

OPERATING PATTERNS FOR THE JENEBERANG RIVER FERRY AS A SOLUTION TO TRAFFIC CONGESTION BETWEEN GOWA-MAKASSAR

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ABSTRACT

The rapid growth of the Gowa - Makassar urban area has increased daily mobility and intensified traffic congestion, particularly along the Gowa Twin Bridges corridor. The Jeneberang River ferry service offers an alternative transport mode; however, its operation remains suboptimal due to irregular departure patterns and the absence of a structured timetable. This study aims to formulate an optimal operating pattern for the Jeneberang River ferry service on the Gowa - Makassar route, including transport capacity, trip frequency, and operational scheduling based on user demand. A descriptive quantitative approach was employed using operational data collected over a 14-day observation period, representing normal weekday and weekend travel conditions without seasonal peaks or special events. The analysis covered passenger and motorcycle demand, sailing frequency, transport capacity, and operational scheduling based on vessel cycle times. The results indicate that demand follows a relatively stable commuter-oriented pattern. The theoretical service frequency was calculated at 60 trips per day; however, after accounting for operational allowances and crew rest periods, a more realistic frequency of 52 trips per day was obtained. Under this operating scenario, the ferry service can accommodate up to 1,040 passengers and 780 motorcycles per day. The utilisation rate of 47% shows that available capacity is not fully utilised. This condition is primarily associated with irregular scheduling and low service reliability rather than insufficient fleet capacity. A fixed 15-minute headway is operationally feasible, although a dynamic peak-off-peak schedule is recommended to better match demand fluctuations. The study concludes that service optimisation should focus on operational efficiency and schedule reliability rather than fleet expansion. The implementation of an integrated real-time scheduling information system is recommended to improve service predictability, increase user confidence, and strengthen the role of ferry transport in reducing traffic pressure along the Gowa - Makassar corridor.

Keyword: ferry services, operating patterns, sailing frequency, transport capacity, operating timetable

Introduction

The rapid growth of the Gowa - Makassar urban area has led to a significant increase in population mobility, particularly among daily commuters. The phenomenon of urbanisation, rising motorcycle ownership, and the expansion of economic activity have placed heavy pressure on the main road network connecting the two regions. This situation has led to increased traffic congestion, particularly along the Gowa Twin Bridges corridor, resulting in longer journey times, higher energy consumption, and worsening urban environmental degradation [1-5].

This situation is consistent with urban transport studies, indicating that the imbalance between travel demand and road network capacity is a key factor in the occurrence of congestion in developing areas [6-8].

By utilising the Jeneberang River, which offers strategic potential as an alternative mode of transport capable of reducing the burden on road traffic. Ferry transport forms part of a multimodal transport system that has been proven globally to enhance connectivity whilst reducing the negative externalities of road transport, such as congestion and emissions [9-11].

Conceptually, the performance of ferry services is heavily influenced by operational patterns, including transport capacity, fleet size, frequency of trips, and a structured, user-demand-based service schedule [12-14].

However, the current state of the Jeneberang River ferry service remains suboptimal. At present, the service is operated by a single vessel with a capacity of 20 passengers and 15 motorcycles per trip. Based on field survey results, the operational system in place is flexible, with vessel departures heavily dependent on the number of available passengers. Consequently, service schedules become unpredictable, waiting times increase, and service frequency becomes irregular. Previous studies have shown that schedule uncertainty and low service frequency can increase waiting times to more than 70% of the total journey time, thereby reducing confidence in the ferry transport service [15-17].

Furthermore, the current operation is served by only one vessel, resulting in service limitations during peak periods, particularly in the morning and evening. However, field observations indicate that the main operational issue lies not in the fleet size itself, but in the irregular departure pattern and the absence of a structured timetable, which increases passenger waiting times and reduces service reliability. This condition reflects a mismatch between service operation and user demand patterns. In transport systems, such operational inefficiencies can significantly affect service performance and user satisfaction [18, 19]. Previous studies have shown that optimising service frequency and scheduling according to demand patterns can effectively reduce waiting times, improve service reliability, and enhance the utilisation of water transport systems without necessarily increasing fleet size [20-23].

