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Abd. Rakhman
Magister Manajemen, Fakultas Ekonomi Dan Bisnis, Universitas Mulawarman, Indonesia

Tetra Hidayati
Magister Manajemen, Fakultas Ekonomi Dan Bisnis, Universitas Mulawarman, Indonesia

Musdalifah Azis
Magister Manajemen, Fakultas Ekonomi Dan Bisnis, Universitas Mulawarman, Indonesia

Corresponding Author:
Abd. Rakhman
Magister Manajemen, Fakultas Ekonomi Dan Bisnis, Universitas Mulawarman, Indonesia

Optimization of assignment model based on tugs service performance using the hungarian method in the waters of the kupp tanjung santan area

Abd. Rakhman, Tetra Hidayati and Musdalifah Azis

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Abstract
Method of assignment on the tugboats Samara & MR 702 shows that the movement of tugboat services can minimize tugboat service costs. The population and sample are the same, using the saturated sampling technique. The data used is the number of tugboat service movements, totaling 900 over an observation period of 30 months, starting from March 2021 to October 2024. It can be seen that the greater the tugboat service movement, the tendency is to lower the service costs. In the 30-month observation period, the tugboat service movement in this study showed that 9 minimal service activities and 23 maximal monthly service activities have been achieved, and this is the optimal solution for the services in months 1-10. For services in months 11-20, it showed 26 minimal service activities and 36 maximal tugboat service activities have been achieved. Furthermore, for services in months 21-30, 33 minimal service activities and 43 maximal tugboat service activities have been achieved. This analysis confirms that the higher the frequency of tugboat service movements, the lower the service costs, showing a trend that higher service movement frequency directly correlates with cost efficiency. This is reflected by the achievement of minimal and maximal service activities in each observation period. The three observation periods provide a strong basis for operational decision-making and future planning. The results of this study are to adjust service strategies, allocate resources more efficiently, and optimize the rotation of tugboat services to reduce overall costs while maintaining service standards.

Keywords: Model optimization, hungarian assignment method, tugboat services, and tugboat service costs

Introduction

Tugboats assist barges in need of pilotage services as they approach or depart the jetty and river channel in the waters of KUPP Santan. Because it has a significant impact on shipping service movements, it is an important consideration when making decisions. In this study, the tugboat assignment problem is formulated using the Hungarian model and the service assignment method. The model's performance was then demonstrated by numerical experiments, which also evaluated the impact of tugboat service performance on the barge's operating time. River water tidal oscillations, the safety and security of coal loading and unloading facilities for the barges under the tugboats' control at the jetty, and the environment all have an effect on the monthly performance of this tugboat service. the KUPP Tanjung Santan area, and the fluctuating coal prices, leading to a reduced demand for PT Karya Royal Perkasa's tugboat services.

PT Karya Royal Perkasa operates in the tugboat service industry, primarily offering ship traffic services such as pilotage within the port services environment of PT Pelabuhan Indonesia III for ships entering and leaving the port. PT Karya Royal Perkasa also plays an important role in the tugboat service industry in Eastern Indonesia. The availability of the pilot fleet is essential for meeting the diverse needs of tugboat services, as it can be supplied through rental or charter options to fulfill operational requirements effectively.

Assurance Agency; there has been a gradual and slow level of the growth of the insurance The performance of this tugboat service takes into account both the best use of the Hungarian assignment method to minimize time length and the computation of the frequency of service movements.

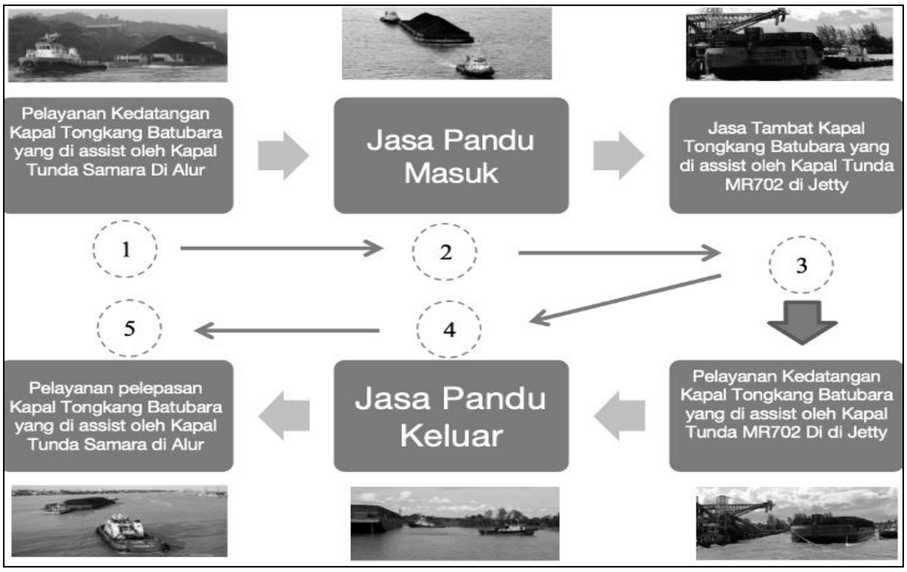


Fig 1: Process Diagram of the Movement of Samara Tugboat Service and MR702
Source: Results of the observation of the Tugboat Service Movement of PT Karya Royal Perkasa

This tugboat service performs better when using the Hungarian assignment method to calculate the frequency of ship movement services, time, and fixed service charges than other companies do. With the primary difference being the amount of repetitions required for each technique, the latter research attempts to attain similar optimal results between the penalty method and the Hungarian method. According to several studies ((P. *et al*., 2023); (Carmen *et al*., 2020) [4] (Giuseppe *et al*., 2017) [8]; (Monika *et al*., 2013) [13]; (Trust *et al*., n.d.); (Aamir & Abdul, 2019) [1]; (Elfrida *et al*., 2021) [6], this Hungarian calculation method will yield the best assignment results. The assignment problem is similar to the linear transportation problem: each source and destination has the same number, but in the assignment, the number is only one.

