, & & Palúch, 2020).

Indonesia's development in the automotive world continues to increase every year. Motorcycles are vehicles that are mostly used by most of the Indonesian population. Many cities' road networks have roundabouts, but some are non-standard roundabouts (Purwanto & & Basuki, 2022). The number of vehicles compared to the width and size of roads in Indonesia, which are not evenly distributed, and the use of signalized intersections or roundabouts that are not good cause terrible traffic jams. In addition, the approach of the passenger car unit to predominantly non-passenger traffic (i.e., mixed or motorcycle-dominated traffic) will lead to potential bias in the results (Sudibyo & & Fauzan, 2021). Lane changes, turns, and random motorized vehicles most likely cause congestion.

Batam gets the nickname industrial city, meaning many employees come from outside the area to work in Batam. This incident caused the city of Batam to be congested on the way to and from work, resulting in traffic jams at several road points. The intensity of this vehicle continues to increase every year; With a total of 939,505 vehicles, Batam City topped the rankings in the

number of vehicles in the Riau Islands (Kepri, 2022). The volume of vehicles is what makes several road points in Batam, especially roads with 1 and 2 lanes, become congestion points. In response to this, the Batam Government is carrying out road widening projects at several points, to overcome this congestion problem in the future.

The most common definition of congestion in the state of traffic flow is when the travel demand exceeds road capacity (Afrin & Yodo, 2020). For example, the Tuah Madani Roundabout links Batam Center, Seipanas, and Nagoya. However, this roundabout becomes ineffective on the way home from work due to 3 intersecting roads, resulting in a reasonably severe traffic jam. The large volume of vehicles differs from a roundabout whose rotation current is not good. In addition, another factor that causes congestion is the vehicle that deliberately cuts from the third road section.

The effectiveness of this roundabout will be calculated based on the flow of the road and the length of time the vehicles are stopped due to cuts from 3 directions. The intensity of 2-wheeled vehicles compared to 4-wheeled vehicles will be one of the data. This roundabout is jammed during work hours until the next 2 hours. This study aims to analyze the performance of the road, namely the smooth traffic flow at the Tuah Madani Roundabout. Reducing one of the cut-out directions is hoped to prevent it from overloading traffic congestion.

LITERATURE REVIEW

Road Performance

Road performance is whether the road responds well to human movement. Of course, it can be said that the performance is bad on roads that are permanently closed to traffic or are likely to be congested (Chen, et al., 2019). The most common definition of congestion in traffic flow conditions is when traffic demand exceeds road capacity (Afrin & Yodo, 2020). The main characteristics of a road affect its capacity and performance when there is traffic underneath. The characteristics used in the calculation procedures in this manual are either direct or indirect. Most of them are also known and used in other road capacity manuals (Tama, Setiawan, & Wasono, 2021).

Road capacity, defined as the maximum design capacity of a given lane at the link and intersection level for automotive traffic, is well known for various lanes and lane widths. To model road capacity, consider how many vehicles can be packed onto the road with all vehicles traveling at their rated speed and within their reaction time constraints (Lazar, Pedarsani, Chandrasekher, & Sadigh, 2018). Drivers do not react to events immediately. Instead, we need time to perceive events, process information, determine reactions, and ultimately implement decisions. All these processes introduce time delays. Less delay means more road capacity and smoother traffic flow (Makridis, Mattas, & Ciuffo, 2019).

One of the factors that affect road performance is traffic signs. Traffic signs are the main interaction between the driver and the environment, and the amount of information is the main factor influencing the driving load. Many previous studies have shown that road sign images can be used as an index to evaluate the road sign threshold for the number of road names by capturing the driver's reaction time (Lyu, Xie, Wu, Fu, & Deng, 2017). Traffic signs regulate vehicles' movement to increase safety and road performance.

Some problems hinder road performance, such as a significant increase in motorized vehicles and cars. Cars overflow urban and suburban transport routes (Romanyuk, Likhanov, & Lopatin, 2018). This event will cause the road to become whole and cause congestion. Good road planning, such as road widening or driving restrictions, must balance this growth.

