Alternative Passenger Port: Optimizing Crossing Performance and Supporting Inter-Island Transportation

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Abstract. Ciwandan Port acts as an alternative port to reduce the burden and congestion at Merak Port during peak periods, such as holidays, homecoming flows, and return flows. This study aims to measure the performance of Ciwandan Port as an alternative port to reduce the burden and congestion in crossings between Java and Sumatra during peak periods. The methods used include traffic data analysis, passenger analysis, parking capacity, waiting time evaluation, and user satisfaction surveys. The results of the study indicate that Ciwandan Port is able to reduce congestion at Merak Port. This performance evaluation provides a basis for recommendations for increasing capacity and services at Ciwandan Port, as well as more effective management policies. This study emphasizes the importance of performance measurement as an important step to ensure the success of alternative ports in reducing congestion and supporting better inter-island mobility.

Keywords: Alternative Port, Port Performance, Merak Port, Ciwandan Port; Ferry Transport

1. INTRODUCTION

Ports as maritime traffic nodes in multimodal transportation are vital factors that support the country's economy which requires appropriate strategies and policies to meet demand (Belcore et al., 2024), maritime ports are at the heart of global trade and a key system in the supply network (Fahim et al., 2022). Ports play an important role in connecting land and sea supported by the level of connectivity and spatial integration as important indicators of competitiveness (He & Xu, 2023), need to provide land and sea transportation modes that act as economic levers and service providers (Nanyam & Kumar Jha, 2023). Challenges in developing the port industry by building adaptation and resilience, especially optimizing digitalization and decarbonization (Song et al., 2024). Digital transformation is an important component in the integrated port business to improve company performance in strengthening smart and green port-based logistics services (Putra et al., 2024). The port industry is primarily directed to encourage

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economic growth and also needs to avoid environmental pollution where port management needs to realize the importance of prioritizing green development to improve port sustainability (Ji et al., 2023). Ferry transportation becomes a connecting bridge between transportation nodes separated by land and sea which is supported by various necessary facilities (Tampubolon et al., 2024), transportation continues to require technological innovation and increasingly complex needs (Sarjana, 2023). Ferry ports reflect accessibility support related to spatial, social, economic and environmental conditions (Schreurs et al., 2023). Zero-emission passenger ferries with renewable energy development that connect ports play an important role in building a sustainable transportation system (Guo & Cao, 2024), clean energy is a solution to reduce emissions in ferry operations (Abu Bakar et al., 2024).

Merak Port often experiences high traffic volumes due to a significant increase in demand for transportation between Java and Sumatra via Merak Port, especially during holiday periods or during homecoming and return flows. Factors such as large vehicle volumes, limited infrastructure, and administrative processes at ports can cause congestion around the area (Liu et al., 2023). Merak Port experienced severe traffic jams of up to 20 kilometers from the Merak Port gate to the Tangerang Kilo Meter (KM) 90 Toll Road in 2022, this occurred due to a surge in vehicles at Merak Port. Land Transportation Management Center (BPTD) Class II Banten noted that 29 April 2022 was the peak of homecoming traffic with a total of 37,692 vehicles per day. There will be an increase in vehicle demand in 2022 by 31% compared to 2019 Eid transportation. Meanwhile, the daily transportation capacity at Merak Port during busy times only reaches 29,804 vehicles per day, so Merak Port cannot accommodate the surge in demand and congestion occurs. Congestion that occurs at Merak Port has broad negative impacts, such as increasing air pollution, delays in travel, and disruption to the economic and social activities of communities around the port.

One of the government's efforts is in accordance with concerning submission of minutes of coordination meetings following up on presidential directions, optimizing the use of piers around Merak Harbor and Bakauheni Harbor by adding routes alternative crossing via Ciwandan Port as a response to congestion at Merak Port. This diversion was carried out to reduce pressure on Merak Port, which often experiences severe congestion due to increasing vehicle volumes and transportation demand. The addition of alternative crossing routes via Ciwandan Harbor will be implemented starting with Christmas and new year transportation but it is still not optimal. The addition of alternative crossing routes through Ciwandan Harbor is still being carried out to reduce the congestion that occurs at Merak Harbor during Eid, Christmas and New Year transportation by diverting two-wheeled vehicles and goods vehicles to cross to Bakauheni via Ciwandan Harbor. However, the addition of alternative crossing routes is still receiving complaints from service users. Motorbike travelers waited too long to board the ship and complained about the lack of service facilities. Collaborative efforts between relevant parties are required to ensure that this transfer runs smoothly and effectively. The addition of an alternative crossing route via the Ciwandan port with the Ciwandan - Bakauheni route is going quite well, but evaluation of the alternative crossing route still needs to be carried out.

This study aims to measure the performance of Ciwandan Port as an alternative port to reduce the burden and congestion in crossings between Java and Sumatra during peak periods. Measuring the performance of Ciwandan Port as an alternative port is very important to ensure that traffic diversion efforts from Merak Port are truly effective in reducing the burden and congestion during peak periods such as holidays, homecoming and return flows. Performance measurement allows evaluation of how well Ciwandan Port is in reducing congestion at Merak Port which includes aspects such as reducing vehicle volume, crossing speed, and reducing queues at Merak. Through performance measurement, areas where Ciwandan Port is lacking can be identified, such as long waiting times or minimal service facilities so that corrective measures can be taken to improve user satisfaction. Measuring performance is also important to ensure that Ciwandan Port has sufficient capacity to handle the surge in vehicle volume during peak periods. This helps in long-term planning, including the need for infrastructure improvements or additional facilities. By evaluating operational performance, the port can identify inefficient processes or bottlenecks that slow down operations which allow for improvements that can improve crossing flows and reduce travel times. The results of performance measurement provide a strong basis for decision-making by the government and related parties to determine the policies or investments needed to support the function of Ciwandan Port as an alternative port. Reducing congestion and improving the flow of crossings, the port contributes to the smooth running of economic and social activities in the surrounding area where measuring performance allows for a more comprehensive assessment. Measuring the performance of Ciwandan Port is very important to ensure that this port truly functions as an effective solution in reducing congestion and supporting smoother inter-island transportation, especially during peak periods.

