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Research Article

Traffic Conditions and Characteristics: Investigation of Road Segment Performance

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Abstract: The dimensions of the road affect the flow of traffic passing over it. Even though the traffic lanes are the same width, the traffic flow will not be the same because the environment is different. This study aims to determine traffic conditions and characteristics through density analysis and the level of traffic service on the roads. This research is a type of non-experimental research, like a case study with survey methods and direct field observations to determine the performance of the road network. The primary data collected through direct recording in the field is the number of vehicles passing through Perintis Kemerdekaan Road and observing the side constraints that reduce capacity and service levels and impede smooth traffic flow. Data analysis used the Highway Capacity Manual (HCM) and Indonesia Road Capacity Manual (MKJI) 1997. The service of level (LOS) value is obtained by dividing the peak traffic volume in the west direction of 4728 PCU/hour with the road capacity value obtained by the service level of 0.89 entering category E while in the east direction with a traffic volume value of 4974 PCU/hour obtained the degree of saturation value of 0.94. The results of the study show that the level of road service is between (D – E) with a value of 0.85 to 1.00, which means that it is close to road capacity and sluggish speed, high traffic density due to internal barriers and vehicle drivers who experience traffic jams of medium duration.

Keywords: Level of Service (LOS); Peak Hour; Road Capacity; Transportation System; Traffic Density.

1. Introduction

Roads are a transportation infrastructure that is very important for the development of an area, namely to make it easier to move goods and people from one place to another [1]. Transportation development aims to realize a reliable, orderly, safe, and efficient transportation system supporting development [2]. Along with technological advances, the transportation system in Indonesia is very influential in effectively and efficiently supporting transportation facilities and infrastructure. Roads must also encourage the realization of balance between regions regarding their growth rate [3]. The higher the activity to meet human needs, the higher the need for transportation, so the load on the road will increase [4], [5]. This can result in the emergence of problems of congestion, density, and queues.

It is well known that roads as land transportation infrastructure are vital. Many aspects of life are related to it. These aspects are economic, socio-cultural, defense and security, socio-political and environmental [6]–[8]. Therefore, the progress of a nation can be measured by progress and development in the transportation sector. The growth and development of the current population are increasingly difficult to control, causing human activities to increase and become more complex [9]. To support this growth, it is necessary to provide facilities and transportation infrastructure.

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They realize how important the smooth running of transportation facilities, especially roads; Indonesia, as a country that is growing and developing, continues to make improvements and additions to these facilities and infrastructure, and the need for traffic flow following developments in line with population growth and the magnitude of development. In the current development era, it is necessary to improve transportation facilities on land, sea, and air to support the success of the development. For land transportation activities to run smoothly, adequate road facilities are needed [10], [11].

The transportation system is always closely related to movement systems and activity systems. In a particular area, the transportation system is closely related to the system of human socio-economic activity [12]. The transportation system is also interpreted as a unity of elements and components that support each other and work together to procure transportation that serves urban areas [13]. The transportation system as a whole (macro) can be broken down into several smaller systems (micro), each of which is interrelated and influences one other. Activities such as working, going to school, participating in sports, shopping, and visiting a piece of land are all part of the urban transportation system [14]. Activities on a plot of land are called land use. Based on this understanding, the transportation system is closely related to activities in land use. Every land use or activity system has specific activities that generate and attract movement to fulfill needs. As a result of these linkages, a pattern of movement is formed, which is grouped based on the movement of traffic flow from the destination [15].

Industrialization, population growth, and economic prosperity depend on convenient and accessible modes of transportation. Different countries and regions have different transportation needs, so the industry is split up into niches staffed by specialists who understand local norms and practices. One of the transportation problems that need to be addressed is the problem of congestion on the main roads in this city [16]–[18]. Increased vehicle ownership, limited resources, and no optimal operation of existing facilities such as parking lots cause congestion. The emergence of parking on road bodies scattered in several locations where no parking area facilities harm traffic conditions, especially when vehicles maneuver out of the parking lot. When maneuvering out of the parking lot, vehicles take time, affecting road performance.

The rapid development of road transport, especially in urban areas caused by technological developments, increasing population, and transportation facilities, has led to an increased need for space for traffic infrastructures such as roads and parking locations. Transportation is one of the things that is needed in economic activity. Transportation activities require facilities such as motorized and non-motorized vehicles and infrastructure in the form of roads. With transportation activities, there will be a movement in traffic flow. The construction of roads as a form of government commitment to infrastructure development as a whole is intended as a provider of transportation facilities that make it easier for local people to interact with their surroundings, both in the social, economic, and cultural fields.

