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Prospect of Rolling Highway System Implementation on Makassar–Parepare Freight Transportation Route Based on Operator Perception

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Abstract Goods transportation on the Trans Sulawesi road is dominated by truck transportation which causes problems including high operational costs, road damage due to over-dimension overload (ODOL) vehicles, and increased carbon emissions. Therefore, more efficient and sustainable alternative transportation modes are needed, one of which is the Rolling Highway (ROLA) system. This study aims to analyze the potential for ROLA implementation based on truck operators' perceptions of operational costs, travel time, flexibility, security and safety, policy support, ease of loading and unloading, and environmental impacts. The study used perception analysis and multiple linear regression, from truck operators on the Makassar-Parepare route. The results showed that a 20% reduction in operating costs and up to 120 minutes of travel time could increase operators' willingness to shift to the ROLA system. However, flexibility and ease of loading and unloading are still major constraints that need to be addressed. In addition, the implementation of ROLA has the potential to reduce road damage, lower carbon emissions, and improve the efficiency of logistics distribution. To implement this policy, the government needs to develop economic incentives (operational subsidies) and accelerate investment in ROLA -supporting infrastructure.

Keywords Rolling Highway, Road Damage, Freight Transportation

1. Introduction

Rail freight transport is increasingly in demand globally compared to trucking, mainly due to its advantages in terms of sustainability, efficiency, and cost-effectiveness. Rail transportation has lower external cost margins, especially over long distances, which makes it a greener option than road transportation [1]. Countries such as China, France, and Turkey have made extensive use of rail-based freight transport, with the benefits of reduced emissions and energy consumption [2]. The integration of rail in multimodal transportation systems also improves operational efficiency and helps reduce congestion and environmental impacts [3]. Upgrading the rail system enables more efficient transport of goods, strengthening the competitiveness of rail transportation [4]. With government support in the form of investment in rail infrastructure and technology, the prospects for using rail transit are strong [5].

In Indonesia, rail freight transportation faces challenges and opportunities that are influenced by geography and infrastructure. Geographical factors and road congestion contribute to the high operational costs of road transportation, which can be addressed by the development of rail infrastructure [6]. Rail has great potential to reduce emissions and improve air quality, especially in urban areas that are often exposed to pollution from diesel-fueled trucks [7]. The integration of rail in multimodal transportation systems allows for more efficient intermodal transfer of goods, reducing handling time and costs [8]. However, developing a competitive freight rail network requires substantial infrastructure investment, as such limitations hamper the competitiveness of rail over road transport [9].

The potential for freight transportation in Indonesia is huge, as economic growth and logistics needs continue to increase. However, the dominance of trucks in freight transportation poses some major problems. Over-dimension and overload (ODOL) vehicles, which are often used by truck operators, cause road damage and result in high maintenance costs for road infrastructure [10]. ODOL trucks accelerate road deterioration, resulting in shorter road life and increased repair frequency [11]. In addition, congestion is becoming an increasingly pressing issue, especially in areas around major ports such as Tanjung Priok, where truck traffic often exceeds road capacity [12], [13]. Apart from slowing down travel time, congestion also increases emissions as trucks stuck in traffic produce excess pollution [14]. Likewise, the risk of accidents increases due to the operational characteristics of trucks that worsen visibility and smooth traffic flow [15].

The distribution of goods in South Sulawesi, especially agricultural commodities and manufactured products, is dominated by trucks that serve the movement of goods from production areas to urban centers, including Makassar City and Parepare City. The use of trucks causes a heavy burden on national and provincial roads, especially on the routes connecting Makassar to other cities. The negative impacts in addition to rapidly deteriorating road infrastructure, are increased air pollution and a high risk of traffic accidents due to the high volume of heavy vehicles.

The development of rail mode as an alternative to freight transportation in South Sulawesi, especially on the Makassar-Parepare route, is expected to be a solution to reduce the burden of truck vehicles on the highway while reducing negative impacts on the environment. The potential utilization of rail mode will support the efficiency of goods distribution that is safer, faster, and more sustainable, in line with the needs of regional logistics growth.

The ROLA system, or truck transportation by rail, offers an efficient solution to reduce the burden of goods distribution. The system allows trucks to be transported on trains to cover long distances, which not only reduces emissions but also reduces road damage. In South Sulawesi, the ROLA system has great potential to be implemented on the Makassar-Parepare line, which has a high load level. By accommodating trucks through the ROLA system, it is expected to be a competitive alternative to conventional trucking.

