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CAPACITY INCREASE PLAN ANALYSIS BY ADDING LANE TO THE JAKARTA-CIKAMPEK TOLL ROAD

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ABSTRACT

The Jakarta-Cikampek Toll Road serves as a vital route, connecting Jakarta to its eastern suburbs and facilitating both passenger travel and logistics operations. However, persistent congestion along this stretch of highway has prompted the need for a comprehensive assessment of its capacity performance. This study aims to evaluate the Jakarta-Cikampek Toll Road's capacity performance using the V/C ratio metric. The analysis encompasses the calculation of V/C ratio values for the years 2022–2023, forecasting peak-hour daily traffic volumes for 2024 under three distinct scenarios: (i) no capacity expansion, (ii) capacity expansion through the addition of one lane, and (iii) traffic management intervention involving one-lane contraflow. The findings reveal that the highest V/C ratio values for peak hours in 2024, without lane additions, are 0.65 for Lane A and 0.71 for Lane B. However, these values decrease to 0.49 for Lane A and 0.53 for Lane B when considering capacity expansion through lane addition or contraflow implementation. Therefore, to ensure compliance with the Minimum Service Standards (SPM) until the end of the concession period, it is recommended that the toll road operator implement capacity enhancement by adding one lane in each route.

KEYWORDS *Toll Road; Capacity Increase; V/C Ratio; Traffic Volume Forecasting*

INTRODUCTION

Transportation is closely linked to urban development (Pratama et al., 2022). It allows previously isolated areas to connect with economic centers, opening up new opportunities for investment and development. (Milleda & Hidayanti, 2023).. Transportation itself can be accessed by land, air and sea. However, the majority of people choose to use land transportation, namely both for transportation of goods by 90%, and for passenger transportation by 95%. (Makmur & Rajagukguk, 2015). Based on data from the Central Statistics Agency (BPS), the increase in the number of motorized vehicles is 2-7% per year while the total length of roads in Indonesia

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reaches 549,161 kilometers (km) by the end of 2022 or an increase of 0.46% compared to the previous year which was recorded at 546,630 km. The use of land routes can also be seen from the high growth in the number of private vehicles in Jakarta, which is 9% per year or around 1,117 vehicles per day (Iswanto et al., 2013). Therefore, the government continues to strive to provide better road infrastructure, one of which is through toll roads that involve the private sector in order to realize reliable services. (Makmur & Rajagukguk, 2015)..

Toll roads themselves are part of national roads according to Law of the Republic of Indonesia Number 38 of 2004 concerning Roads. The Toll Road Regulatory Agency (BPJT) said that until 2024 the total length of toll roads in operation has reached 2,836 km. In order to provide reliable services to toll road users, the Government through the Minister of Public Works Regulation number 16/PRT/M/2014 regulates Minimum Service Standards (MSS) for Toll Roads consisting of several indicators, one of which is the average travel speed. In the regulation, the average travel speed of normal conditions on toll roads in the city is more than equal to 40 km / h and more than equal to 60 km / h for toll roads outside the city (Minister of Public Works, 2014). Vehicle speed itself is often correlated with the density of the toll road section (Iskandar, 2012). While congestion itself usually occurs due to the high volume of vehicles or disruptions caused by work or vehicle accidents. To make it easier to evaluate, density can be measured through the saturation degree index or *V / C Ratio* by comparing the volume of vehicles and the capacity of the toll road section.

Road capacity can be defined as the maximum number of vehicles that can travel on a road segment. (Asgharzadeh & Kondyli, 2018).. Capacity calculations will reach an optimum value when the right configuration between the number of lanes and the number of incoming vehicles is found (Zarrillo et al., 2002). Therefore, road planning and development must be done by considering various factors, including future needs, technological developments, and environmental impacts (Efriansyah et al., 2022). However, the determination of toll road capacity will have a direct impact on the investment costs incurred by the Toll Road Business Entity (BUJT). If the investment value of a toll road is high enough, the government must provide a longer concession period because otherwise the toll road manager will find it difficult to get a return on investment (Chen et al., 2021).

One of the toll roads that underwent various developments and updates to meet the growing needs of road users is the Jakarta - Cikampek Toll Road. Built in several stages since the 1980s, the Jakarta - Cikampek Toll Road is considered to play an important role in the movement of people and goods on the island of Java. The Jakarta - Cikampek Toll Road is part of the Trans Java Toll Road where 40.76% of the total length of the toll road or 1,167 km is Trans Java Toll Road. Currently the Jakarta - Cikampek Toll Road is managed by PT Jasamarga Transjawa Tol (PT JTT). In 2023, the number of vehicle transactions on the Jakarta - Cikampek Toll Road is 165,955,795 vehicles or 40.45% of the total number of vehicle transactions along the Trans Java Toll Road managed by PT JTT. The Jakarta - Cikampek Toll Road offers various classes of toll rates that are adjusted to the type of vehicle and distance traveled. These rates are set based on calculations that consider operational costs, infrastructure maintenance, and investment for further development.

