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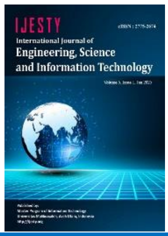

Performance and Capacity Analysis of Pabringan Road in The City of Yogyakarta

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Abstract

This study aimed to ascertain the traffic volume, evaluate the performance and degree of saturation, and identify the service level category on Pabringan Road in Yogyakarta City. We surveyed to obtain primary data for the research method. We then analyzed the data using the Indonesian Road Capacity Manual 1997. According to the survey results, Pabringan Road experiences peak volumes of 792.1 pcu/hour in the morning, 979.3 pcu/hour in the afternoon, and 1103.3 pcu/hour at night. The road capacity calculation yielded a maximum capacity of 1185.52 pcu/hour. The speed on Pabringan Road decreased by 43.52% compared to the design flow speed of 23.72 km/hour, which was approximately 0.75. The analysis results indicate that during the morning peak hour, the level of service falls into category C, characterized by stable flow, increasing traffic density, and an increase in internal obstacles. During the afternoon peak hour, the service level falls into category D, indicating an approaching unstable flow and a high traffic volume. Changes in traffic flow conditions significantly impact the speed, even though it remains manageable. Moderate traffic density, fluctuations in traffic volume, internal traffic obstacles, and temporary obstacles can cause a significant speed reduction. High traffic interval obstacles significantly reduce traffic speed during the evening peak hour, causing drivers to experience short-duration congestion.

Keywords: *Degree of Saturation, Free Flow Speed, Road Capacity, MKJI 1997*.

1. Introduction

Yogyakarta City is the capital city and the center of government and economy of the Special Region of Yogyakarta Province. This city is famous for its ability to maintain traditional concepts and Javanese culture, making it one of the cultural centers in Indonesia. With a total area of 32.5 km2 and a population of around 415,509, Yogyakarta offers a blend of modern life and rich historical values [1] [2]. Three rivers flow around Yogyakarta City, marking its geography: the Winongo River, the Gajahwong River, and the Code River. The Winongo River is located in the western part of the city, while the Gajahwong River is on the east side. The Code River flows through the middle of the town, dividing Yogyakarta into several strategic parts. The existence of these rivers not only functions as a water transportation route but also as an essential element in the city's spatial planning [3]. Despite Yogyakarta's valley location, the Colonial Government's well-organized drainage system prevents frequent flooding. In addition, the Yogyakarta City Government continues to add water channels to overcome the potential for flooding. These efforts ensure that the city remains safe and comfortable, even though it experiences high rainfall in certain seasons [4].

Since its inception, Yogyakarta has had fairly excellent city planning. An imaginary line, stretching from north to south and focusing on the Yogyakarta Palace, determines the direction of the city's development. Along this line, various public facilities were built, including markets, government offices, and abdi dalem villages, which are divided into two parts: Jero Beteng Village, located inside Baluwarti Fort, and Jaba Beteng, which is outside the fort [5] [6]. As a center of culture and government, the palace provides a strong identity for the city. Around it, public facilities were built to support community activities and improve the quality of life among Yogyakarta residents. This well-planned city creates a comfortable and efficient space for residents and visitors. The city of Yogyakarta relies on the industrial, trade, and service sectors, especially in the tourism sector [7] [8] [9] [10]. With its various cultural and historical attractions, Yogyakarta is one of the main tourist destinations in Indonesia. This significantly contributes to the local economy and creates jobs for the community [11].

Yogyakarta has several traditional markets in the trade sector spread across various sub-districts, with the Beringharjo Market being the largest. Beringharjo Market is a shopping center and a cultural and historical icon for the people of Yogyakarta. In addition, several other large markets, such as Kranggan Market, Legi Market in Kota Gedhe, Sentul Market, and Giwangan Market [12], each offering various products and unique shopping experiences. Traditional markets in Yogyakarta not only sell necessities but also provide second-hand goods and antiques, attracting the attention of visitors looking for unique and historical items. These markets offer local traders an opportunity to sell their products while creating social interaction among the community. In addition to traditional markets, there are also busy trading areas on Malioboro Road and Oerip Sumoharjo Road. Malioboro Road is famous as a shopping center and tourist destination, where visitors can find various shops, kiosks, and restaurants selling handicrafts, traditional foods, and other goods. This area symbolizes the dynamic economic life in Yogyakarta while reflecting a blend of tradition and modernity [13] [14].