2. RESEARCH METHOD

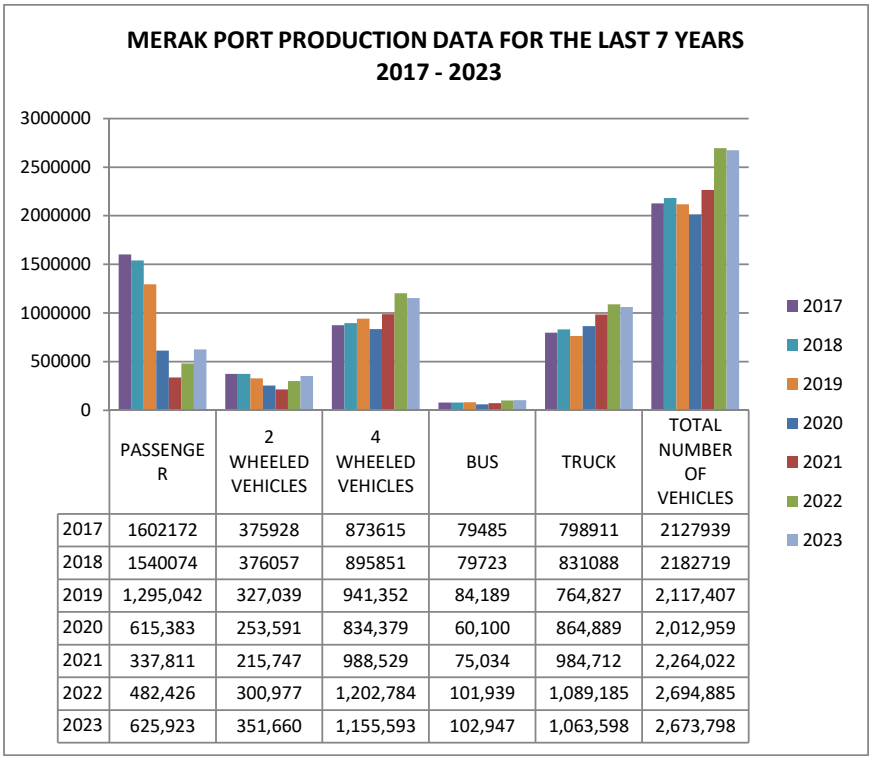
Quantitative methods are used in this research to measure the performance of the Ciwandan alternative port. Quantitative methods are used to test variables to answer the formulation of research problems (Fachri & Sarjana, 2022). Data collection refers to secondary and primary data originating from relevant agencies and the results of field observations (Salas & Sarjana, 2024). The analysis was conducted using a quantitative research approach that was carried out to solve the initial problem by conducting a V/C ratio analysis on port data by calculating port capacity and vehicle volume at Merak and Bakauheni ports, conducting direct observations in the field regarding the mechanism and service of route diversion to Ciwandan port, conduct an analysis of vehicle demand diverted to Ciwandan port and compare the results of the vehicle diversion analysis at Ciwandan port with demand at Merak port and conduct an analysis of future demand forecasting. Quantitative data analysis is a systematic process of both collecting and evaluating and measuring verifiable data that aims to answer research questions (Amruddin et al., 2022).

Field observation by conducting direct observation at Ciwandan Port during peak periods to measure vehicle flow, waiting time, and crossing process. Furthermore, it is necessary to record the time required by vehicles from entering the port to completing the crossing in order to measure operational efficiency. Collect and analyze daily traffic

data such as the number of vehicles crossing, vehicle types and crossing volume during peak periods. This data is obtained from port authorities or related agencies. Analyze port performance data, including dock capacity, ship departure frequency and facility utilization rate. Use questionnaires to measure user satisfaction regarding waiting time, service quality, facilities and overall experience. Respondents can include vehicle drivers, passengers, and transport operators. Conduct in-depth interviews with port users including drivers and logistics operators to gain insight into challenges and unmet needs. Cycle time analysis is conducted by measuring and analyzing the operating cycle time, from ferry entry to completion of crossing, to identify bottlenecks and opportunities for efficiency improvement. Compare actual port capacity with vehicle volume during peak periods to determine whether port infrastructure and resources are adequate. Apply queuing theory to analyze and model vehicle queues at the port to help understand how variations in vehicle volume affect waiting time and operational efficiency. In addition, it is necessary to use simulation software to model port operations and predict the impact of various scenarios, such as increased vehicle volume or changes in operational procedures. By using this method, the study can provide a comprehensive picture of the performance of Ciwandan Port and identify areas that need improvement to increase efficiency and reduce congestion during peak periods.

3. Result and Discussion

Merak Port often experiences high traffic volumes due to a significant increase in demand for transportation between Java and Sumatra, especially during holiday periods or during homecoming and return flows. Factors such as large vehicle volumes, limited infrastructure, and administrative processes at ports can cause congestion around the area. The following is Merak Port production data for the last 7 years:



	PASSENGER	2 WHEELED VEHICLES	4 WHEELED VEHICLES	BUS	TRUCK	TOTAL NUMBER OF VEHICLES
2017	1602172	375928	873615	79485	798911	2127939
2018	1540074	376057	895851	79723	831088	2182719
2019	1,295,042	327,039	941,352	84,189	764,827	2,117,407
2020	615,383	253,591	834,379	60,100	864,889	2,012,959
2021	337,811	215,747	988,529	75,034	984,712	2,264,022
2022	482,426	300,977	1,202,784	101,939	1,089,185	2,694,885
2023	625,923	351,660	1,155,593	102,947	1,063,598	2,673,798

Figure I. Merak Port Production Data for the Last 7 Years (2017-2019)

Merak Port production data covering passenger data, two-wheeled vehicles, four-wheeled vehicles, buses, trucks, and the total number of vehicles over the past 7 years has a very important role in various aspects of evaluation, planning, and decision making. This data helps understand passenger travel trends, both during normal days and peak periods such as holidays and homecoming flows that can reveal significant demand change patterns and help predict future needs. With vehicle data including two-wheeled vehicles, four-wheeled vehicles, buses and trucks, the port can identify movement trends for each type of vehicle where this data is important to understand how various segments of port users contribute to traffic volume. Knowing the number of vehicles and passengers served each year allows for better planning regarding dock capacity, parking areas, passenger facilities and other needs needed to handle increased volume. This data also helps in planning alternative crossing routes, such as those done with Ciwandan Port, to reduce the burden on Merak Port. Complete data on various types of vehicles allows optimization of ship schedules, crossing capacity and other resource allocations to improve operational efficiency. By understanding the volume and type of vehicles, ports can better plan and manage traffic flows in and around the port, reducing congestion and waiting times. This data enables evaluation of existing transport policies, such as restrictions or regulation of certain vehicles, and assists in making necessary policy adjustments. Information on vehicle volumes and types helps

in planning and implementing better safety and security measures at the port. With comprehensive vehicle data, ports can measure environmental impacts such as carbon emissions and plan appropriate mitigation measures, such as reducing waiting times or developing green lanes.