Given the importance of the Jakarta - Cikampek Toll Road in the national transportation system, ongoing efforts to maintain and improve this toll road infrastructure are a top priority. This includes investment in the latest technology for traffic management, periodic maintenance to ensure safe road conditions, and the development of new projects to address dynamic congestion challenges (Ardiansyah & Sudibyo, 2020). The Toll Road Regulatory Agency considers that the density that occurs on the Jakarta - Cikampek Toll Road is getting worse so that the Government encourages the immediate implementation of the construction of a new toll road, namely the Jakarta - Cikampek II Elevated Toll Road. (Hamdani, Infrastructure, 2018). This can be seen from the *V / C Ratio* value of the Jakarta - Cikampek Toll Road which almost reaches 1. (Hamdani, Infrastructure, 2018).. In addition, on the south side of the Jakarta - Cikampek Toll Road, the Jakarta - Cikampek II South Toll Road was also built. The construction of the new toll road was carried out in order to increase capacity to overcome the congestion that often occurs on the Jakarta - Cikampek Toll Road, especially during peak hours and on holidays.

The construction of the Jakarta - Cikampek II *Elevated* Toll Road is an important innovation that aims to separate the flow of long-distance traffic from local traffic, thereby improving smoothness and reducing travel time. In addition to increasing capacity, one of the efforts that toll road operators have made to overcome the congestion that occurs is traffic management, namely *contraflow* (Pamungkas et al., 2014). However, the implementation of *contraflow* is a temporary solution that also creates new problems. *Contraflow* is considered to be dangerous for vehicles that experience problems. (BBC News Indonesia, 2024). In addition, in 2024, a number of accidents occurred during the implementation of *contraflow* on the Jakarta - Cikampek Toll Road, one of which resulted in death. (BBC News Indonesia, 2024).

Although it has experienced development, the Jakarta - Cikampek Toll Road still has the potential to improve services, especially in terms of capacity to support smooth traffic. Currently the Jakarta - Cikampek Toll Road has 4 lanes for each direction. However, there are sections that only have 3 lanes for each direction, namely the Cikarang Timur - West Karawang section. The difference in the number of lanes also has the potential to become an obstacle to smooth traffic. The occurrence of accidents during the implementation of *contraflow*, as well as the potential for *bottlenecks* due to capacity non-uniformity, are several factors that need to be considered by toll road managers to find the most effective solution to overcome congestion problems, especially in the Jakarta - Cikampek Toll Road section.

The problems on the Jakarta - Cikampek Toll Road are mainly related to the non-uniformity of the number of lanes which causes bottlenecks, especially at the transition from 4 lanes to 3 lanes. This study aims to analyze the performance of the toll road based on the current V/C Ratio and predict the V/C Ratio one year ahead with several scenarios: without additional capacity, with additional capacity, and with traffic engineering. The research focus is limited to the Cikarang Timur - Karawang Barat section which has 3 lanes for each direction, using secondary data on daily traffic volume from PT Jasamarga Transjawa Tol (PT JTT) for the period

January 1, 2022 - December 31, 2023. The benefits of this research include suggestions for PT JTT regarding the plan to add lanes and provide alternatives to improve toll road performance, as well as adding literature for academics related to toll road capacity strategies.

Previous research on toll roads covers various aspects of management and evaluation. Zarillo et al. (2002) used the Toll Network Capacity Calculator (TNCC) to calculate toll gate capacity and found that capacity disruptions can impede traffic flow. Makmur & Rajagukguk (2015) examined the Minimum Service Standards (MSS) of toll roads in Indonesia, finding that aspects of road condition and safety are often not met. Persia et al. (2016) analyzed Road Infrastructure Safety Management (RISM) procedures and suggested the importance of a legal basis and adequate training. Pamungkas et al. (2014) proved that contraflow effectively reduces the degree of saturation, but requires official regulations for safety. Jun (2009) evaluated congestion patterns during the Thanksgiving holiday with the Gaussian mixture speed distribution method. Othayoth & Rao (2020) examined the relationship between level of service and V/C Ratio at signalized intersections with heterogeneous traffic conditions, concluding that there is no direct relationship between the two.

RESEARCH METHOD

Research Design

This research uses a descriptive quantitative method to describe the characteristics of the research object. The initial stages involved determining the theme and compiling a bibliography, followed by secondary data collection. After the data is collected, it is analyzed to produce improvement proposals and conclusions. Descriptive studies, as described by Bougie & Sekaran (2020), help in understanding group characteristics, offer ideas for further investigation, and help make decisions.

Research Stages

The research began by identifying problems on the Jakarta - Cikampek Toll Road related to the fulfillment of Minimum Service Standards in the aspect of minimum vehicle speed. The plan to increase capacity by adding one lane in the Cikarang Timur - Karawang Barat section was evaluated. After determining the research problem, a literature study was conducted to obtain a theoretical basis. A research design was developed to predict the daily traffic volume at peak hour in 2024 based on data from 2022-2023. A "what-if" analysis was conducted to compare the impact of capacity improvement conditions on toll road performance.