The development of assignment issues related to the advancement of science and information technology ((Venn *et al*., 2022) [21]; (Elfrida *et al*., 2021) [6]. Linear programming, a component of applied mathematics, can be used to solve problems on how to optimally organize tasks with a limited number of tasks. Harold Kuhn discovered and published the Hungarian method in 1955 to solve the assignment problem. In relation to the assignment problem, the general assumption is that the number of rows is equal to the number of columns in an assignment model matrix. The assignment problem has only one optimization objective. (Bamdad *et al*., 2023) [3]; (Ju-Yeong & Joohyun, 2023) [3]; (Giuseppe *et al*., 2017) [8]; (Monika *et al*., 2013) [13]; (Trust *et al*., n.d.) [19]; (Venn *et al*., 2022) [21]; (Michael & Agustinus, 2021) [12]; (Aamir & Abdul, 2019) [1]; (Alvin *et al*., 2022) [2]; (Rini & Empya, 2019) [15]; (Silvia & Simona, 2022) [18]; (Umi *et al*., 2023) [20]; (Kexin *et al*., 2023) [10]; (F. & Michel, 2006) [7], which is to maximize the performance of tugboat service movements or minimize the service cost of a tugboat service task. The objective of the assignment problem is to optimize tugboat service movement assignments for service requests at the jetty and barge service lane, aiming to minimize service costs while efficiently fulfilling barge service requests. Therefore, to solve the assignment problem by optimizing the frequency of tugboat service movements and the total operational time in providing tugboat services, the Hungarian method is used.

The first stage in solving the assignment problem is to collect data, which includes the monthly service count provided by PT Karya Royal Perkasa tugboats on tugboats and coal barges. Next, form a mathematical model into a linear program to be solved using the Hungarian method.

This research is conducted to provide concrete guidance to industry practitioners on the steps that can be taken to identify the optimization of the assignment model based on tugboat service performance using the Hungarian method at the jetty and channel in the waters of the KUPP Tanjung Santan Area, with the aim of improving the effectiveness of tugboat service movement performance and overall duration productivity, as well as the cost efficiency of the service.

Literature review

The operational performance of tugboat services is very important for port operational activities, as it helps with the maneuvering process of ships for docking and anchoring in the harbor basin area. Ports are also considered safe places for loading and unloading and docking ships. Ports function as the hub of the maritime and land transportation chains. Therefore, a port is a body of water that is safe from storms, waves, and currents, allowing ships to maneuver, dock, and anchor. This allows for the safe loading and unloading of goods and the transfer of passengers and cargo. Therefore, you must have good motor skills. This is in line with the opinion of Padilah and Kurniawan (2022) that maneuvering a ship means mastering the ship both when stationary and in motion to achieve the sailing objectives as safely and efficiently as possible using the ship's equipment such as engines, steering, and others.

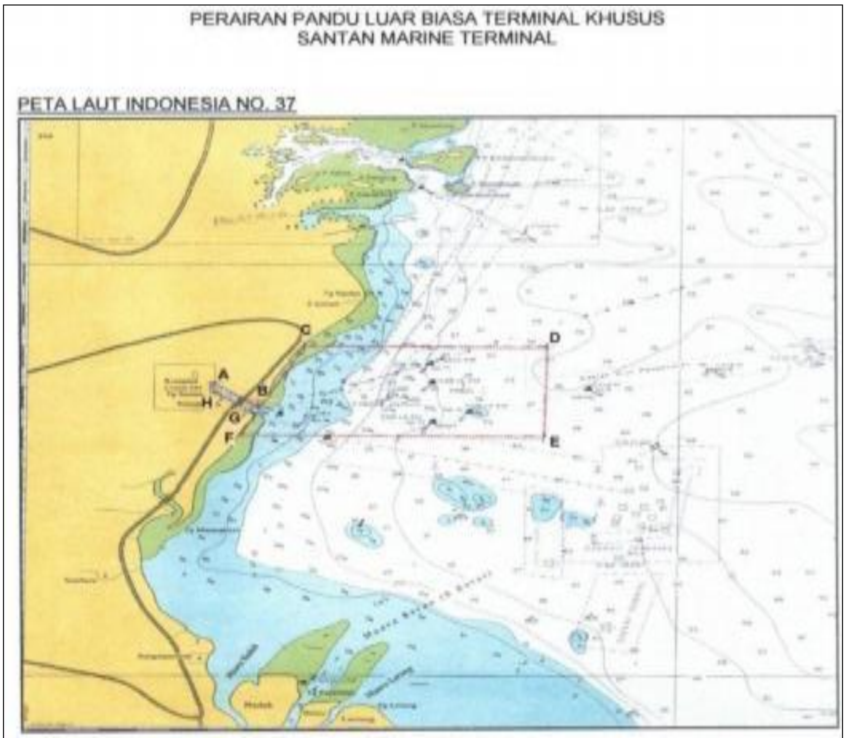
The Hungarian Method is one of the algorithms used to solve assignment problems; this method was discovered and published by Harold Kuhn in 1955. The Hungarian algorithm has two solutions, namely the minimal solution and the maximal solution. In addition, the Hungarian algorithm uses simple calculations, making it easier to understand and apply in real life. The Hungarian method is a method that modifies the rows and columns in the effectiveness matrix until a single zero component appears in each row or column, which can be selected as the assignment allocation. The purpose of this research is to analyze the application of the Hungarian method in optimizing the assignment of tugboat service movements by PT Karya Royal Perkasa for the loading service requests of barge ships at the jetty and the waters of KUPP Tanjung Santan.

