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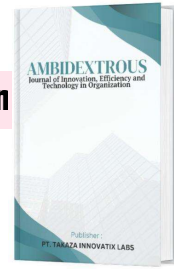
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## Load Factor and Stability Analysis of PT Dharma Lautan Utama's Ro-Ro Ship at Tanjung Perak Port, Surabaya

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**Abstract:** Maritime transportation, particularly Roll-on/Roll-off (Ro-Ro) vessels, plays an important role in supporting passenger and vehicle mobility in Indonesia. Ship stability and load factor are critical aspects influencing operational safety. This study aimed to analyze the relationship between load factor and the stability of PT. Dharma Lautan Utama's Ro-Ro vessels operating at Tanjung Perak Port, Surabaya. The study employed a descriptive quantitative design. The population consisted of operational activities of Ro-Ro vessels at PT. Dharma Lautan Utama Surabaya Branch, while the sample included operational and loading data collected from March to June 2025. Data were obtained through observation, interviews, documentation, and literature review. The research instruments included ship operational reports and stability calculation documents. Data analysis was conducted using load factor calculations and ship stability parameters, including KG, GM, GZ, and rolling period analysis. The results showed that the highest load factor in April reached 33% and was followed by the highest GM stability proportion of 31%, while the lowest load factor in March was 16% with a GM proportion of 23%. The study concludes that a higher load factor can support ship stability when cargo distribution is arranged proportionally and evenly..

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## Introduction

Maritime transportation plays a vital role in supporting inter-regional connectivity in Indonesia, an archipelagic nation. One widely used mode of maritime transportation is the Roll-on/Roll-off (Ro-Ro) ship, designed to transport vehicles and goods with an efficient loading and unloading system. The advantage of Ro-Ro ships lies in their ability to shorten loading and unloading times compared to conventional ships, making them the preferred choice. (Mosyofa & Muammar, 2024); (Rahman et al., 2025). PT. Dharma Lautan Utama is a shipping company that operates a fleet of Ro-Ro vessels in Indonesia. One of the company's main operational ports is Tanjung Perak Port in Surabaya, the second busiest in Indonesia after Tanjung Priok. High loading and unloading activity, safety, and operational efficiency are top priorities for Ro-Ro vessels operating at this port.

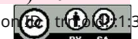
One of the important technical factors that must be considered in Ro-Ro ship operations is ship stability. Ship stability is influenced by various variables, one of which is the load factor, which is the ratio of the actual cargo to the ship's maximum cargo capacity. An optimal load factor can maintain ship stability both at rest and while sailing, while an unbalanced load factor can disrupt the ship's hydrodynamic performance and increase the risk of accidents (Yazid et al., 2023); (Massie et al., 2021). A load factor that is too high can cause the ship to become overweight and have an unstable center of gravity, making it susceptible to tilting or even capsizing if hit by waves or in extreme weather conditions. On the other hand, a load factor that is too low, although safer in terms of stability, can cause operational inefficiencies and reduce the profitability of shipping companies. Therefore, a balance is needed between optimal carrying capacity and shipping safety aspects.

Load distribution issues are also a crucial part of load factor analysis. Ro-Ro ships often carry vehicles and goods, which have uneven load distribution. This imbalance in load distribution can affect the ship's trim and heel, ultimately impacting the overall stability of the vessel. This requires special attention in cargo arrangement to ensure the load factor is not only maximally loaded but also safely distributed.

Analyzing the relationship between load factor and ship stability is crucial for ensuring safe navigation. The results of this analysis can also inform operational decisions such as load planning, stability margin calculations, and route planning. This is particularly relevant for PT Dharma Lautan Utama, which operates a busy ship departure schedule and operates long shipping routes.

Tanjung Perak Port, as a hub for shipping activity, also has unique geographic conditions and ocean currents, which influence ship performance when maneuvering in and out of the port. The role of load factor in ship stability is increasingly significant, as even small errors in cargo calculation or arrangement can have fatal consequences. An in-depth study of the effect of load factor on the stability of Ro-Ro vessels is essential to support safety and operational efficiency (Hanum & Susanti, 2024).

This research focuses on analyzing the effect of load factor on the stability of Ro-Ro vessels owned by PT. Darma Lautan Utama at the Port of Tanjung Perak, Surabaya. This



*Title (Muhammad Akbar Maulana, Sunu Arsy Pratomo, Zihni Ihkamuddin, Capt. Sutini),* Page 3 research is expected to provide scientific and practical contributions to improving the shipping safety standards of Ro-Ro vessels and serve as a reference for shipping operators in managing cargo effectively and safely.