Data Collection

The data used are secondary data in the form of literature, journals, reports, and daily traffic volumes at peak hours for two years (2022-2023) with a total of 730 data. The data is taken from the Cikarang Timur - Karawang Barat section which has the potential to increase capacity with the addition of one lane. This secondary data is also used as a theoretical basis for analysis.

Data Analysis Method

Data analysis began with a diagnostic of daily peak hour traffic volume data for the years 2022-2023. Predictions of traffic volume data for 2024 were made using several methods such as Moving Average, Weighted Moving Average, Exponential Smoothing, Trend Projections, and Seasonal Indices. The prediction results were compared using MAD, MSE, and MAPE parameters to determine the most accurate method.

Predicted V/C Ratio

To measure toll road performance, the V/C Ratio value is calculated based on daily traffic volume data at peak hours in 2022-2023 and predicted results in 2024. The formula and steps for calculating the V/C Ratio follow the Indonesian Road Capacity Guidelines (2023). What-if analysis compares the V/C Ratio values for scenarios without capacity increase, one lane addition, and contraflow traffic engineering. The scenario with the highest V/C Ratio value illustrates the worst condition of the toll road.

RESULT AND DISCUSSION

Toll Road Industry in Indonesia

Since 1978 until mid-January 2024, the total length of toll roads in Indonesia reached 2,816 km, covering 1,782.47 km of Java Island, 865.43 km of Sumatra Island, 97.27 km of Kalimantan Island, 61.64 km of Sulawesi Island, and 10.07 km of Bali Island where all toll roads are managed by 59 Toll Road Business Entities (BUJT) with 73 toll road sections including 132 Rest and Service Points (TIP) spread across the toll roads. (Toll Road Regulatory Agency, 2024). The Indonesian government defines toll roads as public roads that are part of the road network system and are national roads where users are required to pay tolls.

Figure 1. Map of Toll Road Network in Indonesia
Source: (Toll Road Regulatory Agency, 2024)

The toll road itself is one of the infrastructures included in the National Strategic Project (PSN) based on Presidential Regulation (Perpres) number 56 of 2018 concerning the Second Amendment to Perpres number 3 of 2016 concerning the Acceleration of PSN Implementation. Based on the 2020-2024 Medium-Term Development Plan (RPJMN), Indonesia's infrastructure financing needs amount to IDR 6,445 trillion, while the Government's ability to finance these infrastructure

needs is estimated at only 37% of the total funding needs, so that the rest is provided by State-Owned Enterprises (BUMN) by 21% and private sources by 42%. The limitations of the state budget in financing infrastructure expansion cause financial problems (funding) that must be overcome. To solve it, the government uses several financial options, one of which is a development cooperation program involving the private sector or PPP (*Public-Private Partnership*) (Ditjen Pembiayaan Infrastruktur PUPR, 2021).

Based on Government Regulation No. 15 of 2005 concerning Toll Roads, toll road concession can be implemented with 2 (two) schemes, namely *Build Operate Transfer* where BUJT has the obligation to finance, design, build, operate and maintain a toll road section within a certain period of time to be later transferred back to the Government, and *Operation and Maintenance Contract* where BUJT has the obligation to operate and maintain a toll road section within a certain period of time to be later transferred back to the Government. Furthermore, the PP also explains that BUJT can also utilize toll road property space, including the placement of advertisements, utility buildings, road safety spaces, and additional traffic lanes. The addition of traffic lanes itself is carried out in order to increase the capacity of the toll road section with the aim of reducing the volume of traffic on the toll road, especially during peak hours, so that the existing capacity can be used more efficiently (Pratama, 2019).

Traffic Management with *Contraflow* System

Traffic management is a series of activities aimed at promoting safe and effective traffic circulation, overcoming congestion, and reducing the number of road accidents with a variety of strategies, including traffic engineering, the use of traffic control equipment, and careful transportation planning (Almukhalfi et al., 2024). One of the traffic engineering that is often carried out on toll roads when congestion occurs due to high traffic volumes is *contraflow*. *A contraflow* lane can be defined as a lane where the direction of traffic flow is changed to the opposite direction for a temporary period of time. (Transport Association of Canada, 2010).

In some countries, *contraflow* is proven to reduce obstacles and increase lane capacity as seen from the number of vehicles that can be accommodated by the lane (Ma et al., 2018; Kotagi & Asaithambi, 2019). In Indonesia, *contraflow* is commonly used on non-toll roads and toll roads. Parulian & Trisbiantara (2023) analyzed the effect of *contraflow* implementation on the Tomang - Harmoni corridor. As a result, the implementation of *contraflow* on the road section can reduce the degree of saturation (*V / C Ratio*) by 21% to 48%.

