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The Analysis of Road Performance in Tiban Indah Batam, Indonesia

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ABSTRACT

Traffic Congestion is one of the main problems in cities. Although traffic congestion can be a significant problem in a city, most of the time, it only happens during working hours, when people go to work and go home. The research aims to analyze the road performance of Jalan Gajah Mada in the Tiban Indah Area. The data was collected using surveying methods that follow the IHMC (1997) guidelines on Monday, 21st November 2022, from 5 until 6 p.m. for one hour with an interval of 15 minutes. To summarize the conclusion, the analyzed total traffic flow during peak hour is 3,975.75 pcu/hour, a total capacity of 6,468 pcu/hour, and attained a degree of saturation of 0.615, resulting in a level of service C.

Introduction

One of the most significant issues in numerous places worldwide is traffic congestion. It is a universal occurrence affected by economics, population expansion, transportation infrastructure, and the expanding number of ridesharing and delivery services available (Wang & Debbage, 2021). With the increase in the population, every person who had the expenses to buy their vehicle also increases the number of private transportation in a city. Due to this phenomenon, there is bound to be traffic congestion. Traffic backups save time during trips. The urban transportation system has become increasingly crucial to the growth of cities and the standard of living of their inhabitants as urbanization progresses. Among these, determining traffic congestion by examining the variables that cause it is one of the most crucial tasks (Zhou, 2022). One of the primary reasons for traffic congestion is the constant traffic signal timings (Atta, 2020).

Jakarta, Indonesia's capital city, has the heaviest traffic congestion due to overpopulation by the citizens. Besides that, as time passes, each person wants to acquire their vehicle or transportation without looking at the scale of their choices. This will significantly impact the traffic jam in the city. Based on the data from TomTomTraffic Index, Jakarta is the third city with traffic conditions in the world (Kurniawan, 2018). The city implements several TDM (Transportation Demand Management) policies to combat congestion, ranging from improvement to traffic restriction (Nafila, 2018). One of the policies that Indonesia had implemented is called the odd-even. This policy certainly has made some changes by reducing the amount of transportation on the road, but it still cannot entirely decrease the congestion problems.

Although traffic congestion can be a significant problem in a city, most of the time only happens during working hours, that is when people go to work and go home. This case can be seen, for example, at Batam. Because of Batam's industrial aspect, affects Batam economically to develop the city's infrastructure faster. It also affects the people's minimum wage to be approximately 4.2 Million (W, 2022). With the earnings and savings they have, people tend to consume more expensive things, whether to fulfill their desire or to buy only things they need. For example, those with a long distance from their house to their workplace would buy private transportation.

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Heavy congestion will occur when going to the Campus when people usually go home from work. Starting from about 5 p.m., the density on the road becomes denser. Many people who used this road and students who chose the nighttime college felt troubled by the congestion. With the time wasted in the congestion, some people would dare to drive faster, which can lead to accidents that may affect people around them.

The research aims to analyze the road performance on the Gajah Mada Road. The congestion on this road can be quite burdensome, especially for those who go to work and return home for other activities. The starting point will be from the TOP 100 at Tiban Indah until the UIB Campus. The road performance can be described as whether it is likely to be congested, when it will be congested, and how congested it might be. Analyzing how and when congestion will likely become information that can be used as a future reference regarding this problem.

Literature Review

The Problem with Road Network

A road network is a complex system with certain spatial features that are gradually formed by a few regional roads through long-term planning and development (Mo, 2017). The road can be divided into four types of systems according to its usage: arterial streets, collector streets, local streets, and environmental streets.

Table 1 Road Classification Based on The Functionality

Road Types	Minimum Width (m)	Minimum Speed Limit (km/h)	
		Primary	Secondary
Arterial Streets	11	60	30
Collector Streets	9	40	20
Local Streets	7,5	20	10
Housing Streets	6	15	10

First, the arterial streets are used to connect national-regional activity centers. Second, the collector streets are used to connect national-local, regional-regional, or regional-local activity centers. Third, the local streets are used to connect national-environmental activity and regional-environmental activity centers between local activity centers or local-environmental activity centers with environmental activity centers, as well as between environmental activity centers. Fourth, Environmental streets are used to connect roads that connect between rural activity centers and roads within rural areas. This research results not only show that the road network structure has many variations but also indicate that the topological parameters of the road network can explain these changes and also further improve the theory of interaction between transportation and land use (Han, 2020).

In a transportation road network, the most complex and challenging problem is dealing with either link improvements or link additions to an existing road network while giving the route and demand from one destination to another from either direction. In particular, the situation in the growing megacities of developing countries has been worsening and is now attracting considerable attention from researchers and politicians (Zhao, 2019). Well-designed projects can increase employment opportunities, reduce transport costs, and support regional development. However, roads will also drive deforestation, threatening biodiversity and ecosystem services, jeopardizing the welfare of indigenous people, and moving the biome toward irreversible shifts in vegetation (Vilela, 2020). Therefore, an optimal solution to solve those problems is essential to increase road performance quality.