The Beringharjo Market area was originally a banyan forest. Hamengku Buwono IX gave this market, the largest in Yogyakarta, its name. The name implies that the community expects the area filled with banyan trees (bering) to bring prosperity (Harjo). Since 1758, shortly after the establishment of the Ngayogyakarta Hadiningrat Palace, people have used Beringharjo Market as a place for buying and selling. In 1925, Beringharjo Market began to have a permanent building for its economic transactions. Today, it offers various products, including clothes, fruits, vegetables, spices, fish, meat, market snacks, bridal makeup, and engagement gifts. Visitors cannot miss Beringharjo Market, an inseparable part of Malioboro. In addition to being the center of economic activity for hundreds of years, its existence also has a deep philosophical meaning. This market is one of Catur Tunggal's pillars: the Palace, North Square, South Square, and Beringharjo Market. Catur Tunggal symbolizes the economic function as a food supplier for the palace's residents, the servants, and the surrounding community. Beringharjo Market occupies a land area of 25,000 m2 and falls under the class I market category. The location of this market is strategic, bordering Malioboro Road on the north side, Ahmad Yani Street on the east side, Pabringan Road on the south side, and Sriwijaya Road on the west side. With its strategic position and the variety of commodities offered, Beringharjo Market is a center of trade and a symbol of Yogyakarta's diversity of culture and traditions [15] [16] [17].

Pabringan Road, located on the south side of Bringharjo Market, is very crowded and seems chaotic due to the many vehicles parked and passing on the road [18]. Street of Pabringan, with its narrow width of 5 meters, warrants enforcement as a one-way road leading to Street of Malioboro. However, many vehicles violate this rule in reality, and the number of cars parked along the road further narrows the traffic space. Many street vendors exacerbate this situation by selling on sidewalks and roadsides, leading to extended traffic jams, particularly during the holiday season. This condition disrupts the smooth traffic flow and affects the comfort of pedestrians and other road users. While street vendors offer options to the community and tourists, we should better regulate their existence to foster a more orderly and comfortable atmosphere for all road users. We must overcome this problem, including rearranging parking lots, raising awareness of traffic regulations, and allocating unique spaces for street vendors to avoid obstructing road access [19] [20] [21] [22].

2. Research Method

This research methodology systematically analyzes traffic congestion through stages, from preparation to conclusions and recommendations. In the preparation stage, the researcher first conducts a literature study to understand previous studies' theories, concepts, and findings related to traffic congestion. The researcher then performs a location survey to directly observe traffic conditions in the field and identify observation points that will serve as research objects. After conducting an initial study, the researcher continues with problem formulation. Based on the understanding of the literature study and location observations, the researcher compiles the main problems to be studied, especially in identifying the factors causing congestion and efforts that can be made to overcome them.

The next step is data collection, which focuses on primary data through field observations. The data collected includes traffic volume, namely the number of vehicles passing the observation point in a certain period, and side obstacles to traffic, such as parking on the side of the road or pedestrian activities that can disrupt traffic flow. These data are the main ingredients in understanding traffic conditions in the field. Following data collection, the data processing stage transforms raw data into relevant information through processing and analysis. Congestion analysis follows this stage, where researchers scrutinize several crucial factors: traffic volume, free flow speed (the average speed of vehicles in smooth traffic conditions), road capacity (the maximum number of vehicles that can traverse the road without causing congestion), degree of saturation (the ratio between traffic volume and road capacity), and level of service, which signifies the quality of traffic services in terms of speed and comfort for road users. Researchers then interpret the results of this analysis in the discussion stage, deepening their understanding of the traffic conditions at the research location and identifying the main problems that cause congestion [14]. Based on the discussion, researchers prepare a conclusion that includes the main findings of this study as well as recommendations to address the identified congestion problems. We anticipate that these recommendations will assist policymakers in devising strategies to reduce congestion.