Understanding the number and type of vehicles using the port is also important for assessing the impact on the local environment, including air and noise pollution. Data covering 7 years of trends enables better decision-making regarding infrastructure investments, such as increasing berth capacity or other supporting facilities. This historical data also supports funding and investment proposals by providing concrete evidence of the need to increase port capacity and services. By understanding passenger trends and volumes and different types of vehicles, ports can plan service improvements that are more focused on specific user needs, such as parking facilities, service times, and passenger comfort. This data allows for year-on-year comparison of Merak Port performance, as well as benchmarking with other ports with similar functions, to identify best practices and areas for improvement. Merak Port's production data covering passengers and various vehicle types over the past 7 years is a critical tool in supporting strategic planning, operational improvement, and data-driven decision-making that will ensure the port is able to meet the growing transportation needs efficiently and sustainably.

The comparison between volume and capacity, known as the V/C ratio, is an important indicator. If the V/C ratio reaches 0.8 or higher, it indicates that the traffic volume is almost reaching or exceeding its capacity. The V/C ratio provides a direct indication of how well a port or related infrastructure is functioning. When the ratio approaches 1 or 100%, it indicates that the facility is operating near its maximum capacity. When the ratio reaches or exceeds 0.8 (80%), it is a warning signal that the facility is struggling to handle the volume of traffic it is experiencing, which can lead to congestion and reduced operational performance. A high V/C ratio indicates bottlenecks or points of congestion in the transportation system, which require immediate attention. By identifying areas where the V/C ratio is high, port managers can focus on infrastructure improvements or upgrades to prevent severe congestion. Knowing the V/C ratio helps in planning for capacity expansion needs such as berth expansion, adding lanes or building new facilities. When the V/C ratio is consistently high, it indicates that current capacity is inadequate to meet demand, making infrastructure development planning a priority. V/C ratio data allows for more precise allocation of resources to improve operational efficiency such as vessel rescheduling or upgrading support facilities.

Policies such as adjusting departure schedules, restricting vehicle types or diverting traffic can be evaluated for their effectiveness based on changes in the V/C ratio. If the policy is successful, the V/C ratio will decrease and indicate an improvement in operational performance. The V/C ratio provides quantitative data that can be used by decision makers to formulate service improvement strategies, infrastructure investments or policy developments to support more accurate and evidence-based decisions. When the V/C ratio is high, port users are likely to experience delays, increased waiting times and potential congestion. By monitoring and managing the V/C ratio, port managers can take action to reduce these impacts and improve user satisfaction. High V/C ratios are often associated with increased emissions and air

pollution, as well as social disruptions such as travel delays. Managing the V/C ratio helps mitigate these negative impacts, which is important for the well-being of communities and the sustainability of the environment around the port. Using the V/C ratio as an indicator, ports can project future needs based on increasing traffic volume trends, allowing for more proactive planning in the face of spikes in demand during peak periods such as holidays or homecoming flows. The V/C ratio is a key indicator in understanding and managing port operational performance. Monitoring and managing this ratio well is essential to ensuring that ports function optimally, reducing the risk of congestion, increasing efficiency and user satisfaction.

Carrying capacity is influenced by ship operating patterns, ship carrying capacity and ship frequency. Merak-Bakauheni crossing there will be 74 operating vessels in 2022. There are 2 types of operating patterns on this crossing, namely the normal operating pattern and the dense operating pattern, where the dense operating pattern will be implemented when there is an increase in volume. The Merak-Bakauheni crossing implements two operating patterns, namely normal and busy. The normal operating pattern is applied on weekdays, while the busy operating pattern is applied when traffic volumes increase, such as during the homecoming and return flows. The busy operating pattern allows the port to increase carrying capacity by adjusting ship schedules and reducing waiting times at the port. This ensures that the port can handle surges in volume more efficiently and reduces the risk of congestion and delays. The varying carrying capacity of ships will affect how many passengers and vehicles can be transported in one trip. Ships with larger capacities will be able to carry more vehicles and passengers, thereby increasing overall carrying capacity. By using large-capacity ships during busy periods, the port can maximize its carrying capacity, which is important to reduce queues and waiting times, as well as ensure smooth traffic flow on both sides of the crossing.

The frequency of ships or the number of trips makes in a day directly affects the total daily carrying capacity (Pasha et al., 2021). During busy operations, this frequency is usually increased to accommodate the increased traffic volume. The rate of ship turnover, including how quickly ships can dock, load and depart again, is critical to maintaining high frequency during busy operations. Good frequency management will improve the efficiency of crossings and maximize the use of port infrastructure. By implementing a dense operating pattern and maximizing the carrying capacity and frequency of ships, ports can more effectively handle volume spikes during peak periods which are important for maintaining the smooth flow of passengers and vehicles, and reducing negative impacts such as congestion or delays. The use of historical data on passenger and vehicle volumes, as well as previous operating patterns, allows for better planning and prediction of future carrying capacity needs. The combination of ship operating patterns where carrying capacity and ship frequency are very important in managing port carrying capacity, especially on strategic crossing routes such as Merak-Bakauheni. Good management of these three factors will ensure that ports can meet transportation demand efficiently and reduce the negative impacts of increased traffic volumes (Bernacki & Lis, 2024).

Table 1. *Daily Pier Transport Capacity based on Ship Operation Patterns*

PIER	NORMAL OPERATING PATTERN				PEAK SEASON OPERATING PATTERN			
	OPERATING SHIP	TRIP	AVERAGE SHIP CAPACITY	CAPACITY/DAY	OPERATING SHIP	TRIP	AVERAGE SHIP CAPACITY	CAPACITY/ DAY
			SMALL VEHICLE	SMALL VEHICLE			SMALL VEHICLE	SMALL VEHICLE
PIER 1	5	20	135	2.700	5	20	162	3.240
PIER 2	5	20	135	2.704	5	20	177	3.532
PIER 3	5	20	230	4.600	5	20	288	5.764
PIER 4	5	20	172	3.436	5	20	206	4.120
PIER 5	3	12	116	1.397	5	20	123	2.460
PIER 6/PIER 7	5	20	183	3.653	5	20	255	5.092
PIER 7/PIER 6 (EKS)	4	20	201	4.010	4	20	229	4.580
TOTAL	32	132	1.172		34	140	1.439	
	Real Capacity / Day			22.500	Real Capacity / Day			28.788
	Real Capacity / Hour			937	Real Capacity / Hour			1.200

To analyze the V/C ratio of the ports of Merak and Bakauheni, capacity and vehicle volume must be the same variable, for this reason it is necessary to analyze the capacity into SUP units (production units). Based on Minister of Transportation Regulation Number PM 66 of 2019 concerning Mechanisms for Determining and Formulating Ferry Transport Tariff Calculations, the class IV SUP amount of 32.09 is used for small vehicle projections. From the analysis results, it is known that the total daily transportation capacity in the normal pattern is 722,025 SUP and the total daily transportation capacity in the busy pattern is 923,806 SUP.