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Figure 1. Jalan Gajah Mada, Tiban Indah Area, Batam, Indonesia

The Increased number of vehicles will cause congestion, which will continue to occur if transportation facilities and infrastructure are not upgraded (Rifai A. I., International Journal of Civil Engineering, 2021). Based on the Local Statistic Center census, a big city such as Batam is occupied by 1,196,396 people. Although the growth of the population this year is lower by 2,32% from the previous year, the number of people will keep increasing, as well as the number of private vehicles. To avoid the problem in the road and traffic, better condition and performance of the infrastructure is needed.

Poor road performance can be seen by how often traffic congestion occurs. It can save time, longer trips, and a waste of fuel. Besides that, it also causes air pollution. A recent survey that is aimed at assessing the target set by the European Commission (Allen, 2017) reviews freight initiatives that are expected to reduce Heavy Goods Vehicles (HGVs) kilometers and CO2 emissions in European urban areas and ranks vehicle routing and scheduling tools among the top 10 impactful initiatives, which can help to achieve around 23% reduction in HGV vehicle kilometers by 2030. Therefore, introducing pollution-related objectives into traditional Vehicle Routing Problems (VRPs) can be viewed as a significant approach to combat Greenhouse Gas (GHG) emissions and can assist decision-makers in striking a balance between business and environmental objectives (Raeesi, 2019).

Parameter In Traffic Flow

There are three main parameters for road performance quality: speed, density, and volume. These three parameters are related to each other to determine the traffic flow. The definition of speed is the distance that can be covered within a given unit of time. General formula (Melissa, 2018):

$$S = \frac{d}{t} \quad (1)$$

With:
S = Average space speed (m / sec, km / h)
d = Length of the observed road (m, km)
t = Average travel time (seconds, hours)

Density is the number of vehicles in a specific road length in a certain distance in a lane. Complex density is measured directly but can be calculated from speed and volume. The formula (Melissa, 2018):

$$D = \frac{V}{S} \quad (2)$$

With:
D = Vehicle density (vehicle/km, pcu / km) V = Vehicle current/volume (Smp / hour, vehicle/hour)
S = Vehicle speed (km / h)

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Volume is the number of vehicles that pass a certain point in one segment per unit of time. General formula (Melissa, 2018):

$$V = \frac{n}{T} \quad (3)$$

With:
V = Traffic flow (vehicle/hour, junior / hour)
n = number of vehicles (vehicles, junior high)
T = Observation time interval (hours

Analysis of the characteristics of traffic flow for a road segment can be done by studying the mathematical relationship between speed, flow, and traffic density that occurs on the road section.

Road performance material construction

The quality of the current area's road type impacts how well the roads perform. Roads also present a challenge for material flow accounting study since estimating the materials needed for their construction and upkeep is difficult. Most studies have used general accounting principles based on a small number of variables, frequently without mentioning how technical construction standards change over time (Miatto, 2017). Additionally, it is necessary to consider the peculiarities of either road building or renewal and the variations in road kinds. This study intends to increase our understanding of road material needs, the amount of material that accumulates in roadways, and the waste streams from road resurfacing (Miatto, 2017).

In Batam, the Jalan Gajah Mada at the south link had been undergoing road construction to widen the lane. The construction was conducted around July 2022 and will be finished by the end of the year. A section of the road is closed to prevent unwanted accidents during construction and give more room so that the worker who drives the excavators can focus more on his job. This construction eventually made the road become slightly to the already congested road but only for a while. After they finished, many people guessed the congestion would be much lower.

The management and building of pavements today are highly concerned with sustainability. Materials and technology to enhance building and maintenance procedures and minimize environmental responsibilities are needed to reduce carbon footprint and energy consumption (Praticò, 2020). With the minimized burdens, the road performance quality will also increase, and it will positively affect the city's development, such as the way transporting materials. Furthermore, development carried out by a region can reflect the progress of the regional economy, one of which is the improvement of facilities and infrastructure for the community (Rifai A. I., 2021).

This study promotes the method used in researching road performance on a highway. The research methods will be used explicitly on the traffic congestion at Jalan Gajah Mada, starting from the Tiban Indah Area until the UIB Campus. Identifying road properties can be used as a future reference to highways with similar characteristics.

Method

Systematic scientific research must begin with identifying the right problem (Rifai, Hadiwardoyo, Correia, & Pereira, 2016). With the right problem, the next step is to research questions regarding how to solve the problem. The most important thing that will be needed to solve the problem is information and data about the problem. Data is one of the main strengths in developing research and modeling (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, The data mining applied for predicting highway roughness due to overloaded trucks, 2015). With the data, the variables that cause the problem can be determined.