Transportation problems in big cities in Indonesia are increasing from time to time, in line with population growth rates, rapid growth rates in the number of vehicles and vehicle ownership, urbanization, and inefficient public transport systems. The impact of the decrease in road performance; is exacerbated by vehicles parked on the street.

Perintis Kemerdekaan Road is one of the roads in the city of Makassar with dense land use because it is included in the category of State Roads (Class I Roads). This is because many settlements and public access are in the road area, such as educational centers, hotels, hospitals, and commercial areas. Apart from the dense land use, a large number of intersections or alleys on these roads disrupt the performance of traffic flow on this road. According to its function, this road segment is classified as a primary arterial road. The city's population relies on the primary arterial roads, which serve as the primary mode of transportation and have the characteristics of long-distance travel at high average speed. In contrast, the number of access roads is kept as low as possible and contributes to distributing services to residents.

The criteria for primary arterial roads are that the road is designed based on the lowest design speed of 60 (sixty) kilometers per hour based on the government regulation of the Republic of Indonesia Number 34 of 2006. The width of the road body is at least 11 meters. Fast traffic on primary arterial roads should not be disturbed by slow traffic. Primary arterial roads have a capacity equal to or greater than the average traffic volume [19]. From the problems described, the purpose of this study is to determine the conditions and characteristics of traffic through an analysis of traffic density and service levels on the Perintis Kemerdekaan Road in Makassar City.

2. Material and Methods

2.1. Research Approach

This research is a type of non-experimental research, is descriptive and explorative, and is a case study type with survey methods and direct field observations to determine the performance of the road network. In terms of analytical methods, this research uses a combined analysis method between qualitative and quantitative methods. The data used also consists of two kinds, namely data in qualitative

and quantitative measures, for that there is an adjustment to the needs. Both methods are used to complement each other in achieving research objectives.

2.2. Location Study

Makassar is the Capital City of South Sulawesi Province which is located in Makassar is the Capital City of South Sulawesi Province which is located in Makassar is the Capital City of South Sulawesi Province which is located at position 119° 24' 17.38" East Longitude and 5° 8' 6.19" South Latitude average 1-25 m above sea level. The municipality is divided into 14 districts with an area of 17,577 hectares. The research study location is west of Makassar City, in the Tamalanrea District on the Perintis Kemerdekaan Road.

Figure 1. Location Study (Makassar, South Sulawesi, Indonesia)

This research was conducted west of Makassar City in Tamalanrea District, on the Perintis Kemerdekaan Road Section KM. 017 – KM. 018, the authority of the Directorate General of Highways (BBPJN), Makassar XIII National Road Implementation Center. Perintis Kemerdekaan road is a two-way street divided into 4 (four) lanes without being separated by a median for opposite traffic (4/2D). The time for conducting the research will be from March to August 2022.

2.3. Data Sources and Procedures

Primary data was collected through direct recording in the field in the form of the number of vehicles that pass through the road at the research location and observing the side friction factors that reduce capacity and level of service and hinder the smooth traffic flow. In this study, primary data or field data were collected directly through field surveys. The types of surveys conducted to collect primary data or field data are:

2.3.1. Survey of Road Traffic Volume

Traffic variations are usually repetitive (cyclical) and may be hourly, daily, or seasonal. The choice of an appropriate survey time depends on the purpose of the survey. To describe traffic conditions during peak hours, the survey covered rush hours such as in the morning from 06.00 to 08.30 and in the afternoon from 16.00 to 18.00. Surveys are not conducted when traffic is affected by unusual events, such as traffic accidents, public holidays, road repairs, and natural disasters. In this study, the survey was carried out from 06.00 to 06.00 (24 hours).

2.3.2. Travel Speed Survey on Road Sections

This survey was carried out using visualization or direct observation at each study location; this observation was carried out during the traffic volume enumeration survey. The implementation is carried out by placing two observers who record events that cause side obstacles or roadside activities that interfere with the movement of vehicles on the road.

2.3.3. Geometric Survey of Roads and Intersections

This series of survey activities is the geometric measurement of roads and intersections, such as measuring the width of the lanes on the road, the road median, and the width of the sidewalk and identifying the number of existing signs and other infrastructure so that the resulting data is following the needs at the time of calculation and data analysis.