Based on the current literature, research on ferry transport over the past five years has largely focused on scheduling optimisation based on mathematical models, such as dynamic programming, stochastic scheduling, and multi-objective optimisation that takes into account operational costs and service efficiency [24-27]. Furthermore, several studies have also examined the integration of water transport with land transport systems, as well as the impact of improved service levels on changes in user demand [28-30]. However, the majority of these studies have been conducted at a macro scale or in major ports and

remain limited to theoretical or simulation-based approaches.

The research gap lies in the lack of studies that specifically examine the planning of local-scale ferry transport operational patterns based on daily travel demand characteristics, whilst accounting for the limitations of the existing fleet and real-world operational conditions. Furthermore, studies that integrate capacity, fleet size, frequency, and scheduling into a single analytical framework for urban river crossings remain very limited.

Given this gap, the novelty of this research lies in the development of a planning model for the operational patterns of the Jeneberang River ferry service, based on existing conditions and actual user demand, whilst taking into account fleet limitations, variations in peak-time demand, and the need to improve service reliability. This approach is expected to yield operational recommendations that are more practical and relevant than previous approaches, which tended to be of a general nature.

This study aims to analyse and formulate an optimal operational pattern for the Jeneberang River ferry service on the Gowa - Makassar route, encompassing the determination of transport capacity, fleet size, journey frequency, and the formulation of an operational schedule aligned with user demand characteristics.

The urgency of this research lies in the need to develop an efficient, affordable, and sustainable alternative transport system to reduce the burden on the road network, improve public mobility, and support an integrated urban transport system. With a well-planned operational pattern, the Jeneberang River ferry service is expected to provide a tangible solution to traffic congestion in the Gowa - Makassar area.

Methodology

Research Setting and Time

The study was conducted on the Jeneberang River crossing route linking Taeng Pier, Gowa, with Somba Opu Pier, Makassar; details of which are shown in Figure 1.

Data collection took place over 14 days, from 5 January to 18 January 2026. This observation period was chosen to reflect operational conditions on weekdays (Monday - Friday) and weekends (Saturday - Sunday).

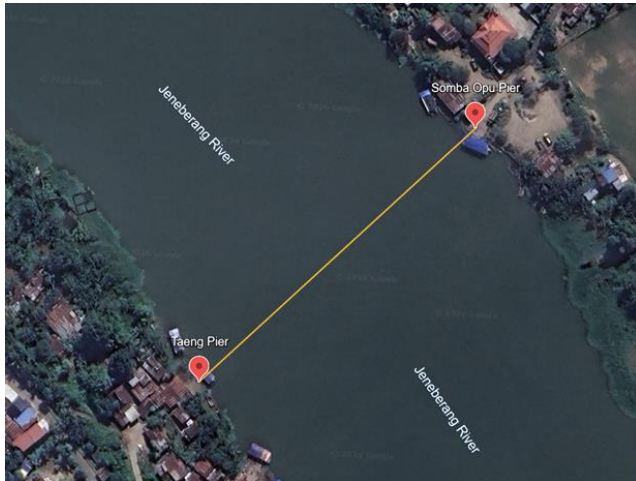


Figure 1. Taeng – Somba Opu Ferry Route [31].

Research Procedure

The research procedure began with an assessment of the current operational conditions of the Jeneberang River ferry service on the route between Taeng Pier (Gowa) and Somba Opu Pier (Makassar), including the number of vessels (1 unit), carrying capacity (20 passengers and 15 motorcycles), and a crossing time of 3 minutes over a distance of 200 metres. This was followed by 14 days of field data collection, recording the number of passengers and motorcycles, as well as departure and arrival times for each trip. The data was then grouped by working days and public holidays to identify demand patterns.

The next stage involved data processing and analysis to determine sailing frequency, transport capacity, and operational schedule requirements based on daily operating hours. The results of the analysis were used to evaluate the performance of the existing service and to formulate an optimal operating pattern, covering frequency, timetable, and fleet requirements, to improve service efficiency and reduce passenger waiting times.

Research Instruments

The instruments used in this study comprised observation sheets and timekeeping records, which were used to record the number of passengers and motorcycles, and the departure and arrival times of the vessels on each trip during the observation period. In addition, mobile phones were used as documentation tools to ensure the accuracy and validity of the field data.

