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Original Article

Road Performance and Traffic Density Assessment on Urban Road Segments in Maros

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Abstract - *This study analyzes traffic performance and congestion on urban road sections in Maros Regency. The assessment applies the 2023 Indonesian Road Capacity Guidelines (PKJI) and covers road capacity, free-flow speed (Vb), and road user perceptions of congestion. Traffic performance indicators, namely Degree of Saturation (DS) and Speed Performance Index (SPI), were derived from field observations and a user survey. Results indicate a free-flow speed of 47.3 km/h and an effective capacity of 2,674 pcu/h on the observed segment. Congestion patterns are directional and time-dependent. The Maros to Makassar direction is busiest in the morning, while the Makassar to Maros direction reaches its peak in the late afternoon, with DS values at or above 0.85. The highest DS reaches 0.91, while the lowest SPI is 16, indicating severe congestion conditions. Survey responses corroborate these peak periods, aligning perceived congestion with empirical indicators. The findings provide evidence for operational controls and targeted geometric improvements to enhance traffic flow and reliability on this corridor.*

Keywords - *Road infrastructure, Free-flow speed, Traffic congestion, Road performance, Traffic engineering.*

1. Introduction

Good road infrastructure supports interregional connectivity, accelerates the distribution of goods and services, and drives economic growth [1]. Additionally, transportation provides economic, social, political, and territorial benefits, making it a crucial element in regional development [2, 3]. The quality of road infrastructure is affected by a number of things, including traffic flow, vehicle density, side friction, and the connection between volume, speed, and road capacity [4]. Maros Regency, which is part of the Mamminasata metropolitan area, is important for the growth of South Sulawesi [5]. This area includes Makassar City, Maros Regency, Gowa, and Takalar. It is 245,230 hectares in size [6]. The Makassar–Maros National Road is one of the main roads that connects these two big cities. It is also an important transportation route that connects production areas, urban areas, the airport, and the port. However, a major challenge in realizing the region's development vision is accessibility, which is affected by congestion and suboptimal road infrastructure conditions [7]. Traffic congestion is a major issue in many developing cities, including on the Makassar–Maros National Road [8]. The factors that cause congestion are more cars on the road because of population and industrial growth, roads that are getting worse, and changes in land use that are not being managed [9]. Road damage, such as uneven surfaces and poor drainage, can make traffic flow worse and make accidents more likely [10]. Traffic patterns can also change when people move or new economic centers grow, which can make roads busier [11]. Traffic jams not only make it harder to get around, but they also hurt the economy, make pollution worse, and make people more stressed [12]. To get current information and help plan better transportation infrastructure development, it is important to look at how well the roads work and how many cars are on them in Maros Regency's urban areas. A good road network that works well is very important for regional growth. It makes it easier for people to move between regions and helps the economy grow as a whole. The Makassar-Maros National Road is crucial in Maros Regency since it facilitates transportation, promotes commercial development, and ensures the delivery of products and services. To comprehend and address the challenges associated with managing this road infrastructure, a comprehensive examination of the characteristics, capacity, and traffic performance of this road segment is essential. This study seeks to define the attributes of the Makassar-Maros National Road, linking two principal cities in South Sulawesi, evaluate its road capacity and traffic performance through the analysis of traffic flow and speed, and investigate road users' perceptions of traffic congestion on the specified road segment. Based on these considerations, this study aims to identify the profile of urban road sections in Maros Regency, evaluate traffic performance, and assess traffic congestion levels on these roads. Additionally, this research seeks to evaluate traffic density based on road users' perceptions. The assessment of traffic performance and congestion levels will be conducted using the road capacity calculation approach outlined in the 2023 Indonesian Road Capacity Guidelines (PKJI). The outcomes of this study are expected to provide a framework for local government officials to formulate strategies for regional development initiatives and enhance the effectiveness of road infrastructure. Previous research on urban road performance has predominantly focused on technical metrics, including traffic volume, average speed, travel time, density, and capacity. Many of these works applied classical mathematical models (e.g., Greenshields, Greenberg) or even artificial intelligence-based approaches to predict traffic conditions. While informative, most of these studies have not specifically integrated the Indonesian Road Capacity Guidelines (PKJI) 2023 in the context of inter-urban arterial roads, nor have they incorporated road user perceptions as a validation tool. This leads to a gap in knowledge, especially when it comes to measuring changes in traffic density based on travel direction and time of day, which are very important issues on the Makassar-Maros corridor. This study presents a more holistic methodology by integrating PKJI 2023-based analysis, the computation of the degree of saturation (Dj), the Speed Performance Index (SPI), and validation via a road user perception survey.

This research utilizes the updated PKJI 2023 framework and corroborates technical results with user perception surveys, distinguishing it from prior studies that predominantly employed classical models or AI-based predictions, an approach not systematically explored in earlier investigations of Indonesian commuter corridors.. By considering directional (Makassar–Maros vs. Maros–Makassar) and temporal (morning vs. afternoon) dimensions, the research reveals congestion patterns that are more detailed than those reported in previous studies. The main new thing is that it shows how to diagnose traffic performance in a way that is both technically sound and backed up by real-world user experience. As a result, the findings offer more specific suggestions for traffic management plans that work best at certain times and for certain types of travel.

2. Materials and Methods

2.1. Location and Time

This study was conducted on the Maros–Makassar arterial road. This road plays a crucial role as a main artery connecting Maros and Makassar City. The research was carried out from April 2024 to September 2024.