Road

The road is one of the essential parts of the world of transportation, where the driver can pass it and reach the destination in a shorter time. So, the road can be interpreted as an avenue traversed by motorized vehicles to legally reach a destination in the shortest possible time. Different modes of transport in terms of different population groups. H. (i) Drivers/operators of rickshaws, motorcycles, and bicycles. (ii) Passengers in human-operated, autonomously moving trains and cars; (iii) pedestrians in areas with both human-powered and automatic vehicles (Hulse, Xie, & Galea, 2018). The vehicles are divided into six categories: bus, car, motorcycle, minibus, truck, and van. (Zhuo, et al., 2017).

Based on road function, there are three types of roads i.e: arterial roads, collector roads, and local roads (Sugiyanto & Malkhamah, 2018). Arterials are roads designed to carry high volumes of motorized traffic (McAndrews, Pollack, Berrigan, Dannenberg, & Christopher, 2017). Collector Road is a public road designed for vehicles between the Regency capitals, with average mileage, moderate average speed, and a limited number of entrances (Vitianingsih, Othman, Baharin, & Suraji, 2022). Finally, local roads connect counties to communities, have light traffic, and have the lowest speed limits (Andani, Geurs, & La Paix Puello, 2019).

Categories of roads are classified based on characteristics such as speed of travel, the volume of traffic, volume of traffic, strategic importance, etc (Morales, Reyes, Caceres, Romero, & Benitez, 2018). Kinds of transportation are substantial to traffic volume and traffic mix. The heavier the vehicle (mass), the higher the chance it will take up more space on the road. Separation of vehicles is one of the efforts to overcome overload. In this case, the road under study is a collector road.

There are various ways to define road safety. The most common measures used to judge road safety are the number of road accidents, fatalities, and related adverse effects. (Wegman, 2017). Road safety is a major global health issue since many unintentional injuries are caused by traffic-related crashes (Heydari, Hickford, McIlroy, Turner, & Bachani, 2019). Road traffic injuries represent a major public health burden, with significant consequences in terms of mortality and morbidity and significant health and socioeconomic costs (Organization, 2020). Road safety research plays a vital role in improving socioeconomic conditions by reducing the occurrence and severity of road accidents.

Roundabouts

Roundabouts have proven superior to standard types of level crossings in terms of traffic safety. They are, therefore, very widely used to improve traffic safety on road networks in urban and suburban areas. increase (Deluka Tibljaš, Giuffrè, Surdonja, & Trubia, 2018). Roundabouts enjoy great popularity and favor among designers due to their high level of safety in road traffic (Macioszek, 2022). In addition, converting intersections to roundabouts has been shown to reduce the number of accidents, especially fatalities (Elvik, 2017). Roundabouts can reduce intersection-related fatalities by up to 90% and intersection-related injuries by 75%.

Around the world, there are different types of roundabouts, and each roundabout has its uniqueness. Six types of roundabouts are distinguished in the literature based on size, location, and the number of surrounding lanes: roundabout and Urban Compact Roundabout (Chong & Al-Mamari, 2020). The roundabout is adjusted in the context of the area, road access, field size, and the number of lanes. The many types of roundabouts have only one purpose, namely, to facilitate the movement of vehicles.

Speed is a traffic flow parameter that defines the function and quality of traffic conditions on a road or road network (Davidović, Bogdanović, Garunović, & Papić, 2021). The smoothness of a path is a benchmark for road performance, and the application of roundabouts is an example. Using roundabouts to replace intersections creates a smooth road flow and avoids traffic jams. Roundabouts offer an alternative traffic management solution that considers capacity and safety issues at urban intersections where many points of dispute arise (Brahimi, Karatzas, Theuriot, & Christoforou, 2020).

Despite the high level of safety recognized for roundabouts, several factors influence driver behavior (Salvatore, Natalia, & Giulia, 2019). Drivers approaching a roundabout should slow down and look for possible collisions with vehicles already in the roundabout. Causes of motor vehicle accidents include driving at high speeds and violating some safety conditions related to right-of-way rules (Regragui & Moussa, 2018). Although the roundabout is an effort to reduce traffic accidents, driving safety rules must still be observed.