Data Analysis Technique

Data analysis in this study was carried out systematically to identify the optimal operating pattern for the ferry service, which includes:

a. Voyage Frequency Analysis

The voyage frequency (f) analysis was carried out to determine the number of trips that can be served in a single day. The calculation is based on daily operating hours (06.00 - 21.00 WITA) divided by the voyage cycle time, as shown in Equation 1.

$$f = \frac{T}{t_s + t_{tn} + t_{lb}} \quad (1)$$

Where f is the voyage frequency, T is the daily operating time, t_s is the sailing time, t_{tn} is the loading and unloading time, and t_{lb} is the mooring time. The results of this analysis indicate the number of sailing frequencies that can be achieved in a single day of operation.

b. Transport Capacity Analysis

The transport capacity (C) analysis aims to determine the service's ability to accommodate user demand. The calculation is performed by comparing the number of passengers and motorcycles against the sailing frequency, both on weekdays and public holidays, as set out in Equation 2.

$$C = \frac{\text{Total Cargo Demand}}{\text{Frequency}} \quad (2)$$

The results of this analysis are used to evaluate the alignment between available service capacity and actual demand levels.

c. Operational Schedule Analysis

Operational schedule analysis is carried out by establishing a vessel departure pattern based on voyage frequency and cycle times. The schedule is designed within the daily operating hours, taking into account the distribution of passenger demand, particularly during the morning and evening peak hours, thereby resulting in a more regular and efficient service pattern that reduces passenger waiting times.

Conceptual Framework

The research framework systematically outlines the process of evaluating ferry services, as shown in Figure 2.

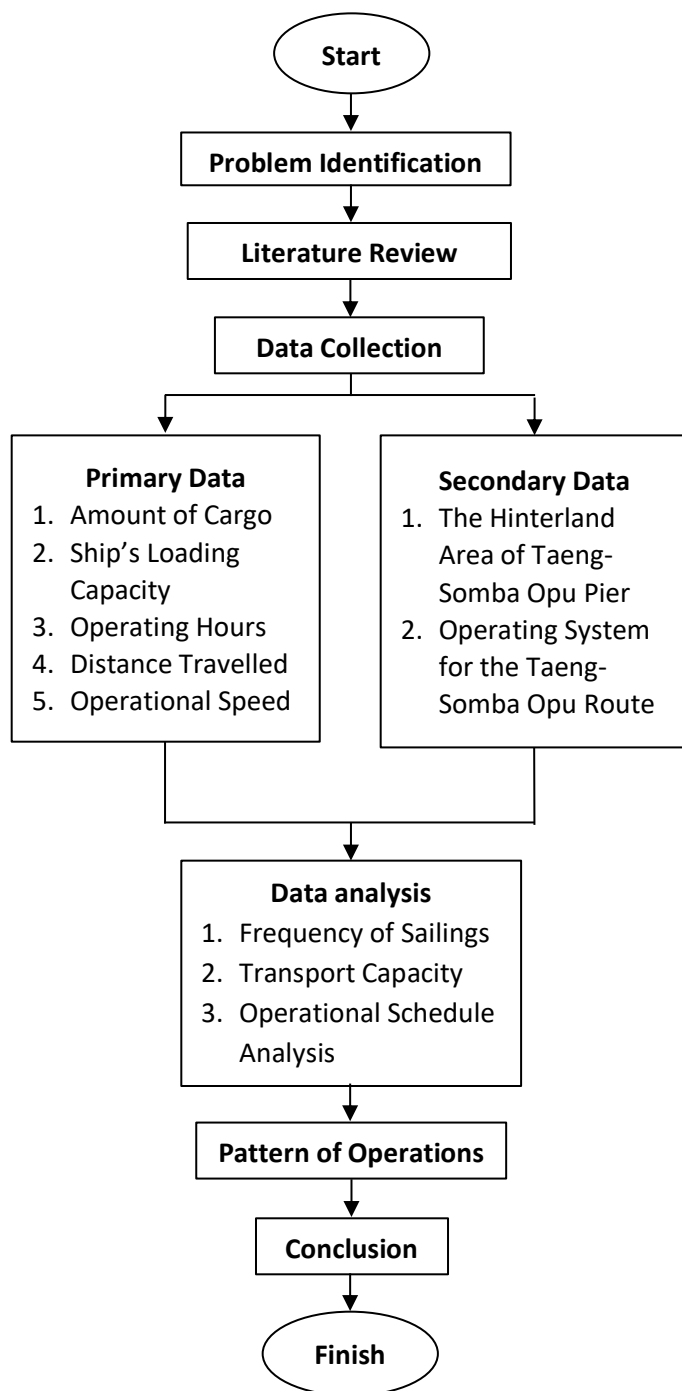


Figure 2. Research Framework.