On toll roads, *contraflow* is usually implemented when congestion occurs due to high traffic volumes, both in the lanes at the toll gate and in the main lanes. At the Sidoarjo Toll Gate, *contraflow* implemented on the eve of Eid al-Fitr 2023 increased the average speed by 62.22% (Radiansyah et al., 2024). The implementation of *contraflow* is also carried out on the Jakarta - Tangerang Toll Road section where the implementation of *contraflow* can reduce the *V / C Ratio* by 0.14 (Pamungkas et al., 2014). Meanwhile, when carried out at the Cawang Interchange on the inner city toll road, *contraflow* is proven to increase vehicle

speed by 39.98% compared to vehicle speed when no *contraflow* is implemented. (Hamidia & Salma, 2021)..

Company Profile

PT Jasamarga Tranjawa Tol (PT JTT) is a subsidiary of PT Jasa Marga (Persero) Tbk in the toll road sector which includes funding, engineering planning, construction implementation, operation and maintenance of toll roads, taking over equity participation in toll road companies, investing in toll roads, carrying out toll road activities, carrying out holding activities and other businesses. (PT Jasamarga Transjawa Tol, 2022). Established on June 2, 2017, currently PT JTT has operated 676 km of toll roads spread from Jakarta to Banyuwangi, East Java and has connected various strategic areas from ports, airports, industrial areas, and tourist destinations. (PT Jasamarga Transjawa Tol, 2022).

PT JTT is led by the President Director together with the Business Director and the Director of Finance and Risk Management. The Board of Directors oversees several divisions including Internal Audit, Corporate Secretary & Legal, *Operation Management*, *Maintenance*, *Business Development*, *Human Capital & Risk*, *Corporate Planning & Finance*, and *Accounting Tax & Performance Review*. In addition to the head office, PT JTT has 3 *Representative Offices* (RO) to manage its toll road sections, including Jakarta - Cikampek Toll Road, Palimanan - Kanci Toll Road, Semarang Toll Road Section A, B, C, and Surabaya - Gempol Toll Road. As for the other sections (Jakarta -Cikampek II *Elevated/Sheikh* Mohamed Bin Zayed (MBZ) Toll Road, Batang - Semarang Toll Road, Semarang - Solo Toll Road, Solo - Ngawi Toll Road, Ngawi - Kertosono - Kediri Toll Road, Surabaya - Mojokerto Toll Road, Gempol - Pasuruan Toll Road, Gempol - Pandaan Toll Road, and Pandaan - Malang Toll Road are managed by Toll Road Business Entity which is a subsidiary of PT JTT. (PT Jasamarga Transjawa Tol, 2022)..

As one of the toll roads owned by PT JTT, the Jakarta - Cikampek toll road section is a toll road that connects Jakarta to Cikampek which is part of the Trans Java connectivity. (PT Jasamarga Transjawa Tol, 2022).. The Jakarta - Cikampek toll road began operating in 1988 and has been fully operational since 2005 with a concession period of 39 years. (PT Jasamarga Transjawa Tol, 2022).. This 72.5 km toll road has 33 toll gates with a total of 184 openly operated substations. (PT Jasamarga Transjawa Tol, 2022).. In addition, the Jakarta - Cikampek Toll Road has 6 (six) Rest and Service Points (TIP) namely TIP KM 19 A, KM 39 A, KM 57 A, KM 6 B, KM 42 B, and KM 62 B which are equipped with facilities for places of worship / mosques, Public Fuel Filling Stations (SPBU), ATMs, toilets, disabled toilets, food courts, workshops and mini-supermarkets, as well as 3 (three) other TIPs namely TIP KM 33 A, KM 52 B and KM 71 B which have facilities for places of worship/mosques, ATMs, toilets, food courts, and mini-supermarkets. (PT Jasamarga Transjawa Tol, 2022).

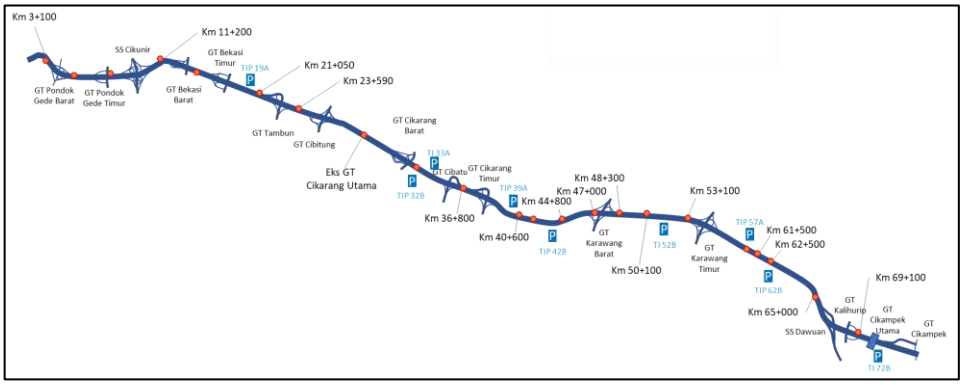

Figure 2. Layout of Jakarta - Cikampek Toll Road
Source: PT Jasamarga Transjawa Tol (2022)

As part of the national toll road network, the Jakarta - Cikampek Toll Road not only facilitates the movement of people and goods between Jakarta and areas on its eastern side, but also reduces traffic congestion on arterial roads and improves logistics efficiency for industries and businesses (Rifai & Tenriajeng, 2021). By providing fast and efficient access, the toll road supports local economic growth by easing the distribution of industrial products and strengthening connectivity between tourist areas and large population centers such as Jakarta (Milleda & Priyanto, 2022). In 2022, there were 163,676,651 vehicles making transactions on the Jakarta - Cikampek Toll Road, an increase of 9% from the previous year. (PT Jasamarga Transjawa Tol, 2022)..