The Hungarian Method is one of the optimization algorithms used to solve the assignment problem, where the goal is to minimize assignment costs or time and maximize the activity of tugboat service movements in a specific context. In the context of tugboat services, this method can be used to determine the optimal assignment between tugboats and the vessels requiring service, thereby minimizing operational costs or assignment time.

Pilotage services, as one form of tugboat service, play a significant role in contributing to the overall performance of tugboat berthing and loading operations. From the perspective of tugboat service, the pilot, in carrying out the task of guiding ships entering and leaving the harbor, is the "first and last contact person," so the performance of the individual pilot will leave a strong impression on the customer's image. (NakhodaKapal dan Perusahaan Pelayaran). (NakhodaKapal dan Perusahaan Pelayaran). Thus, the quality of the guiding service affects the overall performance of the harbor. In other words, "the responsibility for achieving good berth performance partly lies in the hands of the pilot" (da. Lase 1988: 12), whereas the performance of other berths and loading can come from outside the pilot division.

Research Method

In this study, the design used is a quantitative research design. Sanusi (2014: 104) explains that quantitative data is data presented in numerical form related to the research object. Operational research is a discipline that focuses on the development and application of mathematical models, algorithms, and analytical techniques to assist in optimal decision-making. Tugboat Services are ship services designed to operate in and out of the Mahakam River and to tow coal barges at the jetty and channel in the waters of KUPP Tanjung Santan. The Hungarian Assignment Method is a method used to solve problems related to the monthly assignment of resources, in this case, the tugboats of PT Karya Royal Perkasa, to complete service work on coal ships and barges. This resource can be in the form of monthly tugboat services from PT Karya Royal Perkasa. This assignment method is often referred to as the Hungarian method.



Keterangan :
Koordinat Perairan Pandu:
Titik A : 00°-05'-45"LS/117°-27'-00"BT
Titik B : 00°-06'-50"LS/117°-28'-16"BT
Titik C : 00°-04'-00"LS/117°-29'-30"BT
Titik D : 00°-04'-00"LS/117°-36'-18"BT
Titik E : 00°-08'-20"LS/117°-36'-18"BT
Titik F : 00°-08'-20"LS/117°-27'-46"BT
Titik G : 00°-07'-18"LS/117°-28'-12"BT
Titik H : 00°-06'-12"LS/117°-27'-00"BT

Fig 2: Map of Tanjung Santan Waters

The population in this study is the Monthly Service Movement Frequency of Tugboats PT Karya Royal Perkasa, totaling 900 ship service movements over a 30-month observation period from October 2021 to March 2024, with the ship service movements of Samara and MR702. Sugiyono (2019). The data used in this study are primary and secondary data obtained directly from the field and the documents of PT Karya Royal Perkasa. The data collected is an overview of the company. General data of the ship as well as the existing condition of the ship and ship management through direct field surveys. Literature Review to assist the author in obtaining theories and previous research related to this study.

The assignment model to maximize the movement of tugboat services can be optimized using the Hungarian Method, which is used in assignment problems. (assignment problem). (assignment problem). Linear programming seeks the best outcome in solving a problem that meets several specified conditions. In the process, operations research is related to the optimization model of the assignment method.

LINDO is a software package under Windows that can be used to solve linear programming cases, equipped with various commands that allow users to easily obtain information as well as process or manipulate data. The main working principle of Lindo is to input data, solve, and estimate the accuracy and feasibility of the data based on the solution. According to Linus Scharge (1991) [17], the calculations used in Lindo essentially employ the simplex method. Meanwhile, to solve the zero-one integer linear programming problem, Lindo software uses the Branch and Bound Method according to Mark Wiley. (2010) [11]. (2010).

The formulation of a linear model for this problem creates 3 service timelines for the number of ship movements over 10 months of service performance during a 30-month observation period, namely:

Monthly Tugboat Service Movement Formula:

F1: max $n_{t1\text{-}10}L0_{t1\text{-}10}S_{k1\text{-}15} + n_{t1\text{-}10}L0_{t1\text{-}15}MR_{k1\text{-}15}$

F2: max $n_{t11\text{-}20}L0_{t11\text{-}20}S_{k1\text{-}15} + n_{t11\text{-}20}L0_{t1\text{-}15}MR_{k1\text{-}15}$

F3: max $n_{t21\text{-}30}L0_{t21\text{-}30}S_{k1\text{-}15} + n_{t21\text{-}30}L0_{t1\text{-}15}MR_{k1\text{-}15}$

Explanation: nt1-10, nt11-20, and nt21-30: Shows the number of tugboat service activities that occurred during each 10-month period. L0t1-10, L0t11-20, and L0t21-30: Referring to specific locations or service points accessed by tugs within each 10-month period. Sk1-15 and MRk1-15: Are the identification of tugboats involved in the service.