Result and Discussion

Operational Conditions of the Ferry

Based on field observations, the Jeneberang River ferry service on the route from Taeng Pier (Gowa) to Somba Opu Pier (Makassar) is currently operated by a single motor vessel with a capacity of 20 passengers and 15 motorcycles per trip, and a crossing time of approximately 3 minutes for a distance of 200 metres. A summary of the vessel data is presented in Table 1.

Table 1. Ferry Route Data: Taeng – Somba Opu

No	Dimensional Parameters	Symbol	Value	Unit
1	Length Overall	LOA	12	m
2	Breadth Moulded	B	2,6	m
3	Depth	H	3	m
4	Draft	T	0,5	m
5	Deck Length	L _D	12	m
6	Deck Breadth	B _D	2	m
7	Power Engine	P	15	PK

Operationally, the departure procedure begins with the positioning of motorcycles and passengers according to the loading arrangement, followed by engine preparation and the casting-off manoeuvre from the quay to commence the voyage, as illustrated in Figure 3.



(a) Taeng Pier, Gowa



(b) Somba Opu Pier, Makassar

Figure 3. Vessel Departure Conditions at Taeng Pier and Somba Opu Pier

Figure 3 illustrates the ship departure process, which is still carried out manually without a queuing system or structured schedule. Furthermore, the deck space, measuring 12 m in length and 2 m in breadth, is limited to accommodate 15 motorcycles during peak hours. To maximize the limited deck area, the motorcycles are arranged lengthwise in three rows along the hull, as illustrated in Figure 4.