This study aims to analyze the possibility of switching from truck to rail mode with the implementation of the ROLA system for freight transport on the Makassar-Parepare route. The research focuses on the perspectives of truck operators as they are the subjects that determine the success of the ROLA system implementation through their decision to shift from road mode. Their understanding of cost efficiency, travel time, flexibility, and operational needs provides practical input for policy design.

The urgency of this research lies in the pressing need for a more environmentally friendly and sustainable transportation alternative, capable of reducing dependence on road transport and overcoming logistics distribution challenges in South Sulawesi. This research is also expected to have the novelty value in analyzing the potential and readiness of infrastructure and the perspective of industry players to adopt the ROLA system, so that the results can be a strategic guide for the government and business actors in improving the efficiency of goods distribution.

2. Literature Review

2.1. Rail-Based Modal Switching Policy in Indonesia

The ODOL vehicle enforcement policy aims to limit the number of overcapacity trucks on the road. The presence of overloaded trucks contributes significantly to road damage and increases transportation costs, making rail transportation a more attractive alternative for goods movement. The government recognizes that reducing the prevalence of ODOL vehicles can facilitate the shift to rail transport, as it encourages logistics companies to consider rail transport options for heavier loads [16], [17].

In addition to regulatory measures, the Indonesian government has also introduced various incentives to encourage environmentally friendly modes of transportation. Financial incentives, such as tax reductions or subsidies for companies utilizing rail transport, can encourage logistics providers to shift their operations from road to rail [18]. These incentives are becoming increasingly important in the context of Indonesia's commitment to reduce carbon emissions and promote sustainable development, as they are in line with the Sustainable Development Goals [19]. In addition, the government has been working to improve access to funding for green transportation projects, which can facilitate investment in rail infrastructure and rolling stock that meets environmental standards [19].

Railway infrastructure development is the Indonesian government's strategy to encourage modal shifts. Significant investments are being made to expand and modernize the rail network, especially in Java, Sumatra, and Sulawesi, where road congestion is a pressing issue [20]. By improving the capacity and reliability of rail services, the government is making rail transportation a more viable option for freight and passenger services. This includes building new rail lines, upgrading existing lines, and improving intermodal facilities that enable the transition between road and rail transportation [21].

The integration of advanced technologies in rail operations, such as automated loading systems and real-time tracking, can further enhance the attractiveness of rail transportation. These technologies not only improve operational efficiency but also enable logistics companies to monitor and manage their shipments more effectively, which in turn can increase customer confidence [22]. By leveraging these technological advancements, rail transportation can better compete with other modes of transportation, especially in terms of speed and reliability.

The implementation of Rolling Highway System (ROLA) can be considered as one of the strategic solutions in the context of the Indonesian government's policy to address the transportation issues at hand. With ROLA, heavy vehicles such as trucks can be transported efficiently through the rail network, reducing the burden on road infrastructure and minimizing the damage caused by ODOL vehicles. This system is not only in line with the government's efforts to enforce ODOL regulations, but also strengthens incentives to shift to more environmentally friendly modes of transportation. The implementation of ROLA can help reduce the number of trucks on the road, which will reduce congestion and extend the life of roads. In addition, by moving freight from road to rail, ROLA can improve operational efficiency in logistics, and reduce transportation costs. As such, the implementation of ROLA is not only a response to government policy, but also an integral part of a long-term strategy to create a more sustainable and efficient transportation system in Indonesia.

2.2. Concept and Characteristics of Rolling Highway (ROLA)

The ROLA concept offers an innovative approach to intermodal transportation, designed specifically to facilitate the movement of vehicles over rail networks. The design of the trains in the ROLA system is crucial to accommodate a wide range of vehicles, including trucks and trailers. ROLA trains are equipped with special platforms that secure vehicles during travel, highlighting the importance of design in maintaining stability and safety during transit. The design must take into account factors such as weight distribution and aerodynamic efficiency [23]. In addition, the required infrastructure includes specialized rail tracks capable of withstanding the weight and dimensions of the train, as well as loading and unloading facilities that allow for quick transitions between road and rail modes [24].