2.3.4. Survey of Side Barriers on Roads

In this study, the survey method used in collecting travel speed data was using moving observers. How to observe moving is the development of how to go with the flow [20]. Measurements by mobile observation were carried out using a survey car in good condition. Measurements were carried out along the road network at the study location by placing 3 (three) observers, including the survey car driver. As with the observation method with the flow, the survey car is moved back and forth along the road network following traffic flow.

2.4. Data Analysis

This stage is an activity of comparing the results of calculations with the performance parameters of roads and intersections, which are then determined by the selected locations to be the locations to be handled, the provisions for the locations to be handled consist of adjacent signalized intersections in the road network. In this study, the performance of road sections is measured by the Degree of Saturation (DS) value while at intersections. This value determines the Level of Service (LOS) for the road sections under review. The steps for analysis using the Indonesian Road Capacity Manual 1997 [19] are as follows:

2.4.1. Traffic Volume (Q)

Traffic volume is the total of vehicles passing a point on the road per unit of time, expressed in vehicles/hour ($Q_{vehicle}$) and PCU/hour (Q_{PCU}). The traffic volume on the road varies depending on the traffic direction, daily, monthly, and yearly volume, and the composition of vehicles. Traffic volume is calculated based on the equation below:

$$\boldsymbol{Q = \frac{N}{T}} \quad (1)$$

Description:
Q = Volume (vehicle/hour)
N = Total vehicle (vehicle)
T = Observation time (hour)

2.4.2. Traffic Speed (V)

Traffic speed is the distance that can be traveled by a vehicle on a road segment in one unit of time.

$$\boldsymbol{V = \frac{d}{t}} \quad (2)$$

Description:
V = Speed (km/h; m/sec)
d = Vehicle mileage (km; m)
t = Vehicle travel time (hours; seconds)

2.4.3. Traffic Density (D)

The definition of traffic density is the total of vehicles occupying a given length of a road or lane, typically expressed as the total of vehicles per kilometer per lane. Traffic density is quite challenging to measure directly but can be calculated from data on speed and traffic volume with the following equation:

$$\boldsymbol{D = \frac{q}{V}} \quad (3)$$

Description:
D = Density (vehicle/km)
q = Vehicle volume (vehicle/hour)
V = Traffic speed (km/hour)

2.4.4. Degree of Saturation (DS)

The degree of saturation (DS) for roads within the area of influence will be obtained based on the results of the traffic volume survey on the roads and geometric surveys to obtain the current capacity [21], [22]. By using the fundamental relationship between volume, capacity, and travel speed that has been determined by the Highway Capacity Manual [23], the Level of service (LOS) can be determined based on the graph of the ratio of volume capacity or degrees of saturation (DS) to speed [24]. The degree of saturation (DS) on the road segment is obtained using the following equation:

$$\boldsymbol{DS = \frac{Q}{C}} \quad (4)$$

Description:
Q = Total traffic flow volume (PCU/hour)
C = Capacity (PCU/hour)

2.4.5. Road Capacity (C)

Capacity is the maximum current that can be maintained per hour passing a point on the road under certain conditions. The basic equation for determining capacity in the Indonesian Road Capacity Manual 1997 [19] is as follows:

$$\boldsymbol{C = C_o \times F_W \times F_{ks} \times F_{sp} \times F_{sf} \times F_{cs}} \quad (5)$$

Description:
C = Capacity (PCU/hour)
C = Base Capacity (PCU/hour)
F_w = Road width adjustment factor
F_{ks} = Curb and shoulder adjustment factor
F_{sp} = Traffic direction adjustment factor
F_{sf} = Side friction adjustment factor
F_{cs} = City size factor

2.4.6. Level of Service (LOS)

The ratio of road service levels is obtained by comparing traffic volume (V) with road capacity (C), or it can be written as the V/C ratio. The greater the value of the V/C ratio, the worse the net service level. Conversely, if the value of the V/C ratio is smaller, the net service level is getting better. The level of service (LOS) is carried out with the following equation:

$$\boldsymbol{LOS = \frac{V}{C}} \quad (6)$$

Description:
LOS = Level of Service Ratio
V = Total traffic flow volume (PCU/hour)
C = Capacity (PCU/hour)

Table 1. Traffic Characteristics and Level of Service (LOS)

LOS	Traffic Characteristics	Ratio (V/C)
A	Free movement of traffic, low volumes of traffic, high speeds, and user-selectable speeds.	< 0.6
B	Stable traffic flow; increased traffic volume slightly reduces travel times.	0.60 – 0.70
C	Safe and regular traffic flow, with speeds governed by the density of vehicles on the road.	0.70 – 0.80

LOS	Traffic Characteristics	Ratio (V/C)
D	Uneven traffic, slow progress.	0.80 – 0.90
E	The traffic is moving slowly and steadily approaching its capacity.	0.90 – 1.00
F	The traffic volume is too high, the lanes are too narrow, and many cars constantly stop.	>1.00

Source: Indonesian Highway Capacity Manual (1997) [19].