METHOD

Data is information that is recorded through systematic observation. Data is one of the main strengths in developing research and modeling (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, The data mining applied for the prediction of highway roughness due to overloaded trucks, 2015). The systematic scientific research process must begin with identifying the right problem (Rifai, Hadiwardoyo, Correia, & Pereira, 2016). Problems affecting data the first was regarding imbalanced data, and the second was data processing to create a training data set (Irfan, Rasyid, & Handayani, 2018). Decision-makers must consider all data with various methods that are generally accepted. The data will be helpful if interpreted correctly (Rifai, Pereira, Hadiwardoyo, Correia, & Cortez, 2015).

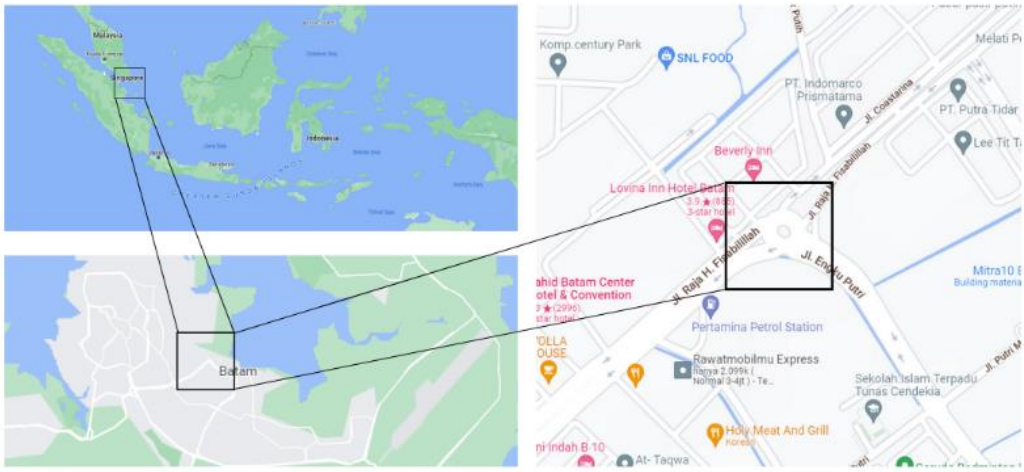

Figure 1. Location of Research

This research is located at the Tuah Madani Roundabout, Batam, Indonesia (Figure 1), using field observations and quantitative methods. The research will be conducted on Thursday afternoon around 06.00 PM and end at 07.00 PM. The reason for conducting this research is to see the effectiveness of the Tuah Madani Roundabout. The analytical method used is IHCM 1997 as a guideline for the analysis, planning, design, and operational activities of road transportation, which is the result of empirical studies at several locations considered representative of the state of transportation characteristics in the territory of Indonesia.

RESULT AND DISCUSSION

Traffic Flow

Volume (Q) can be defined as a method of determining the amount of traffic or the number of vehicles traveling on a particular section of a route. In calculating the volume, a tool can be used to count vehicles, namely the counter. From the table above, the highest LV and MC are at section BC, while the highest HV is at section AB. The greater the number of passing vehicles, the greater the volume will be obtained. The highest volume occurred at section BC with a total of 1881 vehicles with 1125.4 PCU/hour.

Table 1. Traffic Volume Analysis

Braid Section	Vehicles Total							
	LV		HV		MC		Total	
	V/H	PCU/H	V/H	PCU/H	V/H	PCU/H	V/H	PCU/H
AB	821	821	19	22.8	863	215.75	1703	1059.55
BC	852	852	17	20.4	1012	253	1881	1125.40
CA	650	650	5	6	723	180.75	1378	836.75

Road Capacity

Capacity (C) is the maximum number of roads within a certain period and traffic. Capacity can be calculated using the formula in IHCM 1997.