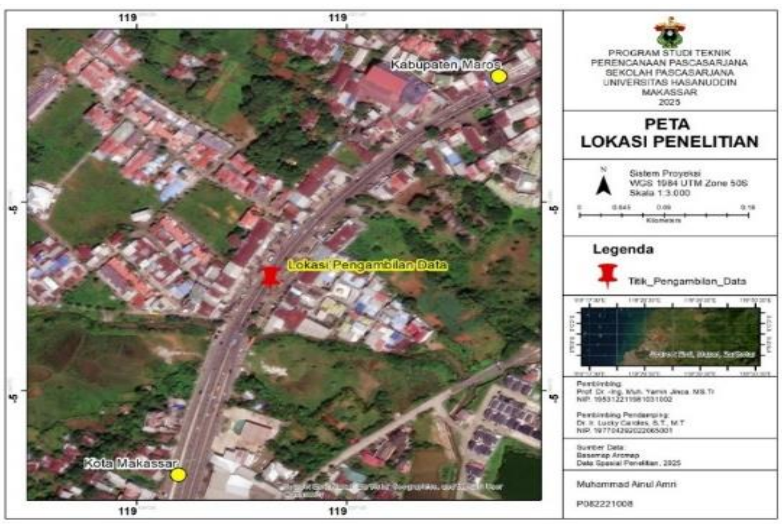

Fig. 1 Research location

2.2. Tools and Materials

This study used a variety of tools, such as a measuring tape, a tape ruler, a counter clicker, and Microsoft Office. The combination of hardware and software should make data collection, analysis, and presentation more accurate and reliable.

2.3. Research Procedure

2.3.1. Urban Road Performance Assessment

This research employs an urban road performance evaluation methodology based on the 2023 Indonesian Road Capacity Guidelines (PKJI). There are three main steps in the research process: finding out what the road is like, checking its capacity and free-flow speed, and seeing how well traffic is moving. Find out what the road is like first. This means gathering information about the type of road, its width, and the geometric and environmental conditions around it. Traffic data were also collected, such as the number of vehicles, the speed at which they can move freely, and the amount of friction on the side of the road, to get a complete picture of the road conditions. The second step is to look at capacity and free-flow speed. This is done by figuring out the maximum road capacity based on geometric factors, the size of the city, and the conditions of side friction. To find the free-flow speed, things like the road's width, the weather, and the kinds of vehicles that are passing through need to be taken into account. The third step is to look at how well traffic is moving by looking at important factors like the degree of saturation (Dj), the speed of travel (VT), and the time it takes to travel (WT). The ratio of traffic volume to road capacity is called the degree of saturation. Travel speed and travel time are used to measure how smoothly traffic flows. Along with this assessment, a survey of road users' preferences will be done to get direct public opinions on how things are going with traffic right now. The results of this analysis are expected to guide the formulation of more effective transportation policies and the improvement of road infrastructure quality in Maros Regency.

2.3.2. Speed Performance Index (SPI)

The Speed Performance Index (SPI) tells you how busy city streets are. To find SPI, use the following formula to figure out the percentage of the average vehicle speed (Vavg) and the maximum speed (Vmax):

$$SPI = (Vavg \,/\, Vmax) \times 100$$

Into four levels of traffic density: Very Smooth (75–100), Smooth (50–75), Mild Congestion (25–50), and Severe/Heavy Congestion (0–25). The higher the SPI value, the better the traffic on the road segment that was looked at. The SPI was calculated using data on how fast cars are going on the road segment we are looking at. Field surveys provided the average speed, and the maximum speed is the speed limit for the road. We looked at the data to see how fast traffic is moving and how road conditions affect the speed of vehicles. The SPI results should help policymakers figure out how to make traffic flow better and improve infrastructure by giving them information about how many cars are on the road.

2.3.3. Road User Preferences

This study examines road user preferences using a quantitative approach with a non-probability sampling method, as the total population of road users cannot be precisely identified. A purposive sampling technique is utilized to select respondents possessing substantial experience with the examined road segment, specifically individuals who traverse the road a minimum of three times per week or reside in the adjacent area. The sample size follows Roscoe's Theory, which suggests a range of 30 to 500 respondents. In this study, a minimum of 30 respondents will be surveyed using simple questions to explore their road usage preferences. The survey results will be used as a justification and comparison to support the findings of the road performance assessment.

3. Results and Discussion

3.1. Existing Road Conditions in Maros Regency

This research centers on Jalan Poros Maros-Makassar, an essential link among various strategic regions in Maros Regency. The main places where the data comes from are the Balai Besar Pelaksanaan Jalan Nasional Sulawesi – Selatan and the Dinas Kominfo Kabupaten Maros. Figure 1 shows this part. This part of the road not only connects the center of Maros with the eastern sub-districts, but it also gives people access to industrial and commercial areas nearby. The Makassar-Maros National Highway is a big road that links Makassar City and Maros Regency. This part of the road has four lanes going in two directions and a median strip to make it safer and help traffic move more smoothly. It is a main road that helps people get around, move goods, and do business in the area around it [13, 14]. On June 12, 2023, a survey was done on two main sections: Mandai Bridge to the Maros City Border Gate Monument (Jembatan Mandai hingga Tugu Gapura batas Kota Maros) and the Makassar City Border. Each section is 100 meters long for further study. There are 413,590 people living in the area around this road segment (BPS South Sulawesi, 2024), and most of them are businesses, which shows that there is a lot of business and trade activity along the road [15].

The Makassar-Maros Highway is a national road with route code 54010. It is an important part of the national transportation network. This road is a 4/2b type, which means it has four lanes, two in each direction, with a median in the middle. This makes it easy for traffic to move between regions. The highest speed limit is 50 km/h, and the types of vehicles that are allowed are light to heavy vehicles, as defined by the old vehicle type code (1, 2, 3, 4, 5A, 5B, 6A, 6B, 7ABC) or the new classification (SM, MP, KS, BB, and TB). Traffic signs and road markings are available as supporting infrastructure, but there are not enough of them, especially in places with many cars and people. The drainage system is not working as well as it could be, either. Some parts of the road often get flooded during heavy rain, especially at lower elevations. In general, this part of the road is very important for connecting different regions and helping the economy. However, there are still problems with traffic management, the quality of supporting facilities, and the drainage system. These need to be fixed to make transportation more efficient and safer for road users.