Using SUP as the standard unit ensures that vehicle capacity and volume can be directly compared. This is important because different types of vehicles have different sizes and capacities and using SUP allows for consistency in the comparison used as the basis for calculating ferry tariffs. Therefore, analysis using SUP not only ensures uniformity in measurement but also complies with applicable regulations. Using SUP to analyze the V/C ratio allows for a more accurate assessment of the port's capacity to

handle traffic volumes which is important for identifying whether the port is operating near, below or above safe capacity. With accurate V/C ratio analysis results, port managers can make more informed decisions regarding operational adjustments such as increasing vessel frequencies or changing operating patterns from normal to busy. The results of the analysis show that the total daily transport capacity in the normal pattern is 722,025 SUP and in the busy pattern it is 923,806 SUP. This information is important for planning when the busy operating pattern should be implemented and how resources should be allocated to meet demand during peak periods. By understanding the daily capacity limits in SUP, ports can adjust vessel schedules, berth allocations and traffic management to optimize the use of existing capacity. SUP-based V/C ratio analysis allows for more accurate projections of when a port might reach its maximum capacity, allowing management to be more proactive in dealing with volume surges. By understanding when the V/C ratio approaches or exceeds critical thresholds, ports can take steps to reduce the risk of congestion, such as increasing vessel frequencies or redirecting vehicles to alternative routes. Analyzing the V/C ratio using SUP as a standard variable is critical to ensuring that the ports of Merak and Bakauheni can operate efficiently, safely and in line with demand. It also supports long-term planning and continuous improvement in ferry services between Java and Sumatra.

The ready-to-load parking capacity at each pier varies depending on the size of the ready-to-load parking area. The total parking capacity of Bakauheni port is 2,572 small vehicles (Group IV) or 82,541.9 SUP and the total parking capacity of Merak port is 1,727 small vehicles (Group IV) or 55,419 SUP.

Table 2.

Parking Capacity at Merak and Bakauheni Ports in SUP Unit

PIER	PORT	
	Bakauheni	Merak
PIER 1	438	174
PIER 2	372	168
PIER 3	450	342
PIER 4	602	330
PIER 5	200	185
PIER 6/PIER 7	387	180
PIER 7/PIER 6 (EKS)	123	348
TOTAL	2.572	1.712
In SUP	82.542	55.419

Adequate parking capacity ready to load allows for more efficient parking arrangements, reduces waiting time and avoids congestion in the port area where with sufficient capacity vehicles can be parked properly and organized and ensures smooth

traffic flow. Adequate parking capacity helps reduce vehicle queues at the port. If the number of incoming vehicles exceeds the parking capacity, queues can form which disrupt port operations and cause delays. The parking capacity of Bakauheni Port (2,572 small vehicles or 82,541.9 SUP) is greater than the parking capacity of Merak Port (1,727 small vehicles or 55,419 SUP). Understanding this capacity difference is important to effectively manage vehicle volumes and optimize the use of facilities at both ports. Different parking capacities require appropriate planning and management of facilities, for example ports with larger parking capacities may require additional facilities to support higher vehicle volumes. Adequate parking capacity supports maximum utilization of the dock and other port facilities. With sufficient parking, vehicles can be easily arranged to enter and exit the dock and improve operational efficiency. With appropriate parking capacity, loading and unloading activities can be carried out more orderly and reduce the time required to complete the crossing process. Adequate parking capacity improves user experience by reducing waiting time and ensuring vehicles can be parked easily. High user satisfaction contributes to the port's reputation and increases public trust.

During peak periods such as holidays or homecoming flows, adequate parking capacity becomes very important to handle the surge in vehicles. Sufficient capacity helps in managing the increased vehicle volume and avoiding congestion in the parking area. Knowing the parking capacity at both ports where managers can create strategies to divert vehicles if necessary, such as directing vehicles to ports with larger parking capacity. The varying ready-to-load parking capacity at each pier is very important to ensure efficient and effective port operations. Parking capacity data such as that listed for Bakauheni and Merak Ports, port managers can make better decisions regarding planning, traffic management and infrastructure development, thereby improving the user experience and overall port operations.

The 2022 Eid transportation production data is the production data for the 2022 Eid transportation period starting from D-7 to D+7 of the 2022 Eid al-Fitr holiday, starting from April 26, 2022 to May 10, 2022. To facilitate analysis and convert data units into SUP (unit of production) form, vehicle production data is grouped into 2-wheeled vehicles (class I, II and III vehicles), small vehicles (class IVA and IVB vehicles), buses (class VA and VB), and trucks (class VB, VIB, VII, VIII and IX). The number of vehicles passing through the 2022 Eid transportation at Merak Port was 7,592,976.5 SUP with an average daily number of vehicles passing through of 474,561.03 SUP. With the peak occurring on the 3rd day of Eid, namely Friday, April 29, 2022 with the number of vehicles passing as many as 37,692 vehicles, but when converted into units of the largest number of SUPs occurred on the 2nd day of Eid, namely Saturday, April 30, 2022, namely 849,697.3 SUP. The number of vehicles passing during the 2022 Eid transportation at Bakauheni Port was 7,318,979 vehicles per hour with an average daily number of vehicles passing as many as 457,436.17 vehicles per hour. With the peak day occurring on the 3rd day of Eid, namely Friday, May 7, 2022 with the number of vehicles passing as many as 775,278 vehicles per hour. The highest peak vehicle volume occurred at 04.00 - 05.00 with a volume of 2,856 vehicles or as many as 849,697.3 vehicles per hour.

To analyze the V/C ratio of the Merak and Bakauheni ports, vehicle capacity and volume must be the same variables, for this reason the analysis of the capacity and

volume of vehicles used is the capacity and volume that have been converted into SUP units (production units).