The loading and unloading mechanism is a crucial aspect of the ROLA system that also plays an important role in the overall efficiency of the logistics distribution system. This process often involves specialized ramps or cranes to move vehicles from road to rail efficiently. Delays in loading and unloading can increase costs and reduce service reliability [25]. Therefore, the integration of automation systems in this process can further improve speed and safety, making ROLA more competitive than traditional transportation methods [26]. This shows that operational efficiency depends not only on the design and infrastructure but also on the mechanisms that support it.

While ROLA offers many advantages, the concept also faces significant challenges, particularly regarding costs. The initial investment required for infrastructure and specialized rolling stock is often a major constraint, especially in regions with limited transportation infrastructure [27]. Given these cost challenges, stakeholders must assess the efficiency of ROLA systems on an ongoing basis to ensure compatibility with modern logistics demands, especially in the context of fluctuating fuel prices and environmental regulations [28].

From an economic perspective, ROLA offers several advantages over traditional modes of transportation, further emphasizing its added value. By utilizing rail for long-distance transportation, ROLA can reduce fuel consumption and lower transportation costs per ton-mile, making it an attractive option for freight operators [24]. In addition, transporting multiple vehicles simultaneously can generate economies of scale, further improving cost-effectiveness [23]. In other words, these economic advantages strengthen the argument for the adoption of ROLA as a more efficient alternative.

Moreover, from an environmental point of view, ROLA has significant potential to reduce greenhouse gas emissions when compared to road transportation. By shifting freight transport from trucks to trains, ROLA contributes to the reduction of overall emissions in the logistics sector, thanks to the more energy-efficient nature of rail transportation [28]. This not only contributes to achieving global sustainability goals but can also improve public perception of a more environmentally friendly freight transportation system [24]. Thus, ROLA addresses not only logistical challenges but also increasingly pressing environmental issues.

ROLA systems can improve the flexibility and reliability of freight transportation, which are important aspects of modern logistics. By integrating road and rail networks, ROLA provides more options for shippers, enabling route optimization and travel time reduction [26]. The ability to bypass congested roadways by using rail can also improve service levels and customer satisfaction [25].

2.3. Criteria and Stakeholder Perspectives on ROLA Implementation

Technical feasibility is a crucial element in the implementation of ROLA systems. This includes designing rail cars that can accommodate different types of vehicles, as well as the supporting infrastructure needed to facilitate efficient loading and unloading processes. The application of advanced technology in ROLA operations is a key component to ensure the efficiency and smoothness of the transportation process [22]. It is necessary to develop special loading mechanisms and adjust the existing rail network to support ROLA operations, especially to ensure that the system is compatible with the existing railway infrastructure, especially on the Makassar – Parepare route. In addition, security is a priority, so efforts need to be made to ensure that every aspect of ROLA's operations can minimize potential risks that may occur in the process of goods distribution [21].

In addition to technical aspects, economic feasibility is also an important factor to consider in determining the potential success of ROLA implementation. Cost-effectiveness analysis is the main basis for comparing the efficiency of ROLA with conventional road transportation. Factors such as operational costs, infrastructure investment, and potential savings from reduced road maintenance costs due to reduced truck traffic volumes are economic aspects that need to be evaluated comprehensively [29], [30]. In addition, the potential revenue from the freight transportation sector and the economic benefits arising from reduced road congestion can provide a strong basis to support the adoption of ROLA in Indonesia [17], [30]. Therefore, economic feasibility analysis is an important basis for the decision to invest resources in the ROLA system.

The environmental impacts of implementing ROLA systems are increasingly relevant to achieving global sustainability goals, particularly in reducing carbon emissions. ROLA has the potential to reduce greenhouse gas emissions by shifting freight transport from road to rail, which is generally more energy efficient [29], [30]. Assessing the environmental benefits of ROLA, including in terms of reduced air pollution and reduced carbon footprint, is an important part of the implementation criteria that stakeholders must take into account. These environmental benefits have been identified in the literature as one of the main advantages of ROLA, especially in the context of the global priority of sustainable transportation.

Stakeholder perspectives also play an important role in the successful implementation of ROLA. The government, as one of the main stakeholders, has the responsibility to establish policies and regulations that encourage modal shifts, such as providing incentives for rail transportation users and sanctioning trucks that exceed load capacity [17], [22]. In addition, the government is also responsible for ensuring that the infrastructure required to support ROLA is developed and properly maintained, which requires substantial investment and long-term planning [29], [30]. Government perspectives often focus on achieving broader transportation and environmental goals, including reducing congestion and emissions.