3.2. Traffic Volume Measurement Results

The traffic volume measurement results show how many cars are on the Makassar-Maros National Highway [16] and how they move. According to the secondary data that was gathered, the average speed of vehicles was 50 km/h, which is the speed limit. This similarity shows that most people who use the road follow the rules of the road, which helps traffic flow smoothly and keeps everyone safe. Also, there are no different speed limits on this road, so all vehicles must follow the same speed rules without any specific zoning restrictions. This rule makes traffic laws easier to understand and less confusing for drivers, but it can also make traffic management harder, especially in busy areas like commercial and office districts. The survey results also show that this part of the road does not have any speed control measures, like extra warning signs, speed bumps, or cameras that watch for speeding.

Because there are no such interventions, drivers have to rely on their own awareness to stay within the speed limit. If traffic is moving smoothly, this might not be a problem. When there are a lot of cars on the road or side friction, like people walking or parking illegally, not having speed limits can make traffic jams or accidents more likely [17, 18]. So, more research is needed to see if traffic changes are needed at busy spots along this corridor to make travel safer and more efficient.

This first analysis is meant to give a general idea of the road segment that was looked at, based on the speed of the vehicles and the need for traffic control along the Makassar-Maros National Road Corridor. The analysis shows that the cars are going the right speed, which is the speed limit that has been set. Even though there are no speed limits, most drivers still follow the rules of the road. However, it is still important to regularly check the condition of the roads to make sure that nothing has a big effect on operational speed or drivers following traffic rules. Also, even though there are no rules to limit speed, the high traffic volume raises safety and efficiency concerns [18]. If there are more cars on this road or safety issues arise, traffic management tools like traffic lights, road signs, or speed limiters could be used. The measurements in Figure 3 show that the amount of traffic on this road changes depending on the time of day. There were four main times during the day when traffic observation intervals were used to show how the flow of cars changed. Interval 1 (07:30–09:00): This is the morning when people are most active in the community, going to work and school. Interval 2 (10:00–11:30): This is when traffic is usually steady after the morning rush hour. Interval 3 (1:00–2:30): This shows how people move from noon to early afternoon. This could be due to business activities, workers, or students who are only going back to work part-time. Interval 4 (16:00–17:30): This is when most people are out and about, usually because they are going home from work or doing other things in the community. This division of intervals lets us look more closely at changes in traffic and find times when traffic is at its busiest, which means we need more ways to manage traffic.

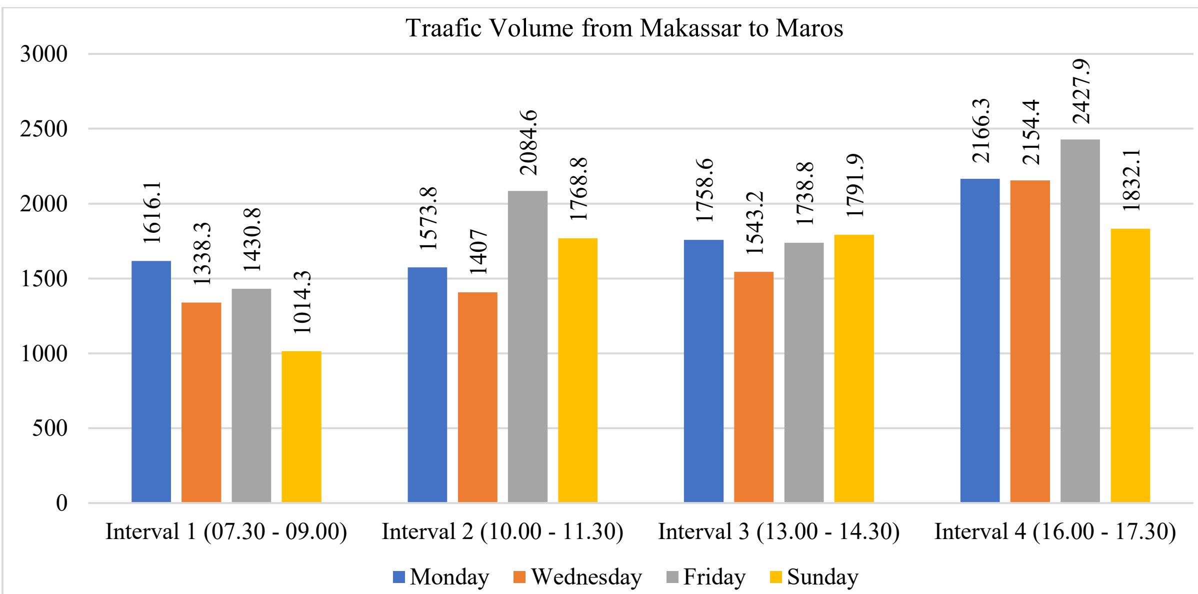

Fig. 2 Traffic volume from makassar to maros

Figure 2 shows the traffic flow from Makassar to Maros at four different times. Data analysis shows that the way cars move around changes a lot depending on the time of day and the day of the week. The fourth interval (16:00–17:30) usually has the most traffic. On Friday, 2,427.9 cars were counted, which is the most ever. This means that the afternoon is when the most traffic is on the road, probably because people are leaving work and community events are starting up for the weekend [19]. On Monday, traffic moves pretty steadily, with a slow rise all day. Wednesday, on the other hand, has less traffic than other days, especially during the first interval (1,338.3 vehicles) and the second interval (1,407 vehicles). This means that fewer people are likely to travel from Makassar to Maros on Wednesdays. This could be because they have jobs or other things to do. The second interval on Friday (2,084.6 vehicles) shows a big jump, which could mean that more people are traveling in the middle of the day, either for work or to get ready for the weekend. On Sunday, there are fewer cars on the road during the first interval (1,014.3 vehicles), but there are still a lot of cars on the road during the third and fourth intervals. This could mean that more people are going out for fun or doing other things in the afternoon. Figure 3, on the other hand, shows traffic flow data going from Maros to Makassar. It shows that the most traffic is during the first interval (07:30–09:00). This is especially clear on Mondays and Wednesdays, when the number of cars reached 2,175 and 2,169, respectively. This pattern shows that a lot of people are moving in the morning, probably workers and students going to Makassar. On the other hand, the morning traffic volume from Makassar to Maros is much lower, which suggests that most of the movement during this time is toward Makassar. Traffic from Maros to Makassar is lower in the second and third intervals, which are in the middle of the day, than in the morning. The numbers are also more stable on all days. There is a big difference on Friday, though. During the third interval (1,885.2 vehicles), the number of vehicles goes up a lot, which is more than on other days. This could mean that more people are going to Makassar for work or to get ready for the weekend.