3. Result and Discussions

To complete this analysis, we used average daily traffic data obtained through a traffic survey and manually calculated. The Indonesian Road Capacity Manual guides the traffic performance analysis for each road. The parameters analyzed include traffic volume (the number of vehicles passing a point in a certain period), free flow speed (vehicle speed when traffic conditions are smooth), road capacity (the maximum number of vehicles that can pass through the road without causing congestion), degree of saturation (the ratio between traffic volume and road capacity), and road service level (the quality of traffic service assessed based on speed and comfort for road users). Through this analysis, we aim to provide an accurate picture of road performance and congestion levels, which can serve as a reference for making traffic management decisions.

3.1. Traffic Volume

We calculate traffic volume to determine the number of vehicles passing during peak hours. At this stage, we systematically record each vehicle's movement to produce accurate data on traffic density levels. This data is essential because it provides an overview of the number of vehicles passing a point in a specific time unit, especially when vehicle volume is at its peak. Calculating vehicle volume produces units of vehicles/hour, which indicates the number of vehicles per hour. However, we convert this unit into passenger car units per hour (pcu/hour) to obtain more representative and standardized data. The pcu/hour unit allows for a more precise analysis because it accounts for the different impacts of each type of vehicle on traffic flow, such as passenger cars, trucks, and motorcycles. Conversion into pcu/hour units is essential for a fairer comparison of road capacity. Each type of vehicle has a different size and impact on road space and flow speed, so the use of pcu/hour helps in a more accurate assessment of road capacity. Thus, the data obtained from this traffic volume calculation becomes an essential basis for congestion analysis and traffic management planning. A traffic counter, a tool that counts each vehicle's movements in a specific time unit, calculates traffic flow. This tool provides accurate data on traffic intensity at various times throughout the day, making it easier to analyze traffic density at the research location. We carried out traffic flow calculations at the Pabringan Road location for three consecutive days: Friday, Saturday, and Sunday. The selection of these days aims to represent weekdays or days with high-density levels. The data obtained can reflect a more representative traffic situation by conducting observations these days. We divide each observation day into three sessions: morning (morning peak hour) at 09.00–11.00, afternoon (evening peak hour) at 15.00–17.00, and evening (evening peak hour) at 18.00–20.00. This division of time allows for a more detailed analysis of the differences in vehicle volume at each peak hour, providing a more comprehensive picture of traffic flow patterns at the location.

3.2. Free Flow Speed

When the road conditions are in a zero-flow state, meaning no other vehicles influence the driver's velocity, a vehicle adopts the free flow speed (FV). It describes the speed drivers would choose if they were driving their vehicles freely without obstacles from other traffic. According to the Indonesian Road Capacity Manual, free flow speed is one of the critical components in assessing traffic performance. This assessment often uses the free-flow speed of light vehicles as the primary criterion. We choose light vehicles because they generally represent the majority of vehicles on the road and have more stable speed characteristics. Thus, the analysis of the free flow speed of light vehicles provides a relevant reference for assessing the performance of road segments under zero flow conditions. Understanding this free-flow speed is essential for determining road capacity and service levels. Researchers can measure the free flow speed under optimal conditions to guide the planning of capacity and traffic flow improvements on specific road segments. The calculation results show that the free flow speed (FV) of vehicles on Pabringan Road is 23.72 km/h, which is lower than the optimal free flow speed (FVo) of 42 km/h. This difference indicates that traffic flow is moving slower than planned, with a speed reduction of 43.52% from the optimal speed. The significant difference between FV and FVo suggests that there are factors that inhibit traffic flow so that vehicle speed does not reach its optimal potential. These factors can include side obstacles, such as parking activities on the roadside, pedestrian activities, or even vehicle volumes that exceed the capacity of the road. This 43.52% reduction in speed also impacts road users' level of service and comfort. With a speed lower than the planned speed, congestion tends to increase, ultimately affecting overall traffic efficiency on the road.