Figure 3. Jakarta - Cikampek Toll Road Network
(Wikipedia, 2024)

The Jakarta - Cikampek Toll Road is also an important route used by the public, especially on holidays. On the peak day of the homecoming flow of the Lebaran holiday in 2024, 255,634 vehicles were recorded through the Jakarta - Cikampek Toll Road to Bandung and Trans Java. (Ruhulessin & Alexander, 2024).. In order to anticipate the large number of vehicles passing through and to maintain the smoothness and comfort of road users, the Jakarta - Cikampek Toll Road operator and related parties carry out traffic engineering such as the *contra-flow* system, the application of even odd vehicle license plate numbers, and restrictions on heavy vehicles (trucks) during the Eid holiday period. (Cabinet Secretariat of the Republic of Indonesia, 2024).

Predicted Traffic Volume and *V/C Ratio of* Jakarta - Cikampek Toll Road Section Cikarang Timur - Karawang Barat

Vehicle Volume Data

The data used is traffic volume data at peak hours every day during the period 2023 to 2024, both on the route towards Bandung (lane A) and the route towards Jakarta (lane B). The use of peak hour traffic volume aims to get an idea of the maximum capacity needed to maintain smooth traffic flow. (PT Jasa Marga (Persero) Tbk, 2022). While the year period is chosen, namely 2022 - 2023 by considering the condition of the section where the Jakarta - Cikampek II Elevated Toll Road (Mohammad Bin Zayed Elevated Road) has been operating and community mobility is starting to normalize after the relaxation of the rules for the Treatment of Restrictions on Community Activities (PPKM). The use of daily data also aims to get a fairly representative amount of data, namely 730 data points.

Diagnostic Data

Time series data has the potential to have certain components, either in the form of *trend*, *seasonal*, *cycle*, or *random* (Render et al., 2016) . Therefore, data diagnosis is carried out to determine certain trends and patterns in peak hour traffic volume data on the Jakarta - Cikampek Toll Road, East Cikarang - West Karawang Section for the period 2022 - 2023 with the following results:

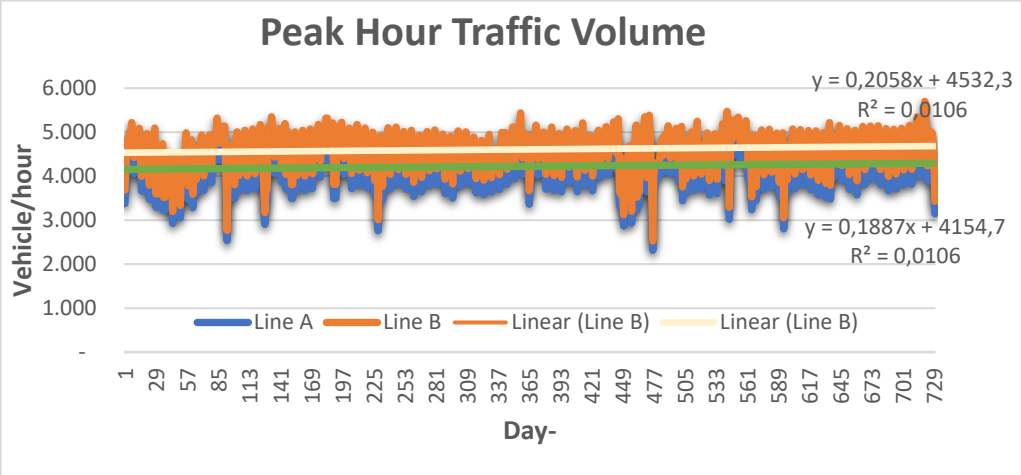

Figure 4. Peak Hour Traffic Volume Chart
Source: Researcher (2024)

Where statistically the data can be described as follows:

Table 1. Peak Hour Traffic Volume 2022 - 2023

Parameters	Line A	Line B
Mean	4.224	4.608
Median	4.308	4.699
Min	2.314	2.524
Max	5.223	5.698

Source: Researcher (2024)

Based on the graph in Figure 4.4, the daily traffic volume data at peak hours has a *trend* but not too significant, both on Line A and Line B. To analyze whether there is a pattern of dependence between data, data processing is carried out using the help of *autocorrelation function* (ACF) on SPSS *software* with the following results:

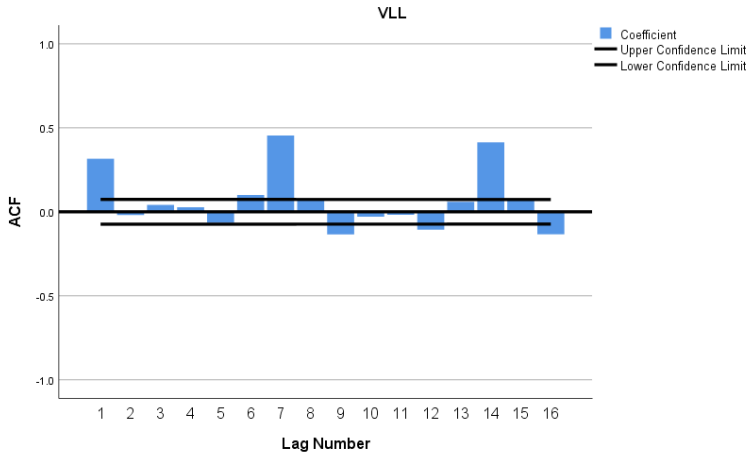

Figure 5. Patterns in Lane A Traffic Volume Data
Source: Researcher (2024)

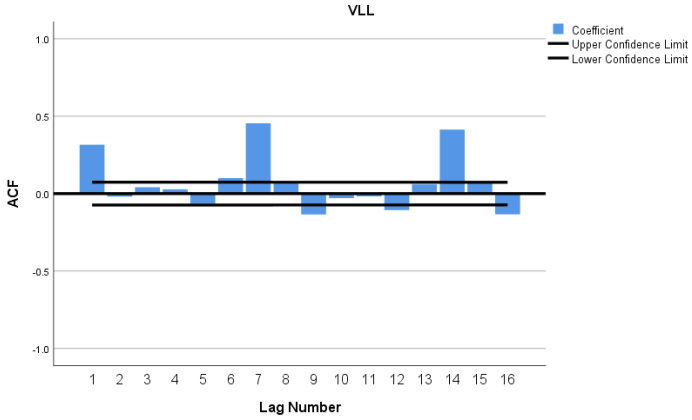

Figure 6. Patterns in Lane B Traffic Volume Data
Source: Researcher (2024)

Based on the results of data processing as shown in Figure 4 and Figure 5 peak hour traffic volume data on both lane A and lane B have a certain pattern according to the number of days in 1 week. Lag 7 is the peak hour traffic volume data on the seventh day and has the same pattern/influence on day 14.

Traffic Volume Data Prediction

The prediction of traffic volume data at peak hours in 2024 was carried out for each direction (lane) using several techniques to get the most accurate prediction value, including the *moving average* (MA), *weighted moving average* (WMA), *exponential smoothing* (ES), and *trend projections* methods. Data prediction is carried out using formula 3.1 for the *moving average* method, formulas 3.2 and 3.3

for the *moving average* method, formula 3.4 for the *exponential smoothing* method, and formula 3.5 for the *trend projections* method.

To determine the level of accuracy and the most appropriate method to use, each method also calculates the MAD, MSE, and MAPE parameters using formulas 3.6, 3.7, and 3.8 with the results of these parameters for each method as follows.

1) *Moving Average* (MA)

By determining the periods of 3 days, 7 days, and 14 days, the prediction of traffic volume data at peak hours is carried out using the *moving average* (MA) method with the following accuracy.

Table 2. Accuracy of MA Path A Prediction Results

Number of Average Periods (*n*)	**MAD**	**MSE**	**MAPE**
3 Days	236	89.878	5,94%
7 Days	260	122.874	6,56%
14 Days	270	135.442	6,82%

Source: Researcher (2024)

Table 3. Accuracy of MA Path B Prediction Results

Number of Average Periods (*n*)	**MAD**	**MSE**	**MAPE**
3 Days	257	106.963	5,94%
7 Days	284	146.231	6,56%
14 Days	294	161.187	6,82%

Source: Researcher (2024)

Based on the percentage error value, it is known that the best MA method prediction is the prediction using a 3-day period, both for line A (Cikampek direction) and line B (Jakarta direction), which is 5.94%.

2) *Weighted Moving Average* (WMA)

Using the same periods of 3 days, 7 days, and 14 days, the prediction of traffic volume data at peak hours using the *weighted moving average* (WMA) method was carried out with the following accuracy.

Table 4. Accuracy of WMA Path A Prediction Results

Number of Average Periods (*n*)	**MAD**	**MSE**	**MAPE**
3 Days	336	179.399	8,04%
7 Days	307	158.873	7,28%
14 Days	290	151,951	6,89%

Source: Researcher (2024)

Table 5. Accuracy of WMA Path B Prediction Results

Number of Average Periods (*n*)	MAD	MSE	MAPE
3 Days	367	213,500	8,04%
7 Days	335	189,072	7,28%
14 Days	317	180,835	6,89%

Source: Researcher (2024)

Based on the error percentage value, it is known that the best prediction with the WMA method is a prediction using a 14-day period, both for line A (Cikampek direction) and line B (Jakarta direction), which is 6.89%.