Tabel III. V/C Ratio Analysis of Merak Port and Bakauheni Port on the Peak Day of Eid 2022

	Merak	**Bakauheni**
Number of Operating Vessels/Day	45	45
Trip/Day	134	134
Capacity/ Hour (SUP)	38.492	38.491,96
Kapasitas/ jam (Unit)	1.200	1.200
Operating hoursi/Day	24	24
Port Capacity (Unit)	1.727	5.738
Number of Carrying Capasity /day (Unit)	28.788	28.788
Total Capacity (Unit)	**30.515**	**34.528**
Port Capacity (SUP)	55.419	184.132
Number of Carrying Capasity /day (SUP)	923.807	923806,9
Total Capacity (SUP)	**979.226**	**1.107.939**
Production of peak day (Unit)	**37.692**	**37.643**
Production of peak day (SUP)	**849.697**	**775.278**
V/C Rasio (SUP)	**0,86**	**0,69**

V/C ratio of vehicles crossing on the peak day of Eid 2022 transport at Merak Port is 0.86. Meanwhile, the average daily V/C ratio of vehicles crossing on the peak transport day for Eid 2022 at Bakauheni Port is 0.69. From the analysis results, the V/C ratio at Merak Port is 0.86, which means it has exceeded the V/C ratio limit which should be a maximum of 0.8, so there is severe congestion at Merak Port and hourly production data also proves that the capacity in Merak Port can no longer accommodate the volume of vehicles, causing queues with a difference between vehicle capacity and queue volume of 259 small passenger vehicles. So, to reduce this congestion, the government issued a policy to use alternative ports around the ports of Merak and Bakauheni so that in 2023 the port of Ciwandan will be used as an alternative port for service users who will cross from the island of Java to the island of Sumatra in order to reduce congestion at the Port of Merak.

On the peak day of Eid al-Fitr 2022, the V/C ratio at Merak Port reached 0.86, exceeding the recommended maximum limit of 0.8. This indicates that the volume of vehicles passing through is approaching or exceeding the port's capacity, causing severe congestion. Meanwhile, the V/C ratio at Bakauheni Port on the same day was 0.69, indicating that the port was still operating below its maximum capacity and did not experience the same congestion. With a V/C ratio at Merak Port of 0.86, severe congestion and vehicle queues occurred. Production data shows that the port's capacity is no longer able to accommodate the volume of vehicles, with a difference between vehicle capacity and queue volume of 259 small passenger vehicles. A high V/C ratio indicates that the port is operating beyond its optimal capacity, reducing operational efficiency, increasing waiting times and negatively impacting user experience. To overcome congestion at Merak Port, the government needs to issue a policy to utilize

an alternative port, Ciwandan Port. Ciwandan Port is planned as an alternative port to reduce the burden and congestion at Merak Port. By diverting some of the traffic volume to Ciwandan Port in 2023, it is expected to reduce pressure on Merak Port and improve operational smoothness at both ports.

V/C ratio analysis helps in evaluating port performance and assessing the extent to which a port can handle existing traffic volumes, which is important for planning future capacity and making informed investment decisions. Understanding high V/C ratios helps in planning infrastructure improvements or facility additions needed to increase port capacity and efficiency. Better capacity management can reduce economic losses associated with congestion, such as additional costs and longer travel times. Severe congestion can affect the social and economic activities of communities around the port, thus by reducing congestion, negative social impacts can be minimized. Ensuring that the V/C ratio does not exceed the maximum limit as per transport regulations is important for effective traffic compliance and management. Implementing policies to divert traffic to alternative ports demonstrates the government's efforts in complying with regulations and improving transport management. Understanding and analyzing the V/C ratio and taking data-based actions, such as diverting traffic to alternative ports, port managers can improve operational efficiency and reduce the negative impacts of congestion. It also supports sustainable planning and development to address future transportation needs.

Apart from the V/C ratio, we can also see how many queues occur at Merak port by using hourly production data at Merak port on peak day, 29 May 2022. The following is a peak day production graph at Merak Port.

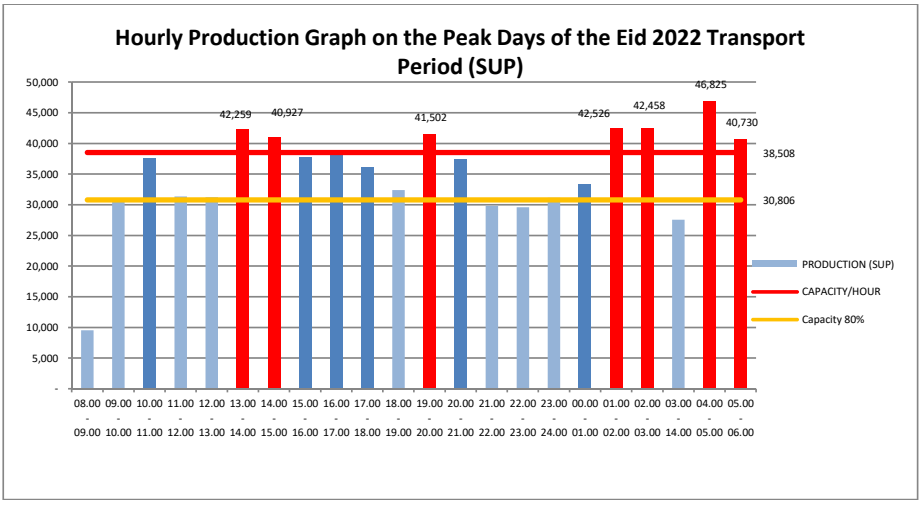


Figure2. Hourly Production Graph on the Peak Days of the Eid 2022 Transport Period

Analysis results the V/C ratio at Merak Port has exceeded the V/C ratio limit which should be a maximum of 0.8, resulting in severe congestion at Merak Port and hourly production data also proves that the capacity at Merak Port can no longer accommodate the volume of vehicles causes queues with a difference that causes queues of 259 small passenger vehicles. So, to reduce this congestion, the government issued a policy to use alternative ports around the ports of Merak and Bakauheni so that in 2023 Ciwandan port will be used as an alternative port for service users who will cross from Java to Sumatra islands in order to reduce congestion at Merak Port.