This first formula maximizes the number of service activities for the Samara and MR702 tugs in the first 10 months. (bulan 1-10). (bulan 1-10). The activities of this service include operations at various service locations relevant to the period. This second formula maximizes the number of service activities in the second 10 months (months 11-20), where the tugboat Samara and MR702 are involved in operations at the designated service locations for this period. And this third formula maximizes the number of service activities over the past 10 months. (bulan 21-30). (bulan 21-30).

The tugboats Samara and MR702 are operating in locations appropriate for this service period.

$K_{1\text{-}10}$: $L0_{t1\text{-}10}S_{k1\text{-}15} + L0_{t1\text{-}10}MR_{k1\text{-}15} = 1$

$K_{11\text{-}20}$: $L0_{t11\text{-}20}S_{k1\text{-}15} + L0_{t11\text{-}20}MR_{k1\text{-}15} = 1$

$K_{21\text{-}30}$: $L0_{t21\text{-}30}S_{k1\text{-}15} + L0_{t21\text{-}30}MR_{k1\text{-}15} = 1$

Explanation: L0t1-10Sk1-15 and L0t1-10MRk1-15: Refers to the service assignment for the tugboat Samara (S) and MR702 (MR) at the service location within a specific time period. L0t11-20Sk1-15 and L0t11-20MRk1-15: Referring to assignments for the period of the 11th to 20th month. L0t21-30Sk1-15 and L0t21-30MRk1-15: Referring to the assignment for the period of month 21-30.

The First Constraint indicates that during the period from January to October, exactly one service must be assigned between the tugboat Samara and MR702. This means that services for each location can only be performed by one tugboat, either Samara or MR702, to ensure there is no duplication of assignments. This second constraint ensures that during the period of the 11th to the 20th of the month, one service must be assigned to one of the tugboats. (Samara atau MR702). (Samara atau MR702). In other words, only one tugboat will perform the task at the given location. This third constraint states that during the period from the 21st to the 30th of the month, service assignment for one location must be carried out by one of the tugboats (Samara or MR702), ensuring that only one tugboat is on duty at any given time. According to the assignment model, the decision variable in this case is Xij, which represents the monthly service to t (t: 1, 2,... and 30) to ships at the jetty and ships in the S channel (S: S1....S15; Channel MR1...MR15), thus there are 30×30 = 900 decision variables.

Results and Discussion

The observation period of 30 months, from March 2021 to October 2024, shows a pattern of decreasing service costs along with an increase in service movement frequency. From the processed results, the optimal solution for each monthly period is found as follows: months 1-10 include a minimum of 9 and a maximum of 23 service activities, months 11-20 include 26 to 36 activities, and months 21-30 include 33 to 43 activities. The results of this research provide an overview of the effectiveness and efficiency of tugboat services operations based on historical data, which are expected to serve as a basis for strategic decision-making in the future for PT Karya Royal Perkasa.

Figure 3 above shows the relationship between the movement activity of the Samara tugboat service and the fixed service costs. From the graph, it can be seen that there is generally a trend of increasing fixed costs along with the increase in the number of movement activities. When movement activity increases, fixed costs also show an increase, but this trend is not entirely linear; there are some fluctuations. Nevertheless, with the increase in activity, the average fixed cost per activity tends to decrease, which supports efficiency in the operation of tugboat services.