3.3. Road Capacity Calculation

Based on the calculation of the amount of traffic flow (Q) on the road section, it is known that during the morning peak hour, the flow volume reaches 792.1 pcu/hour. This figure is still below the existing road capacity, indicating that traffic in the morning is relatively smooth despite the increase in volume. Traffic flow increases to 979.3 pcu/hour during the afternoon peak hour. This volume is close to the maximum capacity of the road section, which is 1185.52 pcu/hour. This indicates that in the afternoon, the Pabringan Road section begins to experience a significant increase in density, approaching the threshold the road can accommodate. Traffic flow is even higher during the evening peak hour, reaching 1103.3 pcu/hour. This volume is close to the maximum capacity of the road, with a slight difference from the existing capacity of 1185.52 pcu/hour. This indicates that Pabringan Road is highly congested at night, nearly reaching a saturation point, where any increase in vehicle volume could lead to congestion or a decline in the quality of road service. The influence of land use along Pabringan Road is very significant in determining road capacity. In addition to road geometry, land use characteristics such as residences, shops, schools, and public facilities create side obstacles that can disrupt traffic flow. When vehicles stop to drop off or pick up passengers, park, or access these facilities, these obstacles can reduce road capacity and increase the potential for congestion. Transportation, work, students, and commerce-oriented land activities contribute significantly to high mobility. For example, during school hours, the number of vehicles passing through increases dramatically, creating peaks that can cause traffic congestion. This shows that the movements generated by these activities directly affect the efficiency of road capacity. Effective land use design is crucial to optimizing road capacity and reducing traffic congestion. Planning land use with consideration of accessibility and its impact on traffic flow will help create a more efficient environment. In addition, supporting infrastructure such as sidewalks, bike lanes, and adequate parking areas can also contribute to reducing side obstacles and increasing overall capacity and comfort.

3.4. Degree of Saturation

The Degree of Saturation (DS) ratio characterizes road capacity utilization in relation to its maximum capacity. This ratio is critical in traffic analysis because it indicates how complete a road section is. The higher the DS value, the greater the likelihood of congestion and decreased road performance. Road sections use DS as a primary factor to determine their performance level, considering factors like average vehicle speed, travel time, and driving comfort. When DS reaches a specific value, usually above 0.85, the quality of road service will decrease, causing increased congestion, delays, and the risk of accidents. Therefore, monitoring DS is essential for effective traffic management and transportation infrastructure planning. By understanding and monitoring the degree of saturation, authorities can take steps to improve road performance, such as implementing traffic management policies, improving infrastructure, or planning better land development. This will help create a smoother traffic flow and enhance the safety and comfort of road users. The results of the traffic flow calculation show that there is significant variation in the volume of vehicles passing during peak hours. The morning peak hour recorded a traffic flow of 792.1 vehicle units per minute (pcu/hour). This figure reflects a relatively high activity level on the road, with many road users heading to their destinations, such as work or school. During the afternoon peak hour, traffic flow increased to 979.3 pcu/hour, indicating increased trade activity and vehicle movement. This increase could be due to more intense trade activity and the movement of people visiting public places or carrying out other daily activities. Then, during the afternoon peak hour, the traffic flow reached a record high of 1103.3 pcu/hour. This increase in vehicle volume is usually caused by many people returning from work or school activities and other social activities. With high traffic flow during these peak hours, it is important to consider effective traffic management to reduce congestion and improve safety.