3) *Exponential Smoothing* (ES)

Prediction of traffic volume data at peak hours with the *exponential smoothing* method uses 3 *smoothing constant* (α) values, namely 0.1; 0.3; and 0.7 where the accuracy value is as follows.

Table 6. Accuracy of Path A ES Prediction Results

Smoothing Constant (α)	MAD	MSE	MAPE
0,1	292	152.545	7,34%
0,3	309	156.723	7,78%
0,7	327	178.276	8,20%

Source: Researcher (2024)

Table 7. Accuracy of Path B ES Prediction Results

Smoothing Constant (α)	MAD	MSE	MAPE
0,1	318	181.542	7,34%
0,3	337	186.513	7,78%
0,7	357	212.163	8,20%

Source: Researcher (2024)

Based on the percentage error value, it is known that the best prediction with the ES method is the prediction using a *smoothing constant* (α) of 0.1, both for lane A (Cikampek direction) and lane B (Jakarta direction), which is 7.34%.

4) *Trend Projections*

By generating a linear equation on the 2022-2023 peak hour traffic volume data graph, the intercept and slope values for each lane were obtained. So the equation that can be used in *trend projections* is as follows:

a. Equation for Path A

$$\hat{Y} = 4.154{,}7 + 0{,}1887X \qquad 4.1$$

b. Equation for Path B

$$\hat{Y} = 4.532{,}3 + 0{,}2058X \qquad 4.2$$

In addition, because there is an indication of a pattern in the time series data as has been done in subchapter 4.4.2, a seasonal index calculation is carried out using the steps described in subchapter 3.4 point 2) e. Peak hour traffic volume data

is averaged based on the day to determine the seasonal index of each day. So that from a period of 2 years (2022 - 2023) or 105 weeks, the seasonal index is obtained for both lane A and lane B as follows.

Table 8. Seasonal Index of Line A and Line B

Day	Seasonal Index	
	Line A	**Line B**
Monday	1,02	1,02
Tuesday	1,02	1,02
Wednesday	1,03	1,03
Thursday	1,02	1,02
Friday	1,07	1,07
Saturday	0,96	0,96
Sunday	0,88	0,88

Source: Researcher (2024)

After obtaining the equation and seasonal index for each day for both the Cikampek direction (lane A) and the Jakarta direction (lane B), predict the peak hour traffic volume using the *trend projections* method. The results of the prediction are then multiplied by the seasonal index for each day and produce the following accuracy values.

Table 9. Accuracy of Trend Projections Prediction Results with the Seasonal Index

Path	MAD	MSE	MAPE
Cikampek direction (A)	195	92.140	4,95%
Jakarta direction (B)	212	109.654	4,95%

Source: Researcher (2024)

Based on the prediction of peak hour daily traffic volume data that has been done with various methods, it can be concluded that the best method is the *trend projections* method with a seasonal index where the method produces a higher level of accuracy than other methods as can be seen in the following table.

Table 10. Comparison of Accuracy of Various Methods Path A

Methods	MAD	MSE	MAPE
Moving Average	236	89.878	5,94%
Weighted Moving Average	290	151,951	6,89%
Exponential Smoothing	292	152.545	7,34%
***Trend Projections* with Seasonal Index**	195	92.140	4,95%

Source: Researcher (2024)

Table 11, Comparison of Accuracy of Various Path B Methods

Methods	MAD	MSE	MAPE
Moving Average	257	106.963	5,94%
Weighted Moving Average	317	180,835	6,89%
Exponential Smoothing	318	181.542	7,34%

***Trend Projections* with Seasonal Index**	212	109.654	4,95%

Source: Researcher (2024)

Calculation of *V/C Ratio* Data

After predicting the peak hour traffic volume in 2024, the *V/C Ratio* was calculated using the steps described in sub-chapter 3.4 point 3). In order to compare the *as-is* and *to-be* conditions with several scenarios, the *V/C Ratio* value is calculated for the peak hour traffic volume in 2022-2023 and 2024. Furthermore, to find out the densest condition in each scenario, a comparison of the maximum *V/C Ratio* value is carried out as follows.

Table 12. Comparison of *V/C Ratio of* various scenarios

Conditions	***V/C Ratio Max***	
	Line A	**Line B**
Without additional lanes (year 2022 - 2023)	0,73	0,79
Without additional lanes (year 2024)	0,65	0,71
Addition of 1 lane (year 2024)	0,49	0,53
1 lane *contraflow* (in 2024)	0,49	0,53

Source: Researcher (2024)

The as-is V/C Ratio value is calculated using peak hour traffic volumes in 2022-2023 to determine the performance of the Jakarta - Cikampek Toll Road, especially the Cikarang Timur - Karawang Barat Section during 2022-2023 for both the Cikampek and Jakarta directions, each of which has 3 lanes. While the *to-be V/C Ratio* value is calculated using the peak hour traffic volume in 2024 with 3 scenarios, namely (1) scenario 1 where nothing is done so that the number of lanes is 3 for each direction; (2) scenario 2 where capacity is increased by adding 1 lane so that the number of lanes is 4 for each direction; and (3) scenario 3 where capacity is increased by implementing *contraflow*. *Contraflow* itself means changing the direction of 1 lane into the opposite direction. So that when implementing *contraflow*, one direction has 4 lanes while the reverse direction only has 2 lanes left. So that the highest V / C Ratio value for each direction when implementing *contraflow* is as follows.