A V/C ratio exceeding 0.8 indicates that the volume of vehicles at Merak Port has exceeded the port's operational capacity, causing severe congestion. This indicates that the port is no longer able to handle the number of vehicles efficiently. Hourly production data showing that the port's capacity is unable to accommodate the volume of vehicles further confirms the significant capacity shortage, with the gap causing a queue of 259 passenger vehicles. Congestion caused by a high V/C ratio can cause travel delays, increase waiting times and reduce port operational efficiency which has a negative impact on user satisfaction. With inadequate capacity, vehicle queues become a major problem that can affect social and economic activities around the port and increase air pollution due to vehicles waiting for a long time. To overcome congestion, the government has decided to utilize alternative ports around Merak and Bakauheni Ports. The addition of Ciwandan Port as an alternative port starting in 2023 is a strategic step to reduce the burden on Merak Port. Efforts to divert some vehicle traffic to Ciwandan Port are expected to reduce pressure on Merak Port, improve traffic flow and reduce congestion that occurs during peak periods. Traffic diversion to alternative ports will help improve operational efficiency at Merak Port, reduce waiting time and improve user experience. The results of the V/C ratio analysis showing congestion at Merak Port are very important to understand the capacity and effectiveness of port operations. The policy of diversion to Ciwandan Port by the government aims to overcome congestion problems and improve efficiency and user satisfaction, while preparing better infrastructure planning for the future.

At the time of implementation of the Ciwandan port during the Christmas and New Year period 2022-2023 it was still not optimal, especially on the Ciwandan-Bakauheni route. The Ciwandan-Bakauheni route during the Christmas and New Year 2022-2023 period only carries 22 vehicles with a total of 2 boat trips. During the Eid 2023 transportation period, services at Ciwandan port are valid from D-7 to D-1 of Eid. Ciwandan Port specifically serves 2-wheeled and truck crossings, while 4-wheeled and buses continue to cross via Merak Port, ticket orders have also been arranged via the Ferizy application, making it easier to socialize with service users. 12 ships have been prepared to serve the Ciwandan-Bakauheni route with 2 operational piers, namely pier 03 & 07 and pier 5A. In the 2023 Eid transport period, 66,790 vehicles were transported with a total of 119 ship trips during the 2023 Eid transport period.

During the 2024 Eid transport period, Ciwandan Port as an alternative port with the Ciwandan-Bakauheni route applies a service mechanism from H-7 to H-1 Eid and serves crossings for 2 (two) wheeled vehicles and trucks, while private vehicles and buses continue to cross via Merak Port. 11 ships have been prepared to serve the Ciwandan-Bakauheni route. Apart from that, 2 operational piers, namely pier 03 & 07, have been prepared as berthing facilities at Ciwandan Port. With a vehicle production

of 74,774 vehicles with a total of 117 ship trips during the Eid 2024 transportation period. With an operating pattern of 4 ships/pier and a port time service pattern (time at the pier) including berthing, unloading or loading, 2 outbound movements. hours and sailing time starting from the initial port exit to the destination port entry for 2 hours with a total Rounds Trip Time (RTT) of 4 hours.

Ciwandan Port serves 2-wheeled vehicles and trucks, while 4-wheeled vehicles and buses continue to go through Merak Port as a strategy to distribute traffic loads, reduce pressure on Merak Port and maximize the use of Ciwandan facilities. The use of the Ferizy application for ticket bookings helps improve efficiency and facilitate communication with service users for effective traffic management. Adequate capacity and number of ships indicate the readiness of Ciwandan Port to handle higher traffic volumes. The operating pattern of 4 ships per pier and port service times that include berthing, loading and unloading, and loading, a planned time system (RTT) of 4 hours reflect efforts to optimize operational efficiency. Vehicle production data and ship trips show that transportation capacity has increased from year to year. This evaluation helps assess whether the increase in capacity is sufficient to meet demand and reduce congestion. Evaluation of performance from the previous period allows for adjustments and improvements for the next Eid transportation period, including improving facilities, services and operational management. Utilizing Ciwandan Port is expected to reduce congestion at Merak Port, distribute traffic volume more evenly and improve the experience of service users. Increasing capacity and optimizing operational time will improve the overall efficiency of the inter-island transportation system, reduce waiting time and increase user satisfaction. Effective management at Ciwandan Port helps reduce the negative impact of congestion on communities around the port and supports local economic activities by improving the smooth flow of traffic. Distributing traffic loads allows the main and alternative ports to function better and minimize disruption to transportation operations. Evaluation of Ciwandan Port's performance during peak periods is essential to ensure that the port can function optimally, reduce congestion at Merak Port and improve user experience. Data and experience from previous periods serve as the basis for improvements and adjustments needed to achieve better performance in the future.

Figure 3. *Layout of Ciwandan Port*

Based on the results of a survey in the field, the facilities at Ciwandan Harbor are quite complete, such as prayer rooms, toilets, vehicle toll gates, loudspeaker facilities, food stands, health facilities, lactation rooms and children's play areas, however these service facilities are not in accordance with regulations. Meanwhile, production data for the Ciwandan-Bakauheni route from H-7 to H-1 for Eid 2024 transport where the analysis of services at Ciwandan Port starting from Christmas and New Year 2022-2023 transportation, Eid 2023 and Eid 2024 transportation have experienced an increase in both service and port production data.

The survey results show that Ciwandan Port has quite complete facilities and has met the basic needs of service users and increased comfort while waiting. Although the facilities are complete, the survey also shows that some service facilities are not fully in accordance with applicable provisions. It is important to ensure that all facilities comply with established standards and regulations to ensure optimal service quality. The results of the service analysis show an increase in port service and production data from the 2022-2023 Christmas and New Year period to the 2024 Eid transportation. This increase shows that the port is increasingly able to handle higher traffic volumes better. The increase in production data such as the number of vehicles transported and the frequency of ships reflects efforts to increase the capacity and operational efficiency of the port to reduce congestion and improve the service user experience. Adequate facilities and better services can increase the comfort and satisfaction of service users (Askari et al., 2024). With facilities such as lactation rooms, children's play areas, and health facilities, the port can meet the needs of various user groups. Increased service capacity and efficiency can reduce congestion, speed up the crossing process, and reduce waiting times. This has a positive impact on user satisfaction and reduces the negative impact of congestion on the surrounding community. The survey results and analysis showing complete facilities and improvements in port service and production data are important indicators of the progress and effectiveness of Ciwandan Port. Continuous evaluation and necessary improvements will help improve service quality, reduce congestion and ensure that the port can better meet user needs.

To carry out demand analysis and find out the percentage of vehicles crossing through Ciwandan port during the Eid 2023 and 2024 transport period, need to know the total amount of production crossing through Merak, Ciwandan and BBJ ports in Table 3.