$$Co = 135 \times Ww^{1.3} \times \left(1 + \frac{We}{Ww}\right)^{1.5} \times \left(1 + \frac{Pw}{3}\right)^{0.5} \times \left(1 + \frac{Ww}{Lw}\right)^{1.8}$$

$$C = Co \times Fcs \times Frsu$$

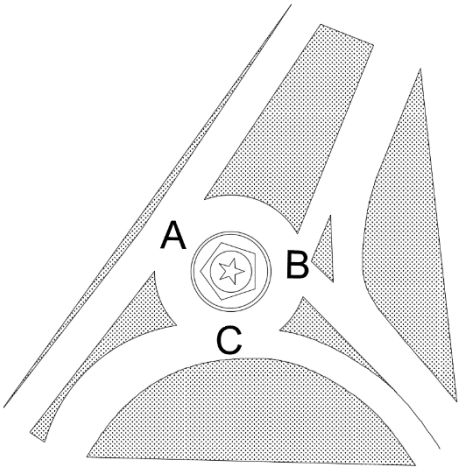

Figure 2 Roundabout Floor Plan

Table 2. Cross Geometry (Fig.2)

No	Description	Braid		
		AB	**BC**	**CA**
1	Approach Width (W1)	9	13	12.5
2	Approach Width (W2)	10	17	12
3	Average Entry Width (We)	9.5	15	12.25
4	Braid Width (Ww)	13.5	16	13.5
5	Braid Length (Lw)	19.76	30.21	19.76
6	Average Entry Width/Braid Width (We/Ww)	0.67	0.91	0.89
7	Width Ratio/Length (Ww Lw)	0.683	0.530	0.683

Table 4. Roundabout Base Capacity Value

Braid Section	Ww Factor	We/Ww factor	Pw Factor	Ww/Lw factor	Base Capacity (Co) PCU/Hour
AB	3978.94	2.152	0.8397	0.3917	2815.9
BC	4962.38	2.632	0.8335	0.4653	5065.2
CA	3978.94	2.596	0.8667	0.3917	3506.8

The braided section BC has the largest capacity of either AB or CA. The population of Batam in 2020, according to the Central Statistics Agency, is 1,196 million. The city size factor (Fcs) is 1.00, and the street circumference (Frsu) is 0.94.

Table 5. Capacity

Braid Section	Base Capacity	Adjustment Factor		Capacity (C) PCU/Hour
		City Size (Fcs)	Road Circle (Frsu)	
AB	2815.9	1.00	0.94	2646.946
BC	5065.2	1.00	0.94	4761.288
CA	3506.8	1.00	0.94	3296.392

Actual Speed

Actual speed is the average speed of vehicles passing through a road. Average speed can be taken by taking several samples from different types of vehicles (MC, LV, HV, etc). The speed of the vehicle that has been taken is calculated to find the average. The actual speed in this paper is 46 km/hour.

Degree of Saturation

Table 6. Capacity

Braid section	Capacity (C)	Volume (Q)	Degree of Saturation (DS)
AB	2646.946	1059.55	0.4
BC	4761.288	1125.40	0.23
CA	3296.392	836.75	0.25

The degree of saturation (DS) is the saturation of a road that can cause congestion. The degree of saturation can be calculated by comparing the volume (Q) to the capacity (C). Based on US-HCM 1985, the degree of saturation value is between 0 ->1. If the value is 0, the vehicle volume is low, and the flow is smooth, but if the value is more than 1, the volume is above capacity, and the flow is restricted. In this paper, the degree of saturation value obtained at Section AB = 0.4, section BC = 0.23, and CA = 0.25.

Level of Services

The level of services (LoS) is an indicator obtained from calculating the degree of saturation. The level of services has six levels, namely from A-F, which can be seen in IHCM 1997. A indicates free flow, low volume, high speed/chooses the desired speed, and F indicates restricted flow, low speed, volume below capacity, and many stops. The level of services obtained in section AB, BC, and CA are B (stable flow, limited speed, volume according to outside the city).

CONCLUSION

The research was conducted at the Madani Tuah Roundabout, Batam, Indonesia, on November 10, 2022, from 06.00 PM to 07.00 PM, which is adequate time after work. Based on the research that has been done, the data results can be presented as follows, volumes (Q): AB= 1059.55 PCU/hour, BC=1125.40 PCU/hour and CA=836.75 PCU/hour; capacities (C): AB=2646.946, BC=4761.288, and CA=3296.392; actual speed is 46 km/hour; degree of saturation (DS): AB=0.4, BC=0.23, CA=0.25; last but not least the level of services (LoS) is B. From the results of these data, it can be concluded that the Tuah Madani Roundabout, Batam, Indonesia is still comfortable for motorists to pass.

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