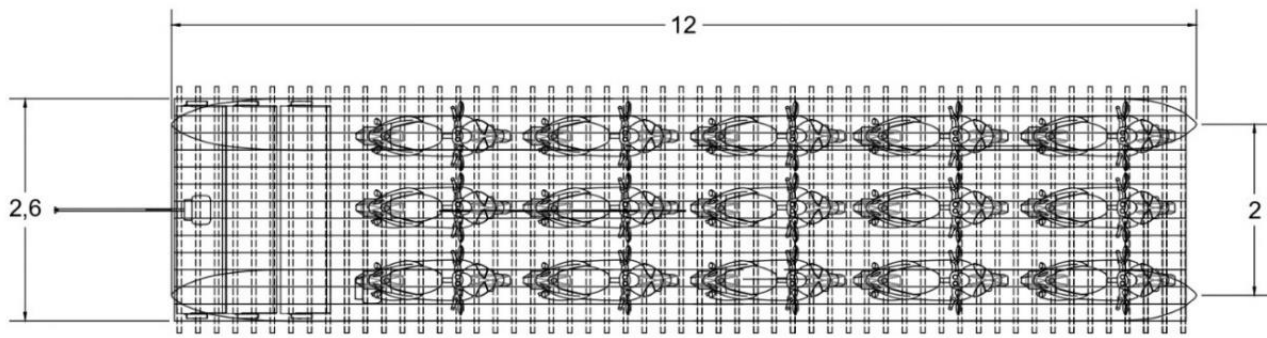


Figure 4. Motorcycle Arrangement on the Vessel Deck

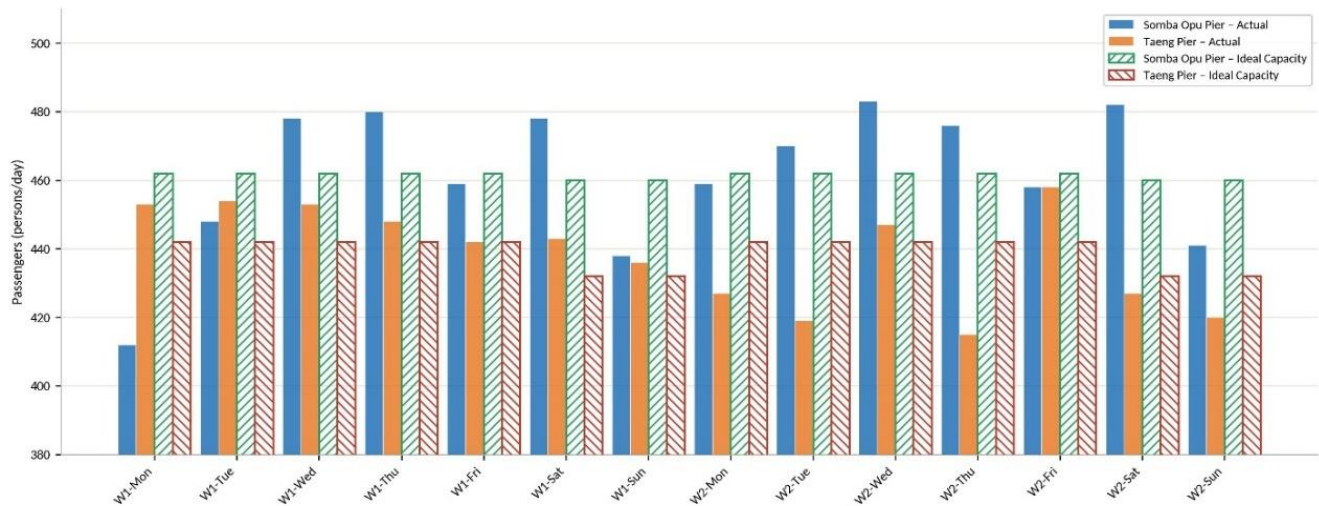


Figure 5. Daily Passenger Demand vs. Service Capacity on the Gowa - Makassar Route

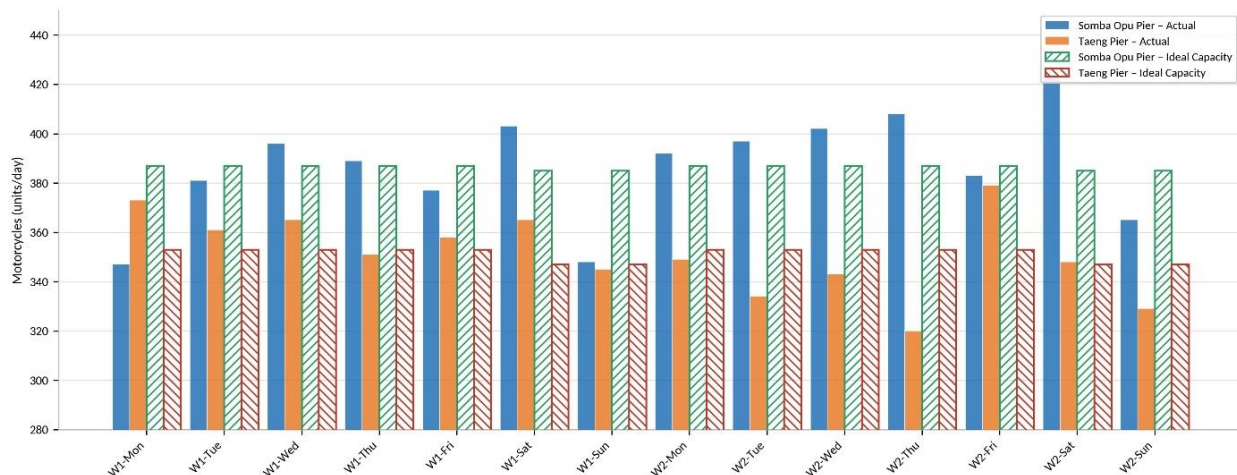


Figure 6. Daily Motorcycle Demand vs. Service Capacity on the Gowa - Makassar Route

This configuration improves spatial efficiency and allows the vessel to accommodate the required capacity within the available deck space. However, the narrow breadth provides limited manoeuvring space during loading and unloading activities,

requiring careful operational control to maintain passenger safety and loading stability.