Table 3. Percentage of the Total Number of Vehicles Crossing Through Ciwandan Port During the 2023 Eid Mubarak Transport Flow Period

Line	Number of vehicles traveling home for the 2023 Eid transport period (H-7 S.D H-1)
Jawa-Sumatera	167.452
Merak-Bakauheni	98.129
Ciwandan-Bakauheni	66.790
Ciwandan-Panjang	2.533
BBJ Bojonegara-BBJ Muara Pilu	3.340
Percentage of Vehicles Crossing Through Ciwandan Port	39,3%

Understanding the total number of vehicles passing through Ciwandan Port and other ports such as Merak and BBJ is key to managing capacity and planning operational needs. This data helps determine whether existing capacity is sufficient or needs to be increased. In the 2023 Lebaran transportation, the percentage of vehicles passing through Ciwandan Port was 39.3%. This data shows that almost 40% of the total vehicles traveling between Java and Sumatra chose Ciwandan Port. This percentage provides an overview of how big a role Ciwandan Port plays in distributing traffic loads. By comparing the number of vehicles passing through each port, the data shows Ciwandan Port's contribution in reducing the load on Merak Port and how vehicles are distributed between various ports. Knowing the percentage of vehicles passing through Ciwandan Port helps in planning resources such as the number of ships, docks and supporting facilities. If the percentage is high, it means that Ciwandan Port requires more capacity and services to meet these needs. Knowing the contribution of Ciwandan Port, steps can be taken to mitigate congestion at Merak Port by distributing traffic more evenly. The percentage of vehicles passing through Ciwandan Port provides an indicator of the effectiveness of the traffic diversion policy. The increasing percentage from year to year shows that the policy to use alternative ports is effective in reducing the burden on the main port. Data related to user satisfaction. Increasing the capacity and quality of service at Ciwandan Port can increase the percentage of vehicles passing through which in turn increases user satisfaction.

Efforts to divert most vehicles from Merak Port to Ciwandan Port can reduce the negative impact of congestion on the community around the port and support local economic activities around the alternative port. Good capacity management at Ciwandan Port will support the overall efficiency of the transportation system, speed up the crossing process and reduce waiting times, thereby supporting the regional economy and reducing pollution and congestion. The data obtained is important for planning infrastructure development at Ciwandan Port including expanding facilities and improving services to handle larger traffic volumes. This information supports the development of better transportation policies, including adjustments in ship schedules, dock allocations and operational management. Analysis of demand and the percentage of vehicles passing through Ciwandan Port provides important insights for capacity management, performance evaluation and operational planning. The use of this data is expected to allow authorities to take the necessary steps to improve services, reduce congestion at the main port and support the efficiency of the overall transportation system.

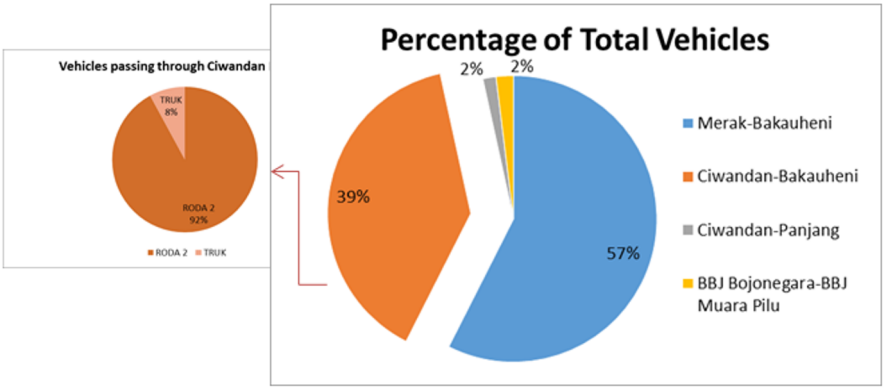


Figure 4. Graph of the Total Percentage of Vehicles Crossing from Java to Sumatra and the Dominance of Vehicles Crossing Via Ciwandan Port for the 2023 Eid Transport Period

The total number of vehicles crossing through Ciwandan Port during the Eid 2023 homecoming flow period was 39.3% with the dominance of 2 (two) wheeled vehicles at 92% and trucks at 8%, shown at Figure 4. This data helps authorities allocate appropriate resources at Ciwandan Port. The dominance of 2-wheeled vehicles indicates the need for improvements to facilities that serve motorcyclists, such as parking areas, special lanes, and safety facilities. The dominance of 2-wheeled vehicles requires consideration of infrastructure development that can accommodate and manage this volume of vehicles efficiently, including larger parking areas and safe and organized lanes for 2-wheeled vehicles. Knowing the proportion of vehicles passing through allows for adjustments to services and facilities at the port. For example, if 2-wheeled vehicles dominate, services such as parking lots, queue lines, and other facilities need to be adjusted to accommodate this type of vehicle. By knowing the percentage of vehicles clearly, the port can adjust their daily operations, such as ship frequency, departure times, and dock capacity to ensure smooth traffic and minimize waiting times. Understanding the total number of vehicles passing through Ciwandan Port, especially with the dominance of 2-wheeled vehicles, is essential for infrastructure planning, service optimization, traffic flow management, evaluation and development of transportation policies. This data helps ensure that the port can function efficiently and meet the needs of service users, while supporting the goals of reducing congestion and environmental impacts.

Tabel V. Percentage of the Total Number of Vehicles Crossing Through Ciwandan Port During the 2024 Eid Mubarak Transport Flow Period

Line	Number of vehicles traveling home for the 2024 Eid transport period (H-7 S.D H-1)
Jawa-Sumatera	185.222
Merak-Bakauheni	107.030
Ciwandan-Bakauheni	107.030
Ciwandan-Panjang	74.774

Line	Number of vehicles traveling home for the 2024 Eid transport period (H-7 S.D H-1)
BBJ Bojonegara-BBJ Muara Pilu	2.686
Percentage of Vehicles Crossing Through Ciwandan Port	40,4%

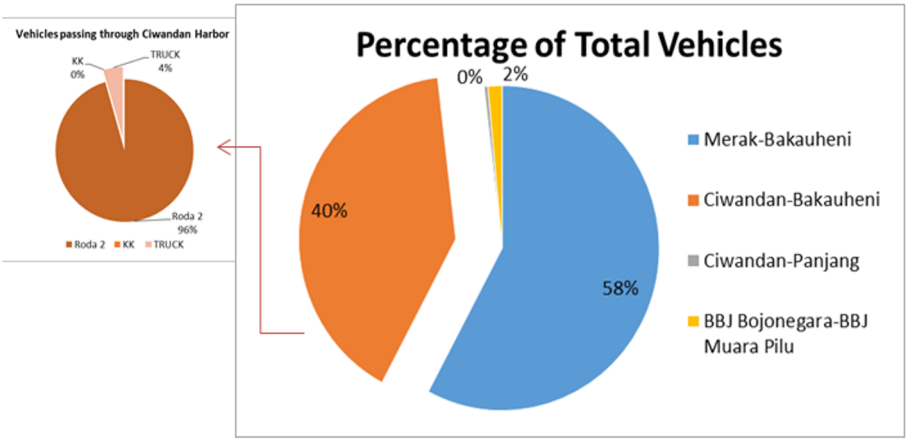


Figure 5. Graph of the Total Percentage of Vehicles Crossing from Java to Sumatra and the Dominance of Vehicles Crossing Via Ciwandan Port for the 2024 Eid Transport Period