With the level of service obtained, it can be determined that the road is included in a certain level of service. From the value of the V/C ratio, a road service level classification will be obtained (Table 1).

3. Result and Discussions

3.1. Traffic Volume

Based on the results of the research, the types of vehicles that pass through Perintis Kemerdekaan Road are Light Vehicles (LV), Heavy Vehicles (HV), Motorcycles (MC), and Unmotorized Vehicles (UM).

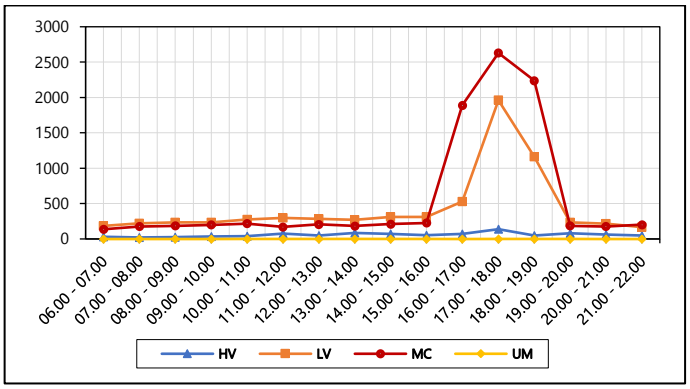

Figure 2. Traffic Volume (West Direction).

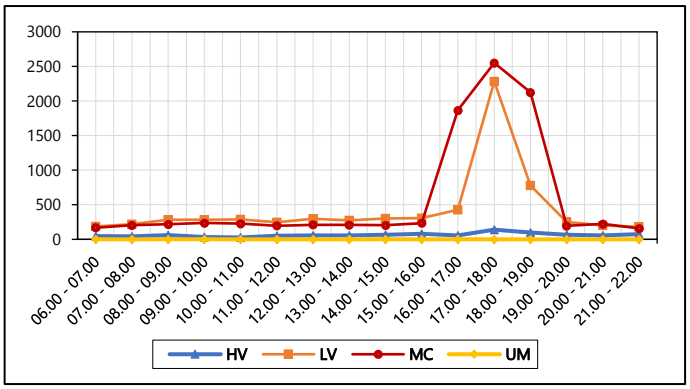

Figure 3. Traffic Volume (East Direction).

Figures 2 and 3 show that the traffic volume in the west and east of Perintis Kemerdekaan Road increases from 15.00 to 20.00. The maximum volume is between 17.00 - 18.00. The number and types of vehicles during the observation period are shown as follows (Table 1).

Table 2. Peak Hour Traffic Volume Survey (PCU)

Direct.	Observation (Time)	Type of Vehicle				Total Vehicles
		HV	LV	MC	UM	
West	17.00 - 18.00	138	1961	2629.2	0	4728
East	17.00 - 18.00	140.4	2282	2551.2	0	4974

From observations made in the west direction, it was obtained that rush hour traffic flow was between 17.00 - 18.00 with a total of 4728 vehicles divided into 1961 Light Vehicles (LV), 138 Heavy Vehicles (HV), and 2929.2 Motorcycles (MC).

3.2. Traffic Speed

Traffic speed conditions at the study location based on survey results in the form of an average hourly speed are presented as follows (Tables 3 and 4).

Table 3. Traffic Speed (West Direction)

Vehicles	Samples of Vehicle						Average	
	01	02	02	03	04	05	Time (sec.)	Speed (km/h)
HV	382	388	372	379	388	382	381.80	0.22
LV	377	386	378	381	380	377	380.40	0.22
MC	342	344	352	360	344	342	348.40	0.27
						Total	370.20	0.24

Table 4. Traffic Speed (East Direction)

Vehicles	Samples of Vehicle						Average	
	01	02	02	03	04	05	Time (sec.)	Speed (km/h)
HV	389	372	383	388	381	389	382.60	0.22
LV	377	380	383	380	383	377	380.60	0.22
MC	334	332	340	337	334	334	335.40	0.29
						Total	366.20	0.24

The average space speed of east and west traffic flows with an observation distance of 50 meters is 0.14 km/hour. Space mean speed is the average speed measured along the observed road section. Space mean speed is the result of comparing the distance traveled and the average time to travel the road [25].