The results of the 14-day observation period (5 - 18 January 2026) are presented in Figures 5 and 6, which compare actual passenger and motorcycle demand with the available service capacity at Taeng

and Somba Opu Piers. The survey was conducted during two consecutive weeks of normal operating days, representing regular travel conditions without the influence of seasonal peaks, public holidays, or special events. Consequently, the observed demand patterns can be considered representative of typical daily mobility between Gowa and Makassar.

Figures 5 and 6 show that passenger and motorcycle demand remained relatively stable throughout the observation period, with a moderate increase during the second week. Daily passenger volumes ranged from 412 - 480 persons at Taeng Pier and 438 - 492 persons at Somba Opu Pier, while motorcycle demand varied between 320 - 379 units and 347 - 423 units, respectively. These patterns reflect the commuter-oriented nature of travel along the corridor, where mobility is primarily associated with work, education, and routine economic activities.

A comparison between actual demand and available service capacity demonstrates that demand consistently remained below the available carrying capacity. Passenger demand approached the available service capacity on several weekdays, particularly during the second week, whereas motorcycle demand remained substantially below the maximum carrying capacity throughout the observation period. This indicates that the existing ferry system possesses sufficient spare capacity to accommodate current demand levels.

Although Figures 5 and 6 present daily demand patterns, field observations revealed that passenger arrivals were not evenly distributed throughout the day. Demand tended to concentrate during morning and afternoon commuting periods, resulting in temporary queues and increased waiting times despite the availability of adequate vessel capacity. This finding suggests that service inefficiencies are primarily related to operational management, particularly irregular departure patterns and the absence of a fixed timetable, rather than to insufficient vessel capacity or fleet size.

From an operational perspective, these results justify the implementation of a regular service cycle with a 15-minute headway. A fixed operating interval would provide greater schedule reliability, reduce

passenger uncertainty and waiting times during peak periods, and improve the overall efficiency of ferry operations. Similar findings have been reported in studies of short-distance ferry transport, where service quality is more strongly influenced by scheduling reliability and frequency optimisation than by capacity expansion alone [32-35].

Therefore, the optimisation strategy for the Jeneberang River ferry service should focus on adaptive frequency and timetable management based on demand characteristics, rather than increasing fleet capacity.

Analysis of Sailing Frequency and Transport Capacity

A voyage frequency analysis was conducted to determine the number of daily trips based on the vessel's operational cycle. Using an operating period (T) of 15 hours (06.00 - 21.00 WITA), a sailing time (ts) of 3 minutes, and a combined docking, loading, and unloading time (ttn + tlb) of 12 minutes, the total cycle time is 15 minutes. Under these ideal conditions, the ferry service can theoretically achieve 60 trips/day through continuous operation without interruption. This value represents the maximum service frequency that can be attained under fully efficient operating conditions.

However, actual operations require allowances for crew rest, passenger boarding management, operational coordination, and minor technical delays. By accounting for 60 minutes of crew rest and 60 minutes of operational allowance per day, the effective operating time decreases to 13 hours (780 minutes). Consequently, the achievable operational frequency is reduced to approximately 52 trips/day.

The comparison between ideal and actual conditions is illustrated in Figure 7, which shows that both weekday and weekend operations experience a frequency gap of 8 trips/day, equivalent to approximately 13,3% of the ideal service level.

The figure clearly demonstrates that the existing system still possesses unused operational potential. Therefore, the observed service inefficiency is not primarily related to vessel capacity, but rather to operational management factors that reduce the effective utilisation of available operating time.