## Research Methods

This study uses a descriptive quantitative research type that aims to analyze the relationship between Load Factor and the stability of Ro-Ro vessels. The quantitative approach was chosen because the data used are in the form of numbers, technical calculations, and ship stability parameters such as KG, GM, GZ, and the ship's rolling period. The study was conducted at PT. Dharma Lautan Utama Surabaya Branch located at Jalan Perak Timur No. 512 Block B 7–8, Pabean Cantikan District, Surabaya, East Java. The research location was chosen purposively because the company is one of the private shipping companies that has Ro-Ro ship operational activities relevant to the research focus. The research period lasted for four months, namely from September 2024 to December 2024. In its implementation, the research was carried out through several stages, namely the preparation stage in the form of permit processing and preparation of research instruments, the implementation stage in the form of field observation and data collection, and the preparation stage in the form of data analysis and writing of research reports.

The data sources in this study consist of primary and secondary data. Primary data were obtained directly through field observations and interviews with operational officers involved in loading and unloading activities of Ro-Ro vessels. Observations were conducted to determine the actual conditions of the loading and unloading process and to obtain information regarding load distribution and ship stability. Meanwhile, secondary data were obtained from company documents, vehicle load data reports, ship-specific data, manuals, journals, and literature related to Load Factor and Ro-Ro vessel stability. Data collection methods were carried out through observation, interviews, documentation, and literature studies. Data analysis techniques were carried out quantitatively using Load Factor, KG, GM, GZ, and the ship's rolling period calculations. The data obtained were then processed, compared, and analyzed to determine the relationship between the ship's load level and the stability conditions of the Ro-Ro vessel so that conclusions can be drawn in accordance with the research objectives.

## Results and Discussion

### Analysis of the Relationship Between Load Factor and Stability of Ro-Ro Ships on the Operational Safety of Ships at Tanjung Perak Port

Analysis of the relationship between Load Factor (LF) and the stability of Ro-Ro vessels shows that increasing the number of passengers and vehicles directly affects the vessel's stability. When the Load Factor is high, load distribution must be managed appropriately to prevent the ship's center of gravity from shifting to a position that could potentially cause it to roll. If the load distribution is unbalanced, the ship's stability can decrease even though the carrying capacity is still within reasonable limits. Conversely, when the Load Factor is low, the ship tends to be more stable, but operational efficiency decreases because the load capacity is

not optimally utilized. This means that load management is a crucial factor in maintaining a balance between efficiency and safety.

At Tanjung Perak Port, one of the busiest ports in Indonesia, the relationship between load factor (LF) and the stability of Ro-Ro vessels plays a crucial role in ensuring smooth loading and unloading and safe navigation. Ships with high load factors require greater attention to cargo management to prevent the risk of rocking, sinking, or even accidents during navigation. By maintaining stability through evenly distributed cargo management, ship operational safety can be assured even when facing surges in passenger and vehicle traffic, especially during peak periods such as holidays. Therefore, the balance between load factor and stability is key to supporting the safe and efficient operation of Ro-Ro vessels at Tanjung Perak Port.

**Proportional Results Per 4 months**

**Table 1. Proportion Load Factor**

Month	LF	Proportion (%)
March	10	16%
April	20	33%
May	15	25%
June	15	25%

Source: Processed Primary Data, 2025

Note:

- Calculation of Total LF Value

$$\text{Total LF} = 10 + 20 + 15 + 15 = 60$$

- Proposition Formula

$$\text{Proportion} = \frac{\text{LF Per bulan}}{\text{Total LF}} \times 100\%$$

A. March:  $100\% = 16.66\% = 16\% \frac{10}{60} \times$

B. April:  $100\% = 33.43\% = 33\% \frac{20}{60} \times$

C. May:  $100\% = 25\% = 25\% \frac{15}{60} \times$

D. June:  $100\% = 25\% = 25\% \frac{15}{60} \times$

**Proportional Results Per 4 months**

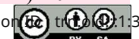
**Table 2. GM Stability Proposition**

Month	GM	Proportion (%)
March	36.15	23%
April	48.59	31%
May	38.3	25%
June	33.47	21%

Source: Processed Primary Data, 2025

Note:

- Total GM Value Calculation



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$$\text{Total GM} = 36.15 + 4.59 + 38.30 + 33.47 = 156.51$$