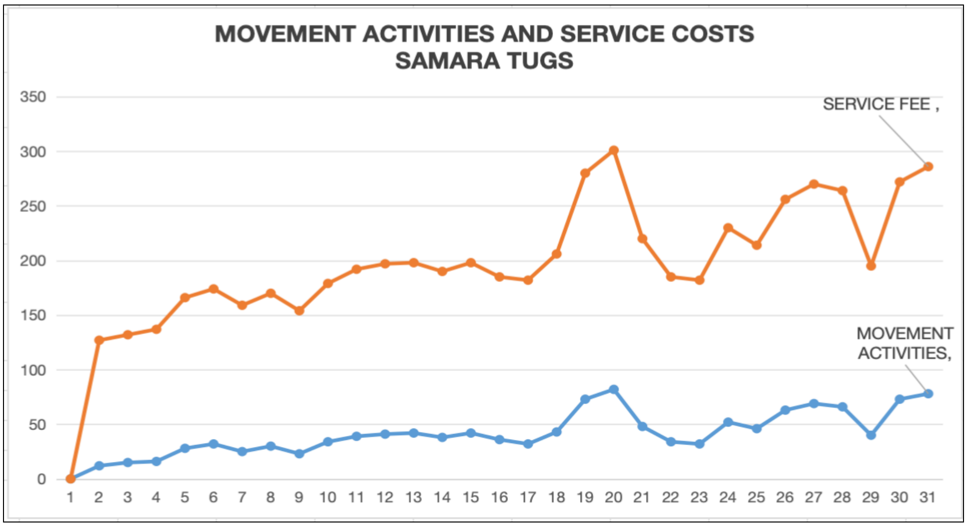


Fig 3: Tugboat Samara Movement Activity and Sevice Costs

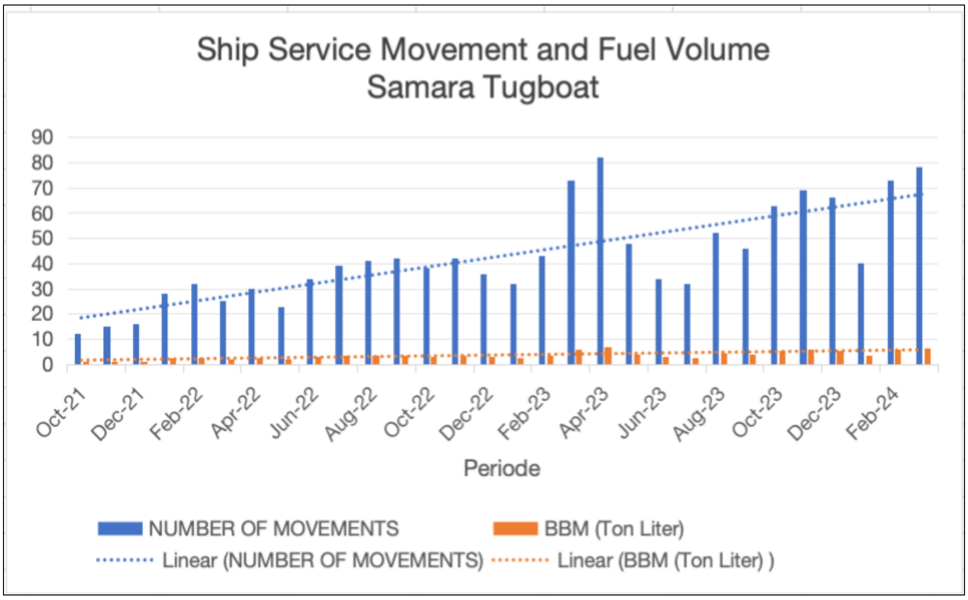


Fig 4: Tugboat Samara Movement Activity and Service Cost
Source: Tugboat Samara Observation Data

Figure 5.3 shows the "Movement of Tugboat Services and Fuel Volume of Tugboat Samara" from the period of October 2021 to February 2024. Here are some points that can be drawn from the graph: (1) The Number of Ship Movements (represented by the blue bars) has experienced a significant increase over time. This amount shows a consistent upward trend with the linear trend line indicated by the blue dashed line; (2) The volume of fuel (Ton Liters) used by the tugboats, represented by the orange bars, is relatively stable and much lower compared to the number of ship movements.

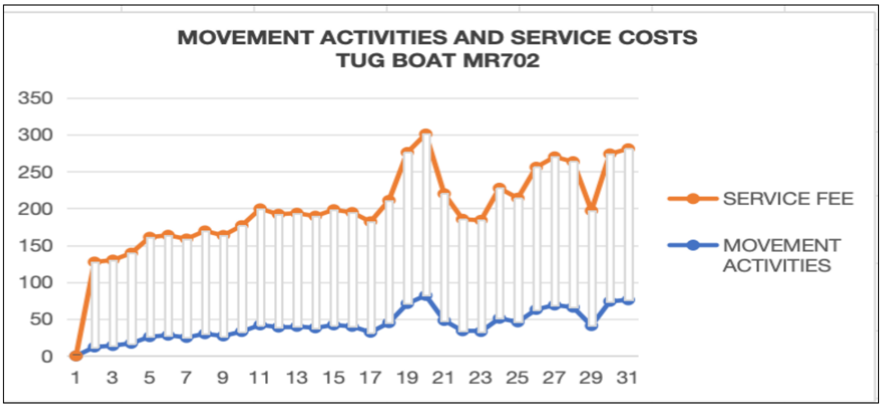


Fig 5: Movement Activity and Fixed Costs of MR702 Tugboat Service
Source: Tugboat MR702 Observation Data

From the calculation of the cost per activity of the tugboat MR702's movements, it is evident that as the movement activity increases, the cost per service unit tends to decrease, indicating that (1) at 12 movement activities, the cost per unit is Rp 9.62 million, (2) at 71 movement activities, the cost per unit decreases to Rp 2.89 million. And (3) at activity 82 movements, the cost per unit decreased further to Rp 2.67 million. The decrease in cost per unit indicates operational efficiency when movement activities increase.