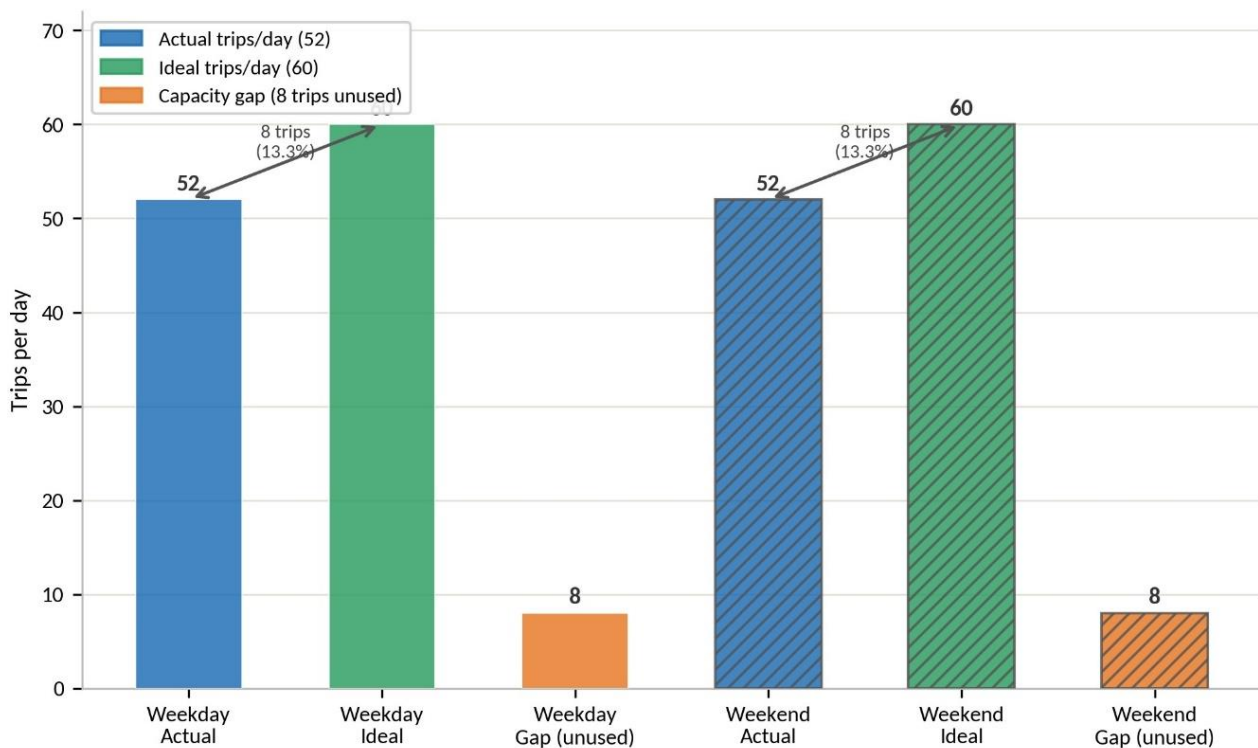


Figure 7. Gap between Actual Service Frequency and Ideal Capacity

These findings support previous studies indicating that operational downtime, crew scheduling, and service management are among the principal factors affecting ferry productivity and service reliability. As a result, optimisation efforts should focus on improving berth utilisation, reducing operational delays, and implementing a more structured timetable to minimise non-productive time.

In addition to operational management factors, several external environmental variables may influence the achievable service frequency. The Jeneberang River is characterised by sedimentation processes and tidal fluctuations that can affect navigation conditions, particularly in shallow sections near docking facilities. During periods of low tide or increased sediment accumulation, vessel manoeuvring may become more constrained, potentially increasing the nominal sailing time of 3 minutes and the docking time of 12 minutes. Conversely, favourable tidal conditions may facilitate faster manoeuvring and improve operational efficiency. Although these variables were not explicitly incorporated into the frequency calculation, their potential influence should be considered in future operational planning and infrastructure development. Incorporating hydrographic parameters such as water depth, sedimentation rates, and tidal variation into

scheduling models would provide a more realistic representation of ferry performance under actual field conditions.

Overall, the results indicate that improving operational efficiency and schedule reliability offers greater benefits than increasing vessel capacity. Therefore, adaptive frequency management supported by regular monitoring of operational and environmental conditions is recommended to enhance the performance of the Jeneberang River ferry service.

Operational Schedule Analysis

The operational schedule analysis is based on two scenarios: actual conditions (52 trips/day) and ideal conditions (60 trips/day). With an operating time of 15 hours (06.00 - 21.00 WITA) and a cycle time of 15 minutes (3 minutes sailing + 12 minutes docking), under ideal conditions, the entire operating time is utilised without any allowance. Table 2 presents the ideal operating schedule (60 trips/day) with a continuous departure pattern.

The analysis shows that, under ideal conditions, the operating schedule is very dense, with a constant 15-minute headway and no breaks. This results in a maximum frequency of 60 trips per day, which increases service capacity to 1,200 passengers and 900 motorcycles per day.