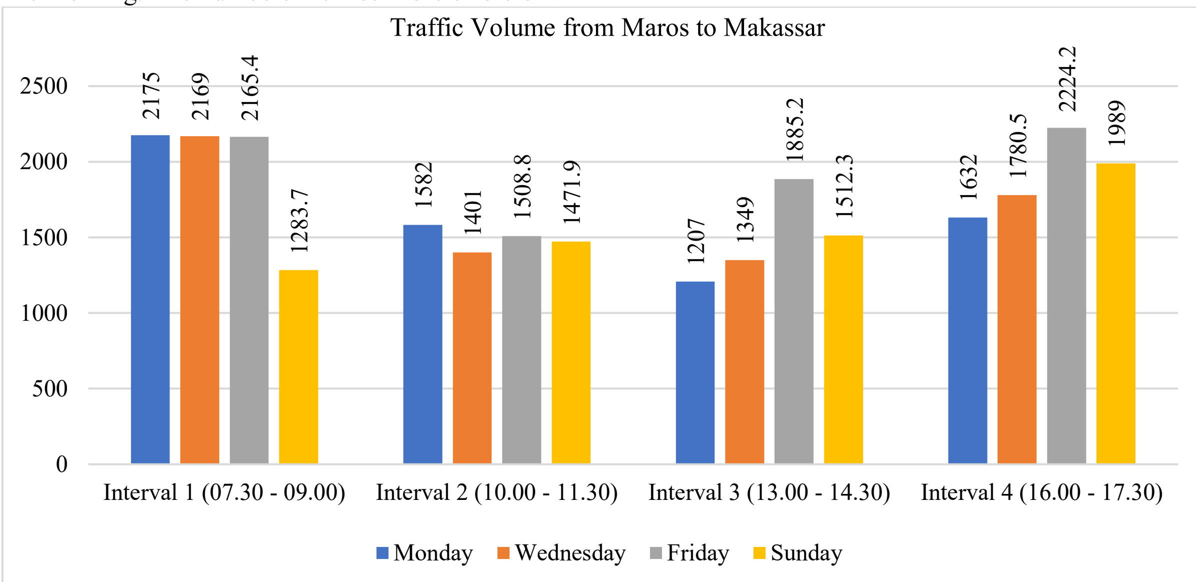

Fig. 3 Traffic volume from maros to makassar

Traffic gets heavier again in the evening (the fourth interval), especially on Friday (2,224.2 vehicles) and Sunday (1,989 vehicles). This rise is similar to what we have seen in the past, when traffic between Makassar and Maros also went up a lot during the same time period. People who are coming home from work or traveling back to Maros from Makassar are to blame for this.

The two datasets show that traffic flows in both directions on the Makassar–Maros route. The busiest times and days change, though. In the morning, more people travel from Maros to Makassar, but in the evening and at night, the opposite is true. Users need to know this pattern in order to plan a traffic system. This includes changing the timing of traffic lights, making rules for traffic engineering, and building new roads to handle times when there are a lot of cars on the road.

3.3. Free Flow Speed (Vb)

A number of road and environmental adjustment factors are used to figure out the free-flow speed for private cars. The baseline free flow speed, which is 57 km/h and shows the best conditions without any obstacles, is used as a starting point. The first change slows things down by 4 km/h and is based on a lane width of 3.00 meters, which is less than the recommended standard. The shoulder width adjustment factor is set to 0.96 because the condition is narrow. The population adjustment factor, on the other hand, has a value of 0.93 and is based on a regional population of 0.1 to 0.5 million. It does not seem to have any effect on speed. Users can use the following formula to figure out free flow speed:

$$VB = (VBD + VBL) \times FVBHS \times FVBUK,$$

Where VB is the private vehicle free flow speed (km/h).

VBD = Basic speed (57 km/h)
Lane width adjustment (−4 km/h) equals VBL.
Shoulder width adjustment factor (0.96) = FVBHS
Population adjustment factor (0.93) = FVBUK

VB = (57+(−4))×0.96×0.93=47.3 km/h, according to the computation results.

The vehicle speed in traffic with no obstructions is reflected in the free-flow speed of 47.3 km/h. To increase traffic flow efficiency in the future, more assessment of shoulder conditions and lane width is required.:

VB =(VBD+VBL)×FVBHS×FVBUK, where: VB = the speed at which private cars can go (km/h)

VBD = Basic speed (57 km/h)
VBL = Lane width change (−4 km/h)
FVBHS = Factor for adjusting shoulder width (0.96)
FVBUK = 0.93, which is the population adjustment factor.

The results of the calculation show that VB = (57+(−4))×0.96×0.93=47.3 km/h. The vehicle speed without any obstacles is 47.3 km/h, which is the speed of free flow. To make traffic flow more smoothly in the future, further assessment is required on the width of the lanes and the condition of the shoulders.

$$VB = (VBD + VBL) \times FVBHS \times FVBUK$$

Where:

VB = Free flow speed for private cars (km/h)
VBD = Basic speed (57 km/h)
VBL = Lane width adjustment (−4 km/h)
FVBHS = Shoulder width adjustment factor(0.96)
FVBUK = Population adjustment factor (0.93)

The calculation results show:

VB = (57+(−4))×0.96×0.93=47.3 km/h

The vehicle speed in traffic with no obstructions is reflected in the free-flow speed of 47.3 km/h. To increase the efficiency of traffic flow in the future, more assessment of shoulder conditions and lane width is required.