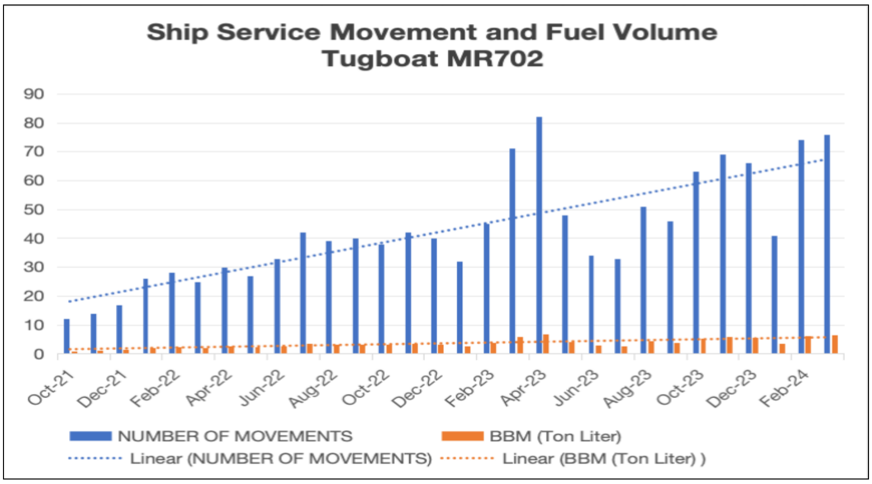


Fig 6: Movement Activity and Service Cost of the Samara Tugboat
Source: Tugboat Samara Observation Data

Trend in Ship Movement Numbers, The number of movements of the MR702 ship has consistently increased from October 2021 to March 2024. At the beginning of the period, the number of movements ranged from 12 to 17 movements per month. However, after January 2023, the number of movements skyrocketed, especially in March 2023 with 71 movements and April 2023 with 82 movements. The peak activity occurred in the months with the highest ship movements, which were April 2023 (82 movements) and March 2024 (76 movements), indicating a significant increase in activity for these tugboats in the second quarter and early year.

From the data on movement activity and fixed costs of the MR702 tugboat service at PT Karya Royal Perkasa, it appears that the increase in movement activity generally affects the increase in fixed costs. However, as the movement activity increases, the fixed cost per unit of service can be minimized. This is because fixed costs can be distributed more evenly over a higher volume of movements, resulting in operational cost efficiency.

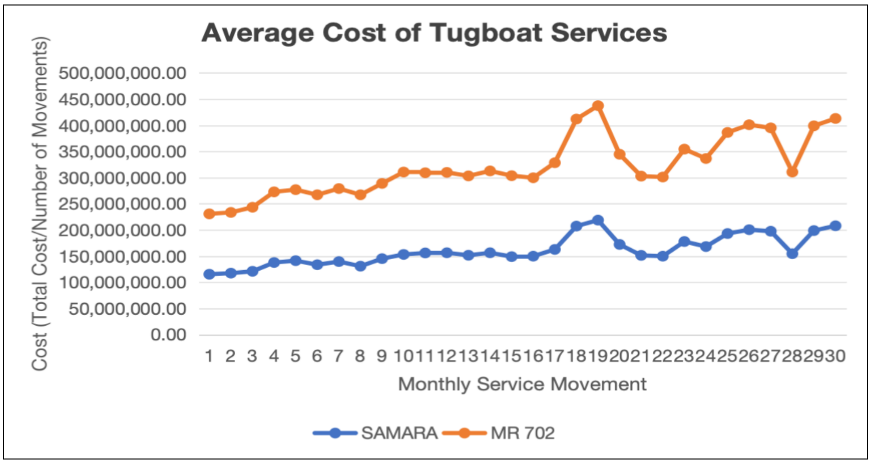


Fig 7: Cost of Tugboat Services Samara and MR702
Sumber; Data Biaya Layanan Kapal PT Karya Royal Perkasa

Figure 5.6 displays the average tugboat service costs in rupiah for two types of vessels, namely MR 702 (red line) and SAMARA (blue line). It can be seen that the average service cost for the MR 702 vessel tends to be higher compared to the SAMARA. There is a significant fluctuation around the 19th monthly service, where the cost sharply rises to nearly 450 million rupiah before eventually dropping and stabilizing again. And overall, the average cost ranges from 300 million to 450 million rupiah. In the graph, it is also seen that the SAMARA ship has a more stable average service cost, with a lower cost range compared to MR 702, although there are some fluctuations, peaking around the 17th monthly service, reaching a cost of around 200 million rupiah, and after that, the cost tends to decrease and fluctuate around 150 million to 200 million rupiah. From this graph, it can be concluded that MR 702 has a higher average service cost with greater variability, while SAMARA tends to be more stable and has a lower cost. This may be related to capacity, efficiency, or other differences in the operations of the two ships.

In Figure 5.7, it can be seen that the trend in the number of movements and movement hours: There is a general upward trend in the number of movements and movement hours during that period. A significant increase in activity can be observed in months such as March 2023, April 2023, and August 2023, indicating a surge in demand or operational needs. Monthly service costs have shown a steady increase, particularly noticeable since the beginning of 2023, with spikes in March 2023 and April 2023. (masing-masing 207 dan 219 juta Rp). There were also cost reductions in several months, such as June 2023 (151 million Rp), indicating possible operational adjustments. Correlation Analysis: Data shows a correlation where a higher number of movements and increased hours generally lead to higher monthly costs. This pattern shows that managing movement and optimizing service hours can be key to controlling costs. Latest Trends (2024): At the beginning of 2024, the number of movements and hours remained high, with costs reaching 199-208 million IDR in February and March, indicating continued high demand for services. This data can be used for further analysis to optimize operations, reduce costs, or adjust service offerings based on demand patterns.