3.3. Capacity (C) and Density (D)

The value of road capacity can be obtained if the values of the basic capacity (Co) and the value of the adjustment factor have been obtained and substituted into the

capacity formula in the Indonesian Highway Capacity Manual 1997 [19]. Then for analysing traffic density, volume and speed data were used. The capacity dan density for the Perintis Kemerdekaan Road section can be seen in the following Table 5:

Table 5. Capacity (C) and Density (D)

Directions	Capacity (C) (PCU/Hour)	Density (D) (PCU/Hour)
West	5296	34937
East	5296	36288

Following the calculation procedure and the calculation steps for the roads, the results of calculating the operational performance of the roads obtained a density value of 34937 PCU/km in the West Direction. At the same time, it was 36288 PCU/km in the East Direction. Then from the calculation of road capacity for the west and east directions, 5296 PCU/Hour is obtained

3.4. Degree of Saturation (DS) and Service of Level (LOS)

By using the capacity (C) from the previous data, the degree of saturation (DS) can be determined by calculating the ratio between the volume of traffic (Q) and the capacity (C). The value of the degree of saturation and the level of service for the Perintis Kemerdekaan Road section is presented as follows:

Table 6. Degree of Saturation (DS) and Level of Service (LOS)

Directions	(PCU/Hours)		DS (Q/C)	LOS
	Volume (Q)	Capacity (C)		
West	4728	5296	0.89	E
East	4974	5296	0.94	E

The road capacity value for both segments is 5296 PCU/hour. The Road Service Level is obtained by dividing the peak traffic volume in the west direction by 4728 PCU/hour with the road capacity value obtained at a service level of 0.89 entering category E while in the east with a traffic volume value of 4974 PCU/hour obtained a degree of saturation value of 0.94. The two degrees of saturation values range from 0.85 to 1.00 with lower traffic conditions than service level D with traffic volumes approaching road capacity and very low speeds and high traffic density due to high internal traffic resistance; Drivers begin to experience short-duration traffic jams.

The density on the road causes long queues, namely during the afternoon rush hour, in the evening until at night. Some of these traffic jams are temporary, and some are routine. This is caused by the number of specific road conditions that are damaged, the presence of vehicles going in and out of the road, and the number of road users who have not obeyed the rules in an orderly manner, thereby disrupting the smooth flow of traffic which can cause congestion traffic. As well as the lack of traffic officers in overcoming/regulating the course of traffic, especially on roads prone to traffic jams. Traffic jams at night are usually caused by road repairs and vehicles using the road as a parking area; as a result, traffic jams can no longer be avoided.

Road performance is generally expressed in speed, travel time, and freedom of movement. Road performance is seen from traffic volume and road barriers. High traffic volumes and obstacles can cause conflicts, affect the movement of traffic flow, and reduce road performance. The problem faced in traffic is the balance between the capacity of the road network and the number of vehicles passing by using the road. If the capacity of the road is almost saturated, let alone if it has been exceeded, then traffic jams happen.

Traffic congestion significantly impacts residents, such as wasting fuel, wasting time for nothing, and causing environmental damage due to air pollution emitted by motorized vehicles [18], [26]–[28]. This waste causes costs that should be used or allocated by the community for other uses to be spent on transportation costs such as fuel consumption. The increase in fuel costs is a loss that every motorized vehicle user must bear [29]. The service level indicator on a stretch provides information about the road's general condition. Service quality is measured in terms of objective metrics like travel time and the driver's ability to set his or her own pace, as well as other qualitative metrics like traffic congestion and rider comfort.

Traffic management or engineering is a traffic control strategy that maximizes existing transportation infrastructure and facilities [16], [30]. New road construction is not part of traffic management. Developments included in traffic management are limited to improving existing facilities due to implementing a traffic management strategy and instruments in the field. An example of its application, namely the fulfillment of the need for transportation, the implementation of one-way roads, setting travel routes, managing traffic flow, prohibiting U-turns at points prone to traffic jams, installing signs in accident-prone areas (black spots), the road network system in congestion-prone points, public transport priorities, multimodal transportation planning, and parking policies.

4. Conclusion

The rapid development of Makassar City has caused many residents to come and settle down. These residents will need a place to live, which will cause the city to become

more crowded. Population mobility increases the need for transportation. Vehicle ownership and trips will also increase demand for transportation facilities and services. Diverse vehicle traffic and the increase in the number of vehicles are faster than the increase in road infrastructure resulting in a decrease in the level of road service.

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