On the other hand, transportation operators, as key stakeholders, have a strong interest in the operational feasibility and cost-effectiveness of ROLA systems. Operators' main concerns include the reliability of train services, the efficiency of loading and unloading processes, and the impact of the system on their logistics operations [21]. Transportation operators also need assurance on the availability of rail capacity and the integration of ROLA in existing supply chains to ensure the smooth distribution of goods [17], [30].

The perspective of the general public also plays an important role in supporting ROLA's implementation. Communities affected by freight transportation activities may support ROLA if its implementation can reduce truck traffic volumes, lower noise levels, and improve air quality [29], [30]. Public acceptance of ROLA may be influenced by their perception of its benefits, such as improved safety and reduced damage to road infrastructure. Therefore, engaging the public and addressing their concerns are important in gaining public support for ROLA's initiatives [21].

3. Research Methods

3.1. Research Design

This study uses descriptive qualitative and quantitative methods to explore the potential for ROLA implementation from the perspective of trucking operators. The descriptive method was chosen to analyze the actual condition of logistics distribution on the Makassar-Parepare route, and the quantitative approach was used to assess operators' perceptions of their willingness to shift and determine the factors that influence the decision to shift to the ROLA system (Figure 1).

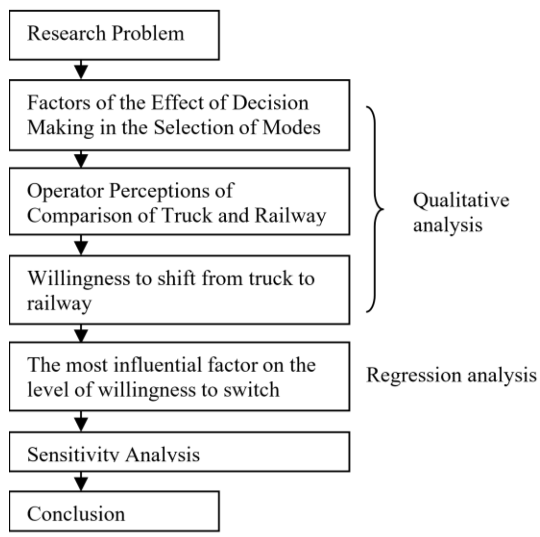


Figure 1. Research design

3.2. Locus Studies

This research was conducted on the Makassar - Parepare service route in South Sulawesi Province, Indonesia. This location was chosen because the route is the densest freight transportation route along the Trans Sulawesi road. In addition, currently, the route is also served by rail transportation. It passes through 5 districts/cities including Makassar, Maros, Pangkajene Islands, Barru, and Pare Pare as shown in Figure 2.