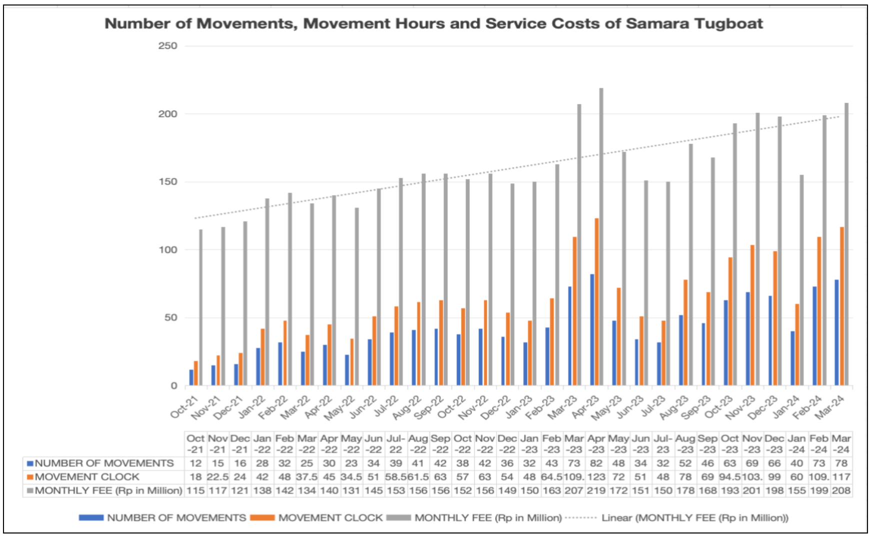


Fig 8: Number of Movements, Duration, and Cost of Samara Tugboat Services
Source: Data on Ship Service Costs from PT Karya Royal Perkasa

The Hungarian method allows flexibility in the assignment of tugboats according to demand fluctuations, ensuring that the most suitable vessel for a particular task can be assigned immediately without delay (Bamdad *et al*., 2023) [3]. Carmen *et al*., (2020) [4]. The Hungarian algorithm in this context does consider maximum and minimum performance, which relates to efficiency in task or resource assignment. In their study, this algorithm was designed to maximize task efficiency based on the understanding that the reduction coefficient, which is a representation of a large reduction or saving, replaces the distance or constraint between users in a system.

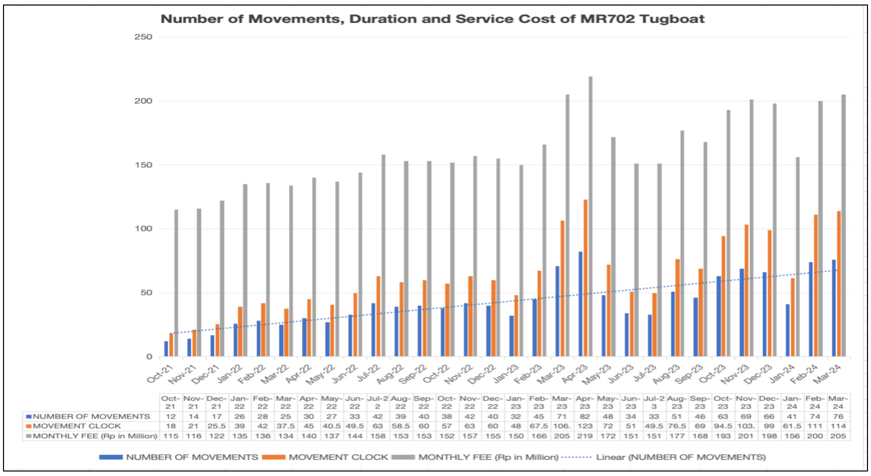


Fig 9: Number of Movements, Duration, and Cost of Tugboat Service MR702
Source: Data on Ship Service Costs PT Karya Royal Perkasa

Figure 5.8 data analysis shows monthly movements, operating hours, and monthly costs for the period from October 2021 to March 2024, indicating a general increasing trend in the number of movements, starting from 12 in October 2021 and reaching 76 in March 2024. The data shows fluctuations, with some months experiencing declines followed by rapid increases in the following months. Monthly expenses generally increase along with the increase in the number of movements. When the movement increased from 12 in October 2021 to 76 in March 2024, the monthly cost also rose from Rp 115 million to Rp 205 million.

As the number of movements increases, there is a corresponding increase in operating hours. This shows a direct relationship between the number of activities performed and the time used, which is consistent with expectations in service operations. Operational hours are closely correlated with the number of movements, where months with high activity such as April 2023 (82 movements) have high operational hours. (123 jam). (123 jam).

Cost per movement can provide insights into operational efficiency. In October 2021, the cost per movement was around Rp 9.58 million; whereas in March 2024, the cost was around Rp 2.7 million. This shows an improvement in cost efficiency over time. Similarly, the cost per hour also decreased, indicating more efficient operational time usage along with the increase in the number of movements.

This data can be used for further analysis to optimize operations, reduce costs, or adjust service offerings based on the MR702 tugboat service pattern. Silvia & Simona (2022) [18] to achieve better efficiency. Rini & Empya (2019) [15]. However, increasing high hours may also indicate that service demand continues to increase, so higher costs are the result of an increase in the number of tugboat service movements. In addition, reducing service hours or optimizing movements may risk reducing service quality and coal barge user satisfaction.