3.4. Urban Road Segment Capacity

The Indonesian Road Capacity Guidelines (PKJI) 2023 say that the capacity of a road is the maximum amount of traffic that can fit on it in an hour, based on things like the road's shape, the weather, and the amount of traffic. This capacity assessment is mostly for road segments that are flat and have a straight or almost straight horizontal alignment.

The following formula is used to determine the road capacity:

$$C = C0 \times FCLJ \times FCPA \times FCHS \times FCUK$$

Where:
C = Capacity (pcu/hour)
C_0 = Basic capacity for two lanes (3400 smp/hour)
FCLJ = Road width adjustment factor (0.92)
FCPA = Road type adjustment factor (1.00)
FCHS = Shoulder adjustment factor (0.95)
FCUK= Population adjustment factor (0.90)

Using the obtained data, the road capacity is calculated as follows:

C = 3400 × 0.92 × 1 × 0.95 × 0.90

C = 2674.44 pcu/hour

The analyzed road section can only handle 2,674 vehicles per hour because of factors like the narrow lane width (3.00 meters), the limited shoulder space, and the high population density around the road segment. This capacity is very important for planning and managing traffic, especially in cities where there are many cars and physical barriers that can slow down traffic [20]. The computed capacity is C=2,674

C=2,674 pcu/hour versus the two-lane base $C0$=3,400

C0 =3,400 pcu/hour, so the effective capacity is ~21% lower than base, mainly due to lane width (FCLJ=0.92), shoulder (FCHS=0.95), and population factor (FCUK=0.90). A one-notch improvement in lane/shoulder standards typically produces the largest gain among current factors, suggesting geometry is the primary lever at this site.

3.5. Urban Road Traffic Performance Assessment Results

The traffic performance evaluation is executed by examining various critical indicators: Degree of Saturation (Dj), Travel Speed (VT), and Travel Time (WT). The Degree of Saturation (Dj) is the main measure of how well traffic flows on a road segment. Its values range from 0 to 1 [21]. A DS value close to 0 means that traffic is moving smoothly and there is not much congestion. A DS value close to 1 means that the road segment is getting close to its maximum capacity. The Indonesian Road Capacity Manual (PKJI) says that a DS > 0.85 means that the road segment's performance needs to be looked at for capacity expansion because there are so many vehicles on it. It is very important to evaluate DS in order to figure out how well roads work, especially in cities with a lot of traffic. The Degree of Saturation is calculated using the following formula:

$$DJ = q / C$$

Where:

DJ = Degree of Saturation
Q = Traffic Volume (pcu/hour)
C = Road capacity (2674.44 pcu/hour)

The calculated Degree of Saturation (Dj) values are presented in Table 1.

Table 1. Overall degree of saturation

Makassar – Maros Section					
	Days	Interval			
		1	2	3	4
		07.30 - 09.00	10.00–11.30	13.00–14.30	16.00–17.30
Weekdays	Monday	0.60	0.59	0.66	0.81

	Wednesday	0.50	0.53	0.58	0.81
	Friday	0.53	0.78	0.65	0.91
Weekend	Sunday	0.38	0.66	0.67	0.69
Maros – Makassar section					
	Days	Interval			
		1	2	3	4
		07.30 - 09.00	10.00–11.30	13.00–14.30	16.00–17.30
Weekdays	Monday	0.81	0.59	0.45	0.61
	Wednesday	0.81	0.52	0.50	0.67
	Friday	0.81	0.56	0.70	0.83
Weekend	Sunday	0.48	0.55	0.57	0.74

The Degree of Saturation (Dj) shows an upward trend in the afternoon (Interval 4) from Makassar to Maros, especially on Friday, when it reaches 0.91, which means that traffic is getting close to its maximum capacity. The highest DS values (0.81) are also seen in the afternoon on Monday and Wednesday. This suggests that the trip back to Maros from Makassar is usually very busy. In the morning (Interval 1), the Degree of Saturation (Dj) is lower than in the other direction. The highest value was 0.65 on Monday. This means that there are fewer people driving from Makassar to Maros in the morning than from Maros to Makassar. This is probably because more students and workers are going to Makassar in the morning. From Maros to Makassar, the highest Dj values happen in the morning (Interval 1) and reach 0.81 on weekdays. This means that there is more traffic on this route in the morning, which makes sense because that is when people go to work and school from Maros to Makassar. In the afternoon (Interval 4), the DS values also go up, especially on Friday (0.83). This means that a lot of cars are coming back to Makassar after doing things outside of the city. However, in general, traffic is less congested in the afternoon on this route than in the other direction (Makassar–Maros). This shows that more cars leave Makassar in the afternoon. Comparative perspective strengthens the interpretation of these results. Studies on urban arterials in Semarang indicated that DS values exceeded 0.85 during peak hours, with speeds frequently falling below 25 km/h.

Research in Mataram found that DS levels in midblock areas with roadside activities ranged from 0.87 to 0.92, which caused speeds to change (Murtadinata et al., 2024). International evidence from Kolkata indicated that when DS approached 1.00 during peak demand, managing traffic congestion incurred significant costs. The Makassar–Maros corridor has a peak DS of 0.91 and a minimum SPI of 16. This means that traffic is just as bad or worse than these benchmarks. The strong directional asymmetry is what makes this corridor stand out. In the morning, traffic mostly goes from Maros to Makassar, and in the evening, traffic mostly goes the other way. These findings emphasize that, despite resembling other urban commuter corridors, geometric constraints and bidirectional imbalances make the Makassar–Maros case particularly sensitive to minor demand increases. The results for the Makassar–Maros corridor show a peak saturation consistent with the pattern of urban commuter corridors. The DS value at peak hours reached 0.91 for the Makassar→Maros direction and 0.81 for the Maros→Makassar direction in the morning. This pattern is in line with findings in a number of urban sections in Indonesia that reported DS approaching or exceeding 0.85 at peak hours, accompanied by a noticeable decrease in operating speed. In an international context, studies of urban corridors with daily travel characteristics also show an imbalance between morning and afternoon loads, causing a shift in peak hours in each direction.