Table 2. Ferry Schedule for the Gowa - Makassar Route

Trip	Ship Operation Schedule			
	Departure (Somba Opu)	Arrival (Taeng)	Departure (Taeng)	Arrival (Somba Opu)
1-2	06.00	06.03	06.15	06.18
3-4	06.30	06.33	06.45	06.48
5-6	07.00	07.03	07.15	07.18
...	...	...	...	...
29-30	13.00	13.03	13.15	13.18
31-32	13.30	13.33	13.45	13.48
...	...	...	...	...
57-58	20.00	20.03	20.15	20.18
59-60	20.30	20.33	20.45	20.48

However, based on the previous analysis (Figures 5 and 6), actual demand ranges only between 450 - 480 passengers and 350 - 420 motorcycles per day, resulting in a very low utilisation rate of around 47% under these conditions.

Conversely, under real-world conditions (52 trips per day), the schedule is more relaxed due to a 120-minute allowance for breaks and other operational factors. Although the frequency is lower, the service capacity (1,200 passengers and 900 motorcycles per day) still meets demand, with a utilisation rate of around 53%. This indicates that real-world conditions are more efficient and realistic than ideal conditions.

A comparison of the two scenarios confirms that the ideal approach tends to exceed on-site requirements. This finding is consistent with studies on ferry transport, which state that schedule optimisation must take into account the balance between frequency, capacity, and actual demand [36-37]. Overly dense schedules have the potential to cause operational inefficiencies, whilst overly sparse schedules can increase user waiting times.

Based on the demand pattern (Figures 5 and 6), there are fluctuations between weekdays and weekends, as well as differences between arrival and departure flows. Therefore, the implementation of a dynamic schedule (peak-off-peak scheduling) is more recommended than a static schedule. This strategy allows for increased frequency during peak hours and reduced frequency during off-peak hours, thereby improving vessel utilisation without expanding the fleet.

Conclusion

This study analysed and formulated the optimal operating pattern of the Jeneberang River ferry

service on the Gowa - Makassar route in terms of transport capacity, fleet utilisation, service frequency, and operational scheduling. The results indicate that passenger and motorcycle demand follow a relatively stable commuter-oriented pattern, with demand concentrations occurring during the morning and afternoon peak periods. Frequency analysis shows that the theoretical service capacity reaches 60 trips per day; however, after considering operational allowances, crew rest periods, and practical field conditions, a more realistic operational frequency is 52 trips per day.

Under this operational scenario, the ferry service is capable of transporting up to 1,040 passengers and 780 motorcycles per day without requiring additional vessels. The utilisation rate remains below the available carrying capacity, indicating that service improvement should focus on operational efficiency and schedule reliability rather than fleet expansion. A fixed 15-minute service cycle is considered operationally feasible, while a dynamic peak-off-peak scheduling approach is recommended to better match demand fluctuations and reduce passenger waiting times.

Importantly, this study quantitatively demonstrates the ferry service's potential contribution to traffic congestion mitigation through modal shift. With an operational capacity of 780 motorcycles per day, the ferry system has the potential to divert approximately 5 - 8% of the daily motorcycle traffic volume from the Gowa Twin Bridges corridor, assuming full utilisation of the recommended 52-trip operating pattern. Although this percentage may appear modest at the corridor scale, its impact becomes substantially more significant during peak commuting periods, when traffic demand is highly concentrated, and roadway performance is most vulnerable to congestion. In

practice, the diversion of several hundred motorcycles during the morning (06.00 - 08.00 WITA) and evening (16.00 - 18.00 WITA) peak hours can contribute to reducing traffic queues, improving travel time reliability, and alleviating pressure on the Twin Bridges corridor.

Therefore, the principal contribution of this research lies not only in proposing an operational optimisation model for the Jeneberang River ferry service but also in providing quantitative evidence that river-based transport can function as a realistic complementary mode within the Gowa–Makassar urban transport system. The findings confirm that improving service reliability through adaptive scheduling, real-time operational management, and integration with land transport modes offers a practical strategy for enhancing ferry attractiveness and encouraging modal shift from motorcycles. Future research should incorporate detailed hourly traffic counts on the Twin Bridges corridor, user mode-choice behaviour, and transport demand modelling to estimate congestion reduction impacts with greater precision and support long-term multimodal transport planning.

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