• Proposition Formula

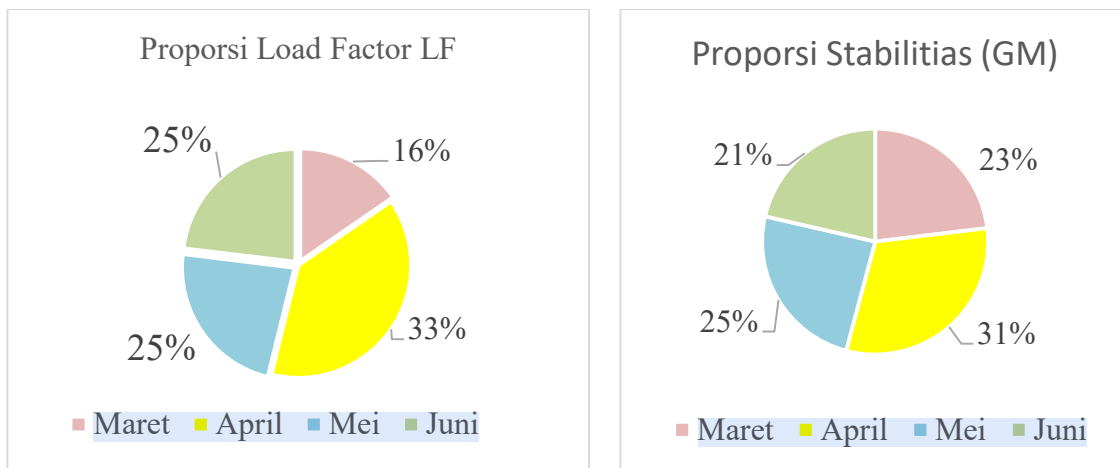
$$\text{GM Proportion} = \frac{\text{GM Per bulan}}{\text{Total GM}} \times 100\%$$

A. March:  $100\% = 23.1\% \times \frac{36,15}{156,51}$

B. April:  $100\% = 31.0\% \times \frac{48,59}{156,51}$

C. May:  $100\% = 24.5\% \times \frac{38,30}{156,51}$

D. June:  $100\% = 21.4\% \times \frac{33,47}{156,51}$



**Figure 1. Load Factor and Stability Relationship Graph**

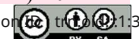
Source: Processed Primary Data, 2025

Based on Graph 1, in April, the Load Factor reached its highest value of 39%, followed by the highest stability of 31%. This condition indicates that when Ro-Ro vessels carry large loads with balanced arrangements, the vessel's stability also increases, resulting in safer operations. Conversely, in March with the lowest Load Factor of 15%, the GM value was only 23%, indicating that the low level of cargo space utilization has an impact on reduced vessel stability.

May and June have the same load factor, namely 23%, but the stability values are different, namely 25% in May and 21% in June. This difference indicates that the load distribution become important factors affecting ship stability. Thus, the relationship between Load Factor and GM is determined not only by the amount of cargo carried, but also by how the cargo is distributed within the ship to ensure operational safety.

**Conclusion and Recommendation**

The relationship between Load Factor and ship stability on operational safety indicates a link between the level of cargo utilization and the stability of Ro-Ro vessels at Tanjung Perak Port. During periods when the Load Factor value is at its highest, ship stability also shows the best condition. This shows that increasing the utilization of a ship's cargo space does not always lead to a decrease in stability, but can still maintain the ship's balance if the load distribution is carried out appropriately and evenly. Conversely, when the Load Factor value is at a lower



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condition, ship stability also tends to decrease. Based on these results, it can be concluded that there is a positive relationship between Load Factor and the stability of Ro-Ro vessels. A high level of cargo space utilization can still support ship operational safety as long as the passenger and vehicle loads are arranged in a balanced manner. Therefore, the arrangement of load patterns plays a crucial role in maintaining the balance between Load Factor and ship stability so that shipping safety at Tanjung Perak Port remains guaranteed.

Based on the research results, it is recommended that the ship operator PT. Dharma Lautan Utama manage the distribution of vehicle loads optimally so that the Load Factor remains balanced with the stability of the ship. The captain and crew also need to pay attention to GM calculations and the stability booklet before departure to minimize the risk of stability disturbances. In addition, shipping companies are expected to improve supervision and training related to cargo management and ship stability, as well as utilize technology-based monitoring systems for more accurate operational decisions. Further research is recommended to consider weather factors, wave conditions, and variations in shipping routes for a more comprehensive study of the relationship between Load Factor and ship stability.

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