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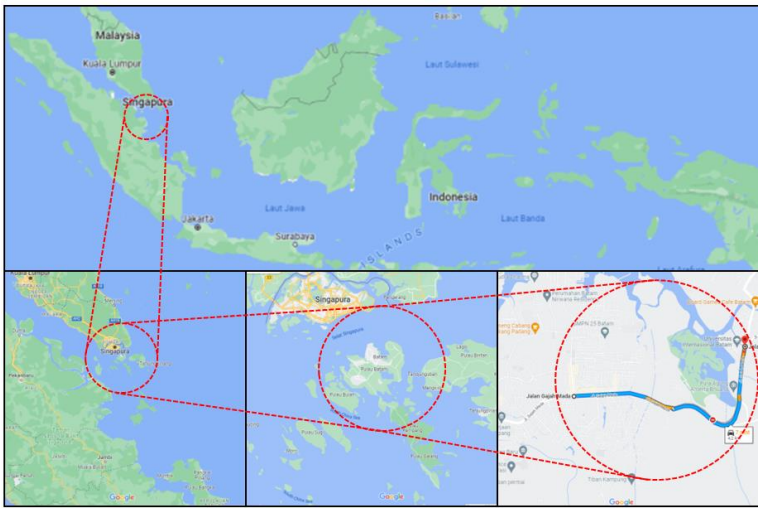

Figure 2. Location of research

The research was conducted during the peak hours on Monday, 21st November 2022, for one hour at 05.00 – 06.00 p.m. at the Jalan Gajah Mada, Tiban Indah Area, Batam City, Indonesia. The method in research uses the quantitative method and survey to collect the data based on the Indonesia Highway Capacity Manual (IHMC) 1997 (Direktorat, 1997). IHMC 1997 guidelines are a method used to guide the analysis, planning, design, operation, and traffic management models for the quality control of the building, upkeep, and use of roads. The result of the survey will be in the form of the road properties, and the total of vehicles consist of light vehicles (LV), heavy vehicles (HV), and motorcycles (MC) that passed within the survey time.

To determine the road properties, the data that will be collected are followed by these variables, such as the traffic flow value (Q), road capacity (C), degree of saturation, and level of services (LoS). The result can be used as a reference to seek a solution to the congestion problem on Gajah Mada Road.

Result And Discussion

Road Properties

The Gajah Mada Road Type is four lanes divided highway (4/2 D). The effective lane for each lane segment is 3,5 meters wide per lane. Light vehicles, Heavy vehicles, and motorcycles always pass the road since it is the shortest way for people who live in Sekupang, Tiban, and other nearby districts to reach the Batam city focal point. Light vehicles and motorcycles that go passed the road are mostly people who live and work or have connections to something there. At the same time, a heavy vehicle is often seen coming from Sekupang industrial area.

Traffic Flow

The number of vehicles passing through the survey location point can measure the traffic flow. The data-gathering process took place for an hour, with intervals of 15 minutes starting from 05.00 – 05.15, 05.15 – 05.30, 05.30 – 05.45, until 05.45 – 06.00). The emp factor, a factor that was used to find the Pcu (Passenger Car Unit) that has been determined according to IHMC (1997) Guidelines for this study are 1.00 for LV (Light Vehicle), 1.2 for HV (Heavy Vehicle), and 0.25 for MC (Motorcycle).

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Table 3 Jalan Gajah Mada traffic flow data (vehicles/hour), IHCM (Direktorat Jenderal Bina Marga, 1997)

Time	LV (unit)		HV (unit)		MC (unit)		Total Traffic Flow (Q)	
Intervals	Veh/hr	Pcu/hr	Veh/hr	Pcu/hr	Veh/hr	Pcu/hr	Veh/hr	Pcu/hr
05.00 – 05.15	487	487	5	6	1,756	439	2,248	932
05.15 – 05.30	496	496	7	8.4	2,005	501,25	2,508	1,005.65
05.30 – 05.45	502	502	4	4.8	2,236	559	2,742	1,065.8
05.45 – 06.00	473	473	4	4.8	1,978	494.5	2,455	972.3
Total							9,953	3,975.75
Factor pcu (Fpcu)							0.3995	

Road Capacity

The road capacity is the maximum vehicle that can cross through a certain point in an hour, in this case, the survey point. Based on the IHMC (1997) guidelines, the road capacity can be determined by following this formula:

$$C = C_O \times FC_W \times FC_{SP} \times FC_{SF} \times FC_{CS} \quad (4)$$

With:

C = Capacity
Co = Base Capacity per lane
FCw = Lane Width
FCSP = Direction Separator
FCSF = Capacity Adjustment
FCCS = City Adjustment with the number of citizens

C = (1,650x4) x 1.00 x 1.00 x 0.98 x 1.00

C = 6,468 Pcu/hour

Degree of Saturation

The degree of saturation (DS) can be defined as the ratio of the total traffic flow (Q) and the road capacity (C). The formula :

DS = Q / C
DS = 3,975.75/ 6,468
DS = 0.615

Level of Services

The level of services refers to the level of road performance following the IHCM guidelines using the US-HCM 1985. Based on the analysis result, the DS is calculated as 0,615. This means that the Jalan Gajah Mada Level of Services is C.

Conclusion

According to the field survey that has been conducted, analyzed, and the result, it can be concluded that Jalan Gajah Madatotal traffic flow during peak hour is 3,975.75 Pcu/Hour, and the Pcu factor is 0.3995. Therefore, the capacity obtained is 6,468 pcu/hour. The degree of saturation is 0.615 resulting in a level of services of C, which means that the flow is stable, and the road is suitable enough in the urban area.

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