The results of the road capacity calculation show that the maximum road capacity is 1185.52 vehicle units per minute (smp/hour). This figure indicates the maximum number of vehicles the road can service under ideal conditions, free from congestion. This capacity is crucial in planning and managing traffic flow because it provides basic information about how many vehicles can pass through a road section in one hour. With a capacity of 1185.52 smp/hour, we can analyze road performance based on the measured traffic flow. The morning peak hour recorded a traffic flow of 792.1 smp/hour, indicating that the road remains in relatively excellent condition, as the vehicle volume remains below the maximum capacity. However, during the afternoon and evening peak hours, traffic flow reached 979.3 smp/hour and 1103.3 smp/hour, respectively, close to maximum capacity. When traffic flow approaches or exceeds road capacity, the risk of congestion and decreased service quality will increase. Therefore, conducting proper monitoring and management of traffic flow on Pabringan Road is essential, including implementing strategies to improve efficiency and safety and considering appropriate infrastructure planning to address potential problems that may arise due to high vehicle volume.

Table 1. Saturation Degree on Pabringan Road

Time	Flow (smp/hour)	Capacity (smp/hour)	Q/C	Service Level
09.00 – 11.00	792,1	1185,52	0,66	C
15.00 – 17.00	979,3	1185,52	0,82	D
18.00 – 20.00	1103,3	1185,52	0.93	E

Based on the calculation results, the saturation degree (DS) value shows significant variations at various peak hours. The morning peak hour recorded a saturation degree value of 0.66. This figure indicates that traffic flow at that hour is still within safe limits, with sufficient road capacity to accommodate passing vehicles. Hence, the quality of service on the road is relatively good. During the afternoon peak hour, the saturation degree increased to 0.82. Although this figure is still below the critical threshold (usually 0.85), a higher saturation level indicates that the road is starting to experience more pressure due to the increasing volume of vehicles. This condition can cause an increase in travel time and a slight decrease in driving comfort, especially approaching rush hour.

Furthermore, the saturation degree value reached 0.93 during the evening peak hour. This figure indicates that the road is approaching maximum capacity and in critical condition. With a high level of saturation, the risk of congestion and decreased service quality is more significant, which can affect the safety and comfort of road users. Therefore, it is essential to conduct further analysis and consider effective traffic management solutions to reduce the negative impacts of this high saturation level.

3.5. Road Service Level

The Indonesian Road Capacity Manual defines a road section's level of service (Level of Service, LOS) as a qualitative measure that reflects the driver's perception of driving quality on the road. This level of service is an essential indicator in assessing how well a road section can serve the flow of traffic passing through. With the service level analysis, we can better understand Pabringan Road's condition and performance in dealing with the existing volume of vehicles. Analysis of the level of service involves various factors, including traffic flow speed, vehicle density, and driving comfort. Based on the previously calculated saturation value, we can evaluate whether the road is in the category of excellent service or not. For instance, when the saturation level nears its maximum capacity, road users may experience a decline in service quality, resulting in longer travel times and an increased risk of congestion. By understanding the level of service, authorities can take the necessary steps to improve the quality of the road. This may involve infrastructure improvements, traffic management, or better land use planning. All of these efforts aim to ensure that Pabringan Road can continue to serve traffic flow efficiently and safely, thus supporting the mobility and comfort of road users.

Table 2. Level of Service of Pabringan Road

Time	Flow (smp/hour)	Capacity (smp/hour)	Q/C	Service Level
09.00 – 11.00	792,1	1185,52	0,66	C
15.00 – 17.00	979,3	1185,52	0,82	D
18.00 – 20.00	1103,3	1185,52	0.93	E

Method analysis results revealed that during the morning peak hour, the level of service falls into category C. This category indicates that the traffic flow is in a stable state, where vehicles can still move well, but traffic density begins to increase. Although cars can still move freely, this increase in density signifies that the road is starting to feel pressure from increased vehicle volumes. In category C, internal obstacles, including interactions between vehicles and activities along the road, also experience an increase. This can cause a decrease in the average speed of cars and the potential for increased travel time for drivers. Although this situation is still considered acceptable, it is essential to monitor it so that it does not continue to fall into a lower category, which can cause congestion and a decrease in service quality. Understanding that the morning peak hour service level falls under category C allows authorities to plan and implement more effective traffic management strategies. Efforts such as regulating traffic signals, implementing parking policies, or improving road infrastructure can help keep traffic flow stable and prevent more severe congestion during the following peak hours.