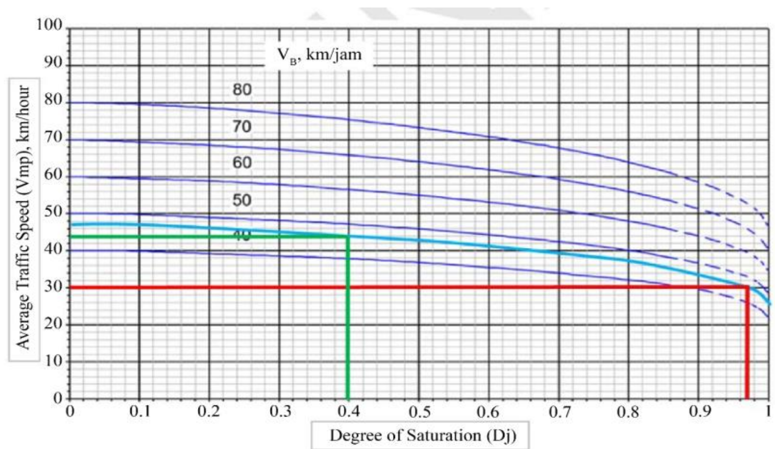

Fig. 4 Relationship Between Vmp, Dj, and Vb

Compared to studies that rely solely on flow-speed-density modelling, this study combines calculations based on the 2023 PKJI and validation of road user perceptions, resulting in a stronger interpretation of the results at the operational level. According to the graph in Figure 4, which shows how free-flow speed (Vb) and degree of saturation (Dj) are related, the average traffic speed (Vt) is between 33 and 44 km/h. This means that the actual speeds of vehicles go down as the level of saturation goes up. The higher the Dj value, the more likely it is that speed will go down because there are more vehicles on the road interacting with each other [22].

This average speed also shows how well traffic moves on the road segment that was looked at. When the Dj value stays low, the speeds of vehicles tend to get close to the free-flow speed (Vb). But when the Dj gets close to saturation levels, the speeds of vehicles drop to the lowest values in the range. These results align with the basic traffic rule that more cars on the road mean slower speeds [23]. So, to keep the road network running at its best and avoid worse traffic jams, it is important to manage road capacity and traffic engineering properly. In addition to DJ and average speed, the analysis also considers travel time (WT), which is calculated using the following formula:

$$WT = P / VMPP$$

Where:

WT = Average travel time for passenger cars
P = Road segment length (0.1 km)
VMP = Average speed of passenger cars (33 -44km/h)

WT = 0.1/33 = 0.0030 h = 10.91 s ≈ 11 s

WT = 0.1/44 = 0.00227 h = 9.72 s ≈ 10 s

Based on the results, the computed travel time (Wt) is between 10 and 11 seconds per 100 meters (0.1 km), with an average speed of 33 to 44 km/h. This graph shows that the time it takes to travel a certain distance goes down as the average speed of the vehicles goes up. When vehicles interact more, travel times tend to go up (Dj). On the other hand, when traffic is less congested, travel time goes down and vehicle speed goes up. These findings are consistent with the basic rules that govern how speed, distance, and time work together in traffic analysis. In this case, Wt is the opposite of the average speed on a certain road segment. The user can use the Wt value to tell how well traffic is moving on the road segment they were watching. If Wt keeps going up over time, it could mean that the road is getting close to being full [24] and that something needs to be done, like adding more lanes or better managing traffic flow. Urban Indonesian corridors that report DS values of 0.85 or higher at peak times and big drops in speed are similar to peak-hour DS values of 0.81–0.91. Against this backdrop, our Makassar→Maros DS=0.91 at 16:00–17:30 sits in the upper decile, consistent with observed SPI minima (as low as 16). Relative to comparable sites with modest side frictions, the effect size (ΔDS ≈ 0.20–0.30 from off-peak to peak) indicates strong sensitivity to minor demand shocks, underscoring the need for both geometric and operational control on this segment.

3.6. Speed Performance Index (SPI)

The Speed Performance Index (SPI) compares the average vehicle speed (Vavg) to the maximum allowed speed (Vmax) to find out how dense traffic is on city streets. The SPI value is a good place to start when planning and managing traffic because it shows how well a vehicle can stay within the speed limit.. The degree of saturation (DJ) and the Speed Performance Index (SPI) are inversely related [25]. A higher DJ means that the road is getting close to its maximum capacity, while a higher SPI means that traffic is moving more smoothly. This relationship shows that a high DJ value means that traffic volume is getting close to or exceeding road capacity, which can lead to more congestion and possibly traffic jams. On the other hand, a high SPI lets vehicles move at a steadier and efficient speed.