From the analysis carried out, it is known that vehicles crossing through Ciwandan port are 39.4% and in 2024 this will increase to 40.4%. This shows in Table 4 and Figure 5 that the diversion of vehicles via the alternative Ciwandan-Bakauheni route via Ciwandan port has proven effective in reducing the burden on Merak Port by almost 50% so that it can reduce the congestion that occurs at Merak Port. This data shows that the diversion of vehicles through the Ciwandan-Bakauheni alternative route has proven effective. The increasing percentage of vehicles crossing Ciwandan Port from 39.4% in the previous year to 40.4% in 2024 has reduced the burden on Merak Port by almost 50%. This significantly reduces congestion at Merak Port, which previously experienced severe traffic congestion. The increasing percentage of vehicles crossing Ciwandan Port indicates the need for infrastructure development and service capacity at the port. This includes improving parking facilities, service areas and managing vehicle flow to accommodate the increasing volume (Zhang et al., 2024). The increasing number of vehicles using Ciwandan Port, optimizing ship operations including trip frequency and departure times are crucial to maintaining smooth traffic flow and reducing waiting times. This percentage is an indicator of the success of the traffic diversion policy. The government can use this data to evaluate current policies and formulate better strategies for the future including further regulations regarding vehicle distribution between Merak Port and Ciwandan Port.

The increase in the percentage of vehicles passing through Ciwandan Port reflects the important role of this port in supporting community mobility during peak periods such as Eid al-Fitr which helps maintain the smooth running of economic and social activities on both sides of the strait. Reducing congestion at Merak Port through traffic diversion to Ciwandan Port can reduce exhaust emissions and pollution around the port area. This has a positive impact on the environment, especially during times with high traffic volumes. Knowing the percentage of vehicles passing through Ciwandan Port during the 2024 Eid al-Fitr transportation period, which reached 40.4%, is very important in evaluating and improving the effectiveness of traffic diversion strategies. This helps in infrastructure planning, operational optimization, transportation policy development, and reducing negative impacts such as congestion and pollution, while supporting more efficient mobility during peak periods.

The method used to forecast demand by paying attention to past demand conditions is trend analysis. Trend analysis is to see demand trends using a regression line equation (Hoefler et al., 2023). Forecasting the production of Merak Port, it is known that every year there will be an increase in vehicle production with an average percentage increase of 4.34% per year. Meanwhile, the average increase in production during the Eid transport period is 5.28% per year and the increase during peak days is 4.50% per year.

Table 4. Merak Port Production Forecasting 2025-2029

YEAR	Forecasting Total Vehicle Production	Port Capacity (SUP)	Carrying Capasity	V/C Rasio	Difference (SUP)	Difference (Unit KK)
2025	927.580	55.419	923.807	1,00	3.773	118
2026	972.701	55.419	923.807	1,05	48.894	1.524
2027	1.017.822	55.419	923.807	1,10	94.015	2.930
2028	1.062.943	55.419	923.807	1,15	139.136	4.336
2029	1.108.064	55.419	923.807	1,20	184.257	5.742

Results of the analysis based on Table 4, it is known that if it is not balanced with an increase in capacity at Merak Port, then Merak Port will no longer be able to accommodate vehicle production on peak Eid transport days in the future, so it is necessary to increase ship carrying capacity by adding docks and expanding parking lots at the port by adding capacity by 2,114 vehicles or to 1,108,064 SUP (34,530 vehicles) so that it can accommodate total vehicle production in the future. Results of forecasting the production of Merak Port, it is known that every year there will be an increase in vehicle production by an average of 4.34% per year. Meanwhile, during the Eid transport period at Merak Port, there will be an average increase of 5.28% per year and on peak days, Eid transport will experience an average increase of 4.50% per year. From the analysis it is known that if there is no increase in capacity at the Port of Merak, then the Port of Merak will no longer be able to accommodate vehicle production on

peak Eid transport days in the future so it is necessary to increase capacity by 2,114 units of vehicles or to 1,108,064 SUP (34,530 Vehicles) so that can accommodate total vehicle production in the future. If Merak Port cannot increase capacity, then the implementation of Ciwandan Port as an alternative port must continue until Merak Port is ready to accommodate demand, especially during the Eid transport period.

This analysis emphasizes the urgency of increasing capacity at Merak Port to cope with the surge in vehicle volume, especially during peak days of Eid transportation in the future. Without adequate capacity addition, Merak Port will not be able to accommodate the increasing vehicle production. Production forecasts show that vehicle volume at Merak Port will grow by an average of 4.34% per year, with a more significant increase of 5.28% per year during the Eid transportation period, and 4.50% per year on peak days of Eid transportation. To overcome this problem, it is necessary to increase ship carrying capacity by adding docks and expanding parking areas at the port. An additional capacity of 2,114 vehicles or to 1,108,064 Production Units (SUP) is needed to accommodate total vehicle production in the future. If not done, Merak Port will continue to experience severe congestion during peak times, which can hinder smooth transportation and have a negative impact on the economy. In addition, until Merak Port is able to increase its capacity, the implementation of Ciwandan Port as an alternative port must continue. The use of this alternative port has proven effective in reducing the burden on Merak Port, especially during the Eid holiday season, and will be an important solution to prevent worse congestion in the future.

4. Conclusion

Ciwandan Port has an important role as an alternative port to reduce the burden and congestion on the crossing route between Java and Sumatra, especially during peak periods such as the homecoming and return flow of Eid. By optimizing the performance of the crossing, such as increasing ship carrying capacity and utilizing more efficient docks, Ciwandan Port can support inter-island transportation more effectively. The results of the analysis show that success in reducing congestion at Merak Port depends on the ability of Ciwandan Port to handle most of the vehicle volume. However, to ensure sustainability and improved performance, continuous evaluation and adjustment of capacity and supporting facilities at Ciwandan Port are needed.

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