During the afternoon peak hour, the analysis results show that the level of service is in category D. This category indicates that the traffic flow is approaching an unstable condition, where high traffic volumes cause pressure on road capacity. Although vehicle speeds are still within tolerable limits, changes in traffic flow conditions can quickly affect these speeds, creating a situation prone to congestion. Traffic density during the afternoon peak hour is moderate. Still, traffic volume fluctuations, along with internal traffic obstacles (such as interactions between vehicles) and temporary obstacles (such as parked vehicles or roadside activities), can cause significant speed reductions. Under these conditions, drivers may feel discomfort and uncertainty in vehicle movement, negatively impacting driving safety and efficiency. With the understanding that the level of service during the afternoon peak hour is in category D, authorities must take proactive measures in traffic management. Strategies such as increasing traffic surveillance, adjusting traffic light times, and providing clear information about road conditions can help minimize the impact of existing obstacles, keep traffic flow relatively smooth, and prevent worse situations during subsequent peak hours.

During the evening peak hour, the analysis results show that the level of service falls into category E. High internal obstacles impede vehicle flow, leading to a significant reduction in traffic speeds. Drivers start to experience congestion, although it typically lasts for a short period. Road users experience discomfort due to slow movement and significant speed fluctuations. The level of service conditions that fall into category E indicates that the road is already operating at its capacity threshold. Although traffic flow can still move, existing obstacles, from interactions between vehicles and other external factors, can cause a drastic decrease in speed. This has the potential to create uncertainty for drivers regarding travel time, which can increase the risk of traffic accidents. With the understanding that the level of service during the evening peak hour is in category E, authorities need to consider remedial measures to reduce the impact of congestion. This could include better traffic management, improving road infrastructure, and introducing a more efficient traffic management system. These efforts are essential to enhance the comfort and safety of road users and maintain service quality.

4. Conclusion

The conclusion of this study can be arranged in several main points that reflect the analysis results related to Pabringan Road. First, the survey results revealed that the traffic volume reached 792.1 pcu/hour during the morning peak hour, 979.3 pcu/hour during the afternoon peak hour, and 1103.3 pcu/hour during the evening peak hour. These data indicate a significant increase in traffic volume as time increases, especially during the evening peak hour. Second, the road capacity calculation results show that the maximum capacity is 1185.52 pcu/hour. Although this maximum capacity is relatively high, there is a decrease in traffic flow speed of 43.52% compared to the design flow speed. We recorded the design flow speed (FV) at 23.72 km/hour, significantly lower than the ideal (FVo) of 42 km/hour. This shows that the current performance assessment can serve less vehicle volume, especially during the morning and evening peak hours. The calculation of the degree of saturation (Degree of Saturation) proves this, revealing a value of 0.66 during morning peak hours, 0.82 during afternoon peak hours, and 0.93 during evening peak hours. This degree of saturation value indicates that the road is already on the threshold of ideal capacity, where the DS value should be less than 0.75. Third, the analysis of the level of service yielded different categories for each peak hour. During morning peak hours, the traffic flow remains stable in category C despite increased density and internal obstacles. During evening peak hours, the traffic flow reaches category D, approaching unstable conditions with high traffic volume and tolerable speeds, yet subject to significant fluctuations. Finally, at evening peak hours, the level of service is in category E, which means that traffic speed is deficient due to high internal obstacles, where drivers begin to feel congestion in a short duration. Thus, the study's results suggest that Pabringan Road encounters significant challenges in handling traffic volumes, particularly during peak hours, necessitating implementing more effective traffic management strategies and enhancements to the road infrastructure.

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