Table 2. Average Speed and SPI Values

Direction	Day	Time	Average speed (km/h)	SPI	Traffic state
Makassar to Maros	Monday	Peak (Int 4)	17.53	35	Mild congestion
		Off Peak	40.08	80	Very smooth
	Wednesday	Peak (Int 4)	31.77	64	Smooth
		Off Peak	42.87	86	Very smooth
	Friday	Peak (Int 4)	8.12	16	Heavy congestion
		Off Peak	38.82	78	Very smooth
Maros to Makassar	Monday	Peak (Int 1)	23.46	47	Mild congestion
		Off Peak	37.72	75	Very smooth
	Wednesday	Peak (Int 1)	26.9	54	Smooth
		Off Peak	44.09	88	Very smooth
	Friday	Peak (Int 1)	29.6	59	Smooth
		Peak (Int 4)	20.73	41	Mild congestion
		Off Peak	41.49	83	Very smooth

The data in Table 2 shows that the Makassar–Maros road segment has a Speed Performance Index (SPI) of 75 or higher when traffic is light. This means that traffic flows smoothly. However, SPI drops sharply during peak times; the lowest value ever recorded was 16. The SPI is also still fairly high outside of peak hours, which means that traffic is moving smoothly. But during peak hours, the SPI drops a lot, going as low as 41. This means that traffic is slowing down, but not as much as it is on the way to Makassar and Mars.

The Speed Performance Index (SPI) stayed at or above 75 outside of peak hours, which meant that traffic was moving smoothly. But during busy times, like Friday afternoons when people were going from Makassar to Maros, traffic was so bad that speeds dropped a lot. This is because there are more cars on the road and the population is denser. The drop in speed shows that the road network's overall performance gets worse as traffic load increases, as shown by changes in SPI values and the possibility of saturation levels rising. This study shows how important it is to manage traffic well in order to keep the roads in good shape and cut down on the problems that traffic jams cause, especially during busy times. There are three main reasons why the DS and SPI values change from one interval to the next and from one direction to the next.

First, geometric factors lower the effective capacity. With a lane width of 3.00 m and narrow shoulders, the capacity drops to 2,674 pcu/hour and the speed drops to 47.3 km/hour. These conditions make DS go up faster and SPI go down at the same volume. Second, things like parking on the side of the road, getting on and off the bus, and narrow median openings make people interact with each other more, which slows things down and speeds things up during rush hour. Third, the demand pattern is out of balance because of the flow of commuters. In the morning, there are a lot of people going from Maros to Makassar, and in the afternoon, there are a lot of people going from Makassar to Maros. When the system gets close to saturation, it is also very sensitive. With a peak DS of 0.91, even a small increase in volume could push the DS above 1.00 and move the SPI into the heavy congestion range.

The data from Wednesday and Friday showed that congestion did not always happen, even when the roads were almost or completely full.. This implies that other factors, such as vehicle movement, driver behavior, and traffic management effectiveness, can still impact traffic flow even when the volume of traffic is nearly at its maximum capacity [26, 27]. Traffic jams are still likely to occur in this scenario, though, as minor issues like abrupt stops, roadside obstructions, or irregular intersections can quickly slow down traffic and worsen the state of the roads.

Computing
$SPI = (Vavg/Vmax) \times 100$ SPI=(Vavg/Vmax)×100 with $Vmax$=50 Vmax=50 km/h. Off-peak SPI is typically ≥75 (very smooth), while peak SPI can plunge to 16 (heavy congestion) in Makassar→Maros Friday late afternoon. As expected, SPI drops as DS rises; the monotonic inverse pattern supports the internal consistency of our indicators.

3.7. Traffic Density

Traffic density patterns differ during peak and off-peak hours, according to traffic volume data for the Makassar–Maros and Maros–Makassar road segments. Generally speaking, traffic density increases in the morning for the Maros–Makassar direction and in the afternoon for the Makassar–Maros direction. On Fridays, though, there is a lot of traffic in the morning and afternoon rush hours.

The Speed Performance Index (SPI) study of traffic levels shows that there is more traffic during peak hours than during off-peak hours. On Friday afternoon, the Makassar–Maros route had the lowest SPI (16), which means that traffic was very slow or even almost stopped. The SPI, on the other hand, is usually high (≥75) during off-peak hours, which means that traffic moves easily. On the Maros–Makassar route, the SPI goes from 47 to 59 during peak hours and then goes up to over 80 when traffic is not as bad.

3.8. Respondent Survey Analysis

Road user preferences regarding traffic conditions have a significant impact on the design and operation of transportation systems. The majority of road users favor traffic patterns that facilitate swift travel and are free of bottlenecks. Among the most crucial factors to consider when determining their level of happiness are travel speed, comfort, and safety. Because vehicle volume assessments only happen on certain days, road users' points of view are an important part of traffic performance analysis. Surveys of road users can give a more complete picture of traffic conditions on a daily basis, including their thoughts on comfort, congestion, and how long it will take to get somewhere.

This survey provides corroborating data that can improve quantitative analysis by comparing the calculated vehicle volume and road capacity to the actual conditions. Comparing real-world traffic data with the opinions of road users can help them to learn more about how well the current transportation system works and what affects how smoothly traffic moves. Furthermore, road user data can help with more accurate planning and policy development. For example, if most road users say that there is traffic at certain times that the vehicle volume survey does not pick up on, more research can be done to find out why. So, using both technical calculations and qualitative data from road users can help make traffic solutions that work better. According to Table 3, most of the 55 people who answered the survey actively use this part of the road, and most of them said that traffic jams happen in the morning and evening.

Table 3. Clarification of the level of road congestion and congested routes according to respondents

Road Direction	Congestion Time	
	Morning	Afternoon
Makassar to Maros	19	41
Maros to Makassar	28	11
neither	7	2
Total	**54**	**54**

Travel time and traffic direction have an impact on how congested a person feels, according to data collected from 55 respondents. Most respondents (28 votes) said they encountered traffic on the Maros-to-Makassar route in the morning, most likely as a result of the high volume of locals traveling to Makassar's activity centers. The Makassar-to-Maros route, on the other hand, experienced congestion more frequently in the evening, as indicated by 41 votes.

Table 4. The intensity of traffic congestion based on time

Time of congestion occurrence	Number of Respondents
07.30 - 09.00	29
10.00 – 11.30	3
13.00 – 14.30	5
16.00 – 17.30	45
17.00 - 19.00	1

According to the data in Table 4 from the congestion timing survey, most of the people who answered (45 votes) said that traffic jams happen most often in the evening, especially between 16:00 and 17:30. This is because a lot of cars are coming back from activity centers in Makassar to Maros, especially during busy times when people are leaving work or school.