Table 13. *V/C Ratio* Value with *Contraflow* for Lane A

Path	**Maximum V/C Ratio**
A	0,49
B	1,06

Source: Researcher (2024)

Table 14. *V / C Ratio* Value with *Contraflow* for Lane B

Path	**Maximum V/C Ratio**
A	0,98
B	0,53

Source: Researcher (2024)

Description: The predicted *V/C Ratio* is calculated if peak hour conditions occur at the same time for both directions.

Discussion

After predicting traffic volume data and *V / C Ratio* values, the highest *V / C Ratio* value for each condition in each direction is obtained as follows:

Table 15. Comparison of the Highest *V/C Ratio* Values

Conditions	***V/C Ratio Max***	
	Line A	**Line B**
Without adding lanes	0,65	0,71
Addition of 1 lane	0,49	0,53
1 lane *contraflow* implemented	0,49	0,53

Source: Researcher (2024)

Based on the statement of the Head of Operations and Maintenance Sub Division of BPJT of the Ministry of PUPR Hari Prayitno on detikFinance media (Hamdani, 2018), so that the speed of vehicles can meet the provisions of the Minimum Service Standards for toll roads, the maximum *V / C Ratio* value is 0.8. When viewed for each direction, the predicted maximum *V / C Ratio* value in 2024 with *as is* conditions (with 3 lanes) is almost close to the ideal limit of 0.65 for lane A and 0.71 for lane B. Meanwhile, if additional capacity or traffic engineering is carried out in the form of 1 lane *contraflow*, the predicted maximum *V / C Ratio* value in 2024 can be said to be ideal, namely 0.49 for lane A and 0.53 for lane B.

The V / C Ratio as is value which is still below the maximum limit can occur because the Jakarta - Cikampek Toll Road has entered the *maturity* phase so that the traffic growth is not too significant. In addition, the increase in capacity such as the operation of the Jakarta - Cikampek II Elevated Toll Road (MBZ Elevated Road), as well as other modes of transportation such as the China Indonesia Fast Train (KCIC) used by the public, especially those traveling from Jakarta to Bandung or Central Java, also has the potential to be one of the factors for the low growth in traffic volume through the Jakarta - Cikampek Toll Road. This can also be seen from the number of KCIC passengers, which is 15,000 passengers per day on weekdays and on weekends the number of passengers can reach 20,000 passengers per day. (Monti, 2024).

Nonetheless, additional capacity is worth considering, given the significant effect of additional lanes on the performance of *the V/C Ratio of the* lane, although there are consequences of additional investment costs if additional capacity is to be added. Another option is to implement *contraflow* if the *V/C Ratio is* greater than or equal to 0.80. The implementation of *contraflow* does not incur significant additional costs, but toll road managers need to evaluate the implementation of *contraflow*, especially for the safety of motorists, given the accidents that occur during *contraflow*. (BBC News Indonesia, 2024).

The following summarizes the results of the analysis of the various conditions/scenarios.

Table 16. Comparison of Each Scenario

No.	Scenario	Deviation of *V/C Ratio Max* to ideal condition (0.8)		Addition of investment costs	Affected period
		Line A	Line B		
1	Without additional lanes	0,15	0,09	No	Long term
2	Addition of 1 lane	0,31	0,27	Yes	Long term
3	Implementation of *contraflow*	0,31	0,27	No	Short term

Source: Researcher (2024)

CONCLUSION

Based on the problem analysis and prediction using trend projections technique and seasonal index for 2024 traffic volume on Jakarta - Cikampek Toll Road, it can be concluded that this toll road is the main route used by private, public, and logistics vehicles. Currently, the number of lanes in some sections, namely Cikarang Timur - Karawang Barat, is only 3 lanes per direction, potentially causing bottlenecks. The V/C Ratio calculation shows that the highest values in 2022-2023 are close to the ideal limit of 0.80, namely 0.73 in lane A and 0.79 in lane B. Predictions for 2024 show that without additional lanes, the highest V/C Ratio is 0.65 in lane A and 0.71 in lane B; with the addition of one lane, the highest V/C Ratio is 0.49 in lane A and 0.53 in lane B; and with contraflow, the highest V/C Ratio can reach 1.06 in lane B. These results indicate that in 2024, toll road SPM is still met below 0.80. Recommendations for toll management include consideration of additional lanes to prevent bottlenecks and maintain a uniform number of lanes, as well as cost and safety evaluations related to traffic management such as contraflow. For further research, it is recommended to use longer historical data and consider simulation to get more accurate results.

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