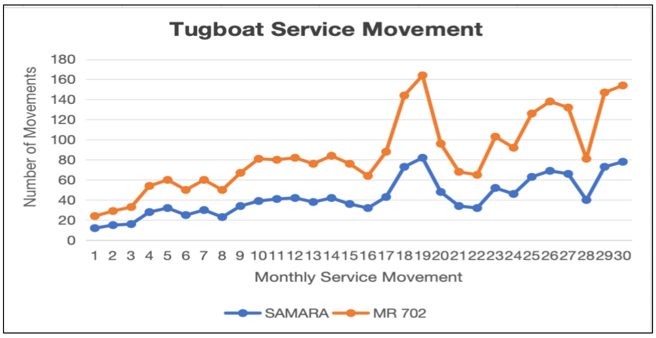


Fig 10: Movement of Samara Tugboat Service and MR702
Source: Data on Ship Service Movements PT Karya Royal Perkasa

Figure 5.9 shows the monthly tugboat service movement counts for two vessels, SAMARA (blue line) and MR 702. (garis oranye). (garis oranye). Here is the analysis of the graph, it can be seen that on the MR 702 Ship, the number of monthly movements is higher compared to SAMARA in almost all periods, there is a very significant peak in movements around the 19th month, reaching more than 150 movements, and after this peak, the number of movements fluctuates within a range of 100 to 150 movements in the subsequent periods. And on that graph, it is also seen that on the SAMARA Ship, the number of movements tends to be more stable and remains below MR 702 throughout the period.

During the period from the 1st to the 15th of the month, the movement ranged between 25 to 75 movements. And there was a significant increase starting from the 17th month, reaching more than 75 movements, before fluctuating around the 50 to 75 movements range in the following period. From this graph, it can be seen that MR 702 has more service movements compared to SAMARA, especially around the 19th month where there was a sharp increase. SAMARA has a more stable and consistent number of movements, but still experiences an increase in some months.

The Hungarian method allows for the identification of optimal assignments that reduce total costs and operational time. For example, the best-performing tugboat for a specific task is assigned to a jetty that requires a higher level of service, thereby reducing operational service time and fuel costs.

The use of the Hungarian method has shown significant results in optimizing the operational performance of tugboat services. This method allows for more efficient assignment allocation, thereby significantly reducing service costs and improving the frequency and quality of vessel movement activities. By adjusting ship assignments based on specific needs, the Hungarian method successfully reduced the cost per service unit and improved the overall performance of the Samara and MR702 tugboat services. The results of this optimization support more efficient operations and responsiveness to service demand.

Table of analysis before and after the use of the Hungarian assignment method on the movement activities and service costs of the Samara and MR702 tugboats.

Tabe l: **Before and after analysis of Hungarian assignment method on movement activity and tugboat service cost Samara and MR702**

Aspect	Before the Use of the Hungarian Method	After Using the Hungarian Method
1. Monthly Movement Activity	25-75 per month, significant increase starting from the 17th month, stable at 50-75 in Samara and 12-76 per month, significant increase in the 19th month (>150 movements)	Lower and fluctuating activity: 9-23 (months 1-10), 26-36 (months 11-20), and 33-43 (bulan 21-30). (bulan 21-30). Activity increased and became more stable according to the optimal period.
2. Biaya per Unit Layanan	Increasing with more movement, not always linear. The cost per unit is higher with an average fixed cost of Rp9.62 million per 12 activities.	Distributed more evenly, decreasing per service unit. The cost per unit decreased to Rp2.67 million per 82 activities.
3. Efficiency of Ship Usage	Low, fixed costs remain high due to uneven burden distribution. The idle time rate is high, and the ships are often not used optimally.	Increased, the allocation of fixed costs becomes more efficient with increased activity. Reduction of idle time by increasing movement frequency.
4. Number of Ship Movements	The number of movements is lower and uneven; the MR702 ship is more active than the Samara.	The increase in the number of movements is consistently more controlled with fluctuations.
5. Monthly Service Fee	Costs tend to be higher and fluctuate, ranging from Rp115-450 million.	Monthly costs are more controlled with a decrease in the average cost per movement.
6. Correlation of Costs and Movement Activities	There is no strong correlation between increased activity and cost efficiency.	Efficiency increases along with the decrease in cost per unit when movement activity rises.

7. Ship Assignment Performance	Performance is less than optimal, with longer distances and waiting times.	Assignments are more efficient and strategic, minimizing wait times and travel distances.
8. Time Management and Operating Hours	Operational hours are lower and more fluctuating, related to service demand.	Operational hours are higher with increased movement activity.
9. Optimization of Flow and Route	Less optimal, potential traffic jams, and longer travel times.	More efficient route, reduced risk of traffic jams

Conclusion
During the 30 months of observation, there was a variation in the minimum and maximum number of service activities achieved per 10-month period. In the period from the 1st to the 10th month, there were 9-23 service activities; in the period from the 11th to the 20th month, there were 26-36 activities; and in the period from the 21st to the 30th month, 33-43 service activities were recorded. This indicates an increase and optimal adjustment of service levels according to needs in each period, which supports better management of tugboat service movements. During the 30-month observation, there was a variation in the minimum and maximum number of service activities achieved per 10-month period. In the period from the 1st to the 10th month, there were 9-23 service activities; in the period from the 11th to the 20th month, there were 26-36 activities; and in the period from the 21st to the 30th month, 33-43 service activities were recorded. This indicates an increase and optimal adjustment of the number of services according to needs in each period, which supports better resource management.

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