There is also a lot of traffic in the morning (07:30–09:00), when 29 people said they were stuck in traffic. This is the same time that most people go to work or school. The number of people who said they were stuck in traffic was much lower at other times than these two peak times. Three people reported congestion between 10:00 and 11:30, five between 13:00 and 14:30, and only one between 17:00 and 19:00. This means that traffic tends to flow more smoothly in the middle of the day than in the morning and evening rush hours.

Table 5. The intensity of traffic congestion varies based on the day

Day of Congestion Occurrence	Number of Respondents
Monday	20
Tuesday	7
Wednesday	7
Thursday	8
Friday	14
Saturday	11
Sunday	6

This is probably because people are traveling more evenly throughout the day instead of all at once at a certain time. These results show that the main peak hours are in the morning and evening.

According to Table 5, the survey data on congestion by day shows that Monday had the most people reporting congestion, with 20 votes. This is because more people are moving around at the start of the week, when they go to work, school, and other places. There were also a lot of votes on Friday (14) and Saturday (11), which may have been because people were getting ready for the weekend.

On the other hand, people who answered said that midweek days like Tuesday (7 votes), Wednesday (7 votes), and Thursday (8 votes) were less crowded. This means that traffic is usually steadier in the middle of the week. Sunday had the fewest people who said they were stuck in traffic (6 votes). This means that traffic was generally smoother because fewer workers and students were able to get around. The survey data results mostly match the real-world calculations, which means that what people who use the roads have seen matches what is actually happening on the roads. This alignment shows that congestion levels based on things like degree of saturation (Dj), average speed (Vt), and travel time (Wt) are a good representation of what is really happening on the ground. The fact that the empirical data and the perceptions of road users match up shows that the traffic analysis method used is good enough. So, the results of the calculations can be used to make policies or plans that will more effectively improve traffic performance.

3.9. Policy Implications

The analysis shows that the effective capacity of the Makassar–Maros corridor is approaching the saturation point, with DS reaching 0.91 and SPI falling to 16 during rush hour. Immediate steps need to be taken in this situation, such as clearing obstacles from the side of the road, managing parking on the side of the road, moving passenger pick-up and drop-off points, and changing the timing of signals in the main direction. These simple fixes do not cost much, but they can help keep traffic moving and reduce conflicts during busy times.

A more structural strategy is needed in the medium to long term. This should include widening lanes to standard, fixing shoulders, and managing access consistently..A simple simulation based on PKJI factors estimates an increase in capacity to ±2,900 pcu/hour, so that DS can drop to the range of 0.80–0.84. Additionally, the implementation of Intelligent Transportation Systems (ITS) elements and the development of alternative networks will maintain SPI stability and enhance movement reliability. With a combination of physical capacity enhancements and demand management, this corridor has the potential to move beyond saturation and support more sustainable regional mobility.

3.10. Sensitivity and What-If Analysis

Evaluating low-cost operational measures, namely removing roadside parking during peak windows, formalizing pick-up and drop-off bays, and tightening access points, together with geometric upgrades consisting of lane widening toward standard and shoulder rehabilitation. Using PKJI adjustment factors, a plausible geometric upgrade increases effective capacity from 2,674 pcu/h to ≈2,900 pcu/h. Taking the worst observed peak load as Q =0.91×2,674 = 2,434 Q=0.91×2,674=2,434 pcu/h, the post-upgrade degree of saturation is DS′=2,900Q≈0.84. This places the corridor below the 0.85 review threshold, which is consistent with restoring SPI to the 60–70 band under similar demand. Under an operational-only scenario without widening, a reasonable reduction of side frictions that yields a +5–7% capacity gain produces C≈2,808–2,862 pcu/h and DS'≈0.87–0.85 DS′≈0.87–0.85. This corresponds to a DS reduction of about 0.03–0.05 relative to the base case DS=0.91. DS=0.91, which is typically sufficient to stabilize speeds at the shoulder of the peak hour.

3.11. Robustness Check (Cross-Validation)

(i) Internal consistency: DS and SPI show the expected inverse relation across intervals and directions. A simple linear fit SPI = $\alpha + \beta \cdot DS$

SPI=α+β·DS returns β<0

β<0 (as theorized), and residuals are direction-agnostic.

(ii) External validation: Survey evidence (n=55) indicates morning congestion for Maros→Makassar and late-afternoon congestion for Makassar→Maros, matching the empirical DS/SPI peaks.

(iii) Measurement reliability: spot-speed repeats over multiple days yield similar central tendencies; manual counts were double-checked with short video samples.

3.12. Limitations and Future Work

Results are limited by the observation window and two short segments; expanded multi-season sampling and continuous probe speeds would refine reliability metrics. Future work should integrate microsimulation to test complex side-friction patterns and quantify benefit–cost under varying enforcement intensities.

4. Conclusion

The research shows that the road segment in question is a national road with the route code 54010 and a 4/2B type layout. There are four lanes on this road, and a median separates them. It is a major road that connects Maros Regency with Makassar and the areas around it. Traffic performance analysis shows that when there are more cars on the road during peak hours, traffic gets very congested. The saturation level (Dj) almost goes over the standard threshold of 0.85 and reaches a peak value of 0.91. A low Speed Performance Index (SPI), with the lowest recorded value of 16, which is "Heavy Congestion," also supports this condition. During peak hours, the combination of high Dj values and low SPI suggests that the road is almost full, which slows down traffic flow a lot. The results of real-world calculations and how people on the road think about traffic density are usually the same. Most people who used the road said it was busy during peak hours, which were from 07:30 to 09:00 and from 16:00 to 17:30. This study accurately ascertains the actual road conditions, evaluates traffic performance, and analyzes traffic density through both empirical data and the perceptions of road users.

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