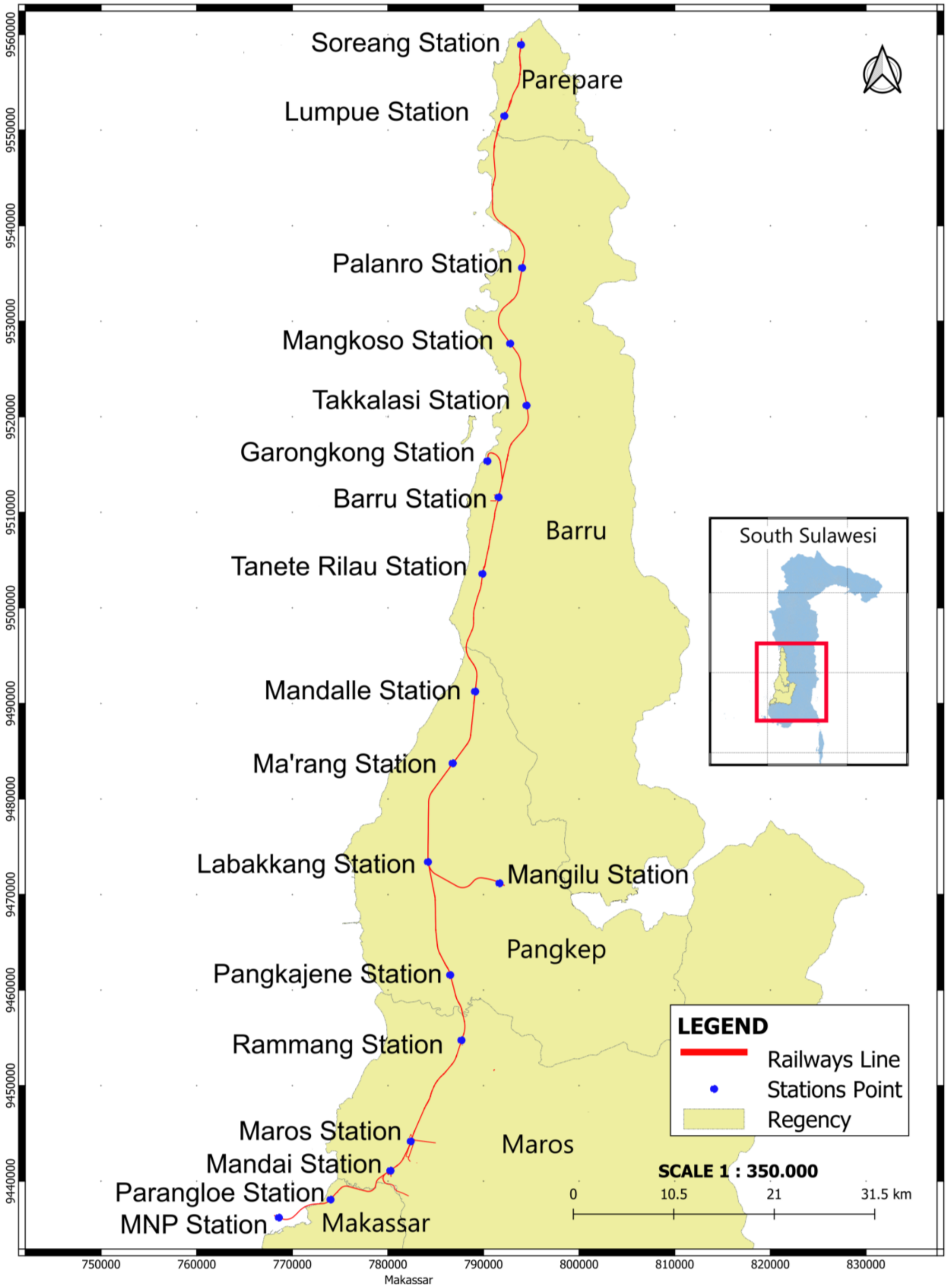


Figure 2. Research location

3.3. Population and Sample

The population of this study is truck transportation companies/operators, or logistics fleet owners who are members of the Indonesian Truck Entrepreneurs Association (APTRINDO) in Makassar City, which is estimated to be 300 companies. The sample used was 35 truck operators using the purposive sampling technique. The criteria for operators who are sampled are that they have a minimum of five years of experience in the field of freight transportation. The number of samples is believed to be representative to explore operator perceptions.

3.4. Data Collection Techniques

Data was collected through semi-structured interviews with truck operators to gather data on their perceptions of the ROLA system, its potential benefits, and the challenges it may face in implementation. The research instrument used a semi-open-ended questionnaire to identify the characteristics of trucking operators, explore the level of influence of freight mode choice decision factors, perceptions of road transport and ROLA comparisons, prospective willingness to switch, and determine the factors that influence the decision to switch.

3.5. Data Analysis

The approach used was a combination of qualitative and quantitative. Qualitative analysis from in-depth interviews was analyzed using thematic analysis techniques to identify factors in decision-making on the selection of freight transport modes. Quantitative analysis was derived from questionnaire data (likert scale) analyzed using descriptive statistical analysis to determine the distribution of truck operators' perceptions of the comparison of road transport and the ROLA system on the Makassar - Pare Pare route related to the variables of operating costs, travel time, flexibility, security and safety, ease of loading and unloading, and environmental impacts. In addition, it is used in analyzing the level of willingness of truck operators to shift to the ROLA system, as well as multiple liner regression analysis to determine the factors that influence the operator's decision to shift to the ROLA system, and finally a sensitivity analysis was conducted on the probability of shifting from truck to train transportation. The analysis stages can be seen in Figure 1 of the research design.

4. Results and Discussion

4.1. Characteristics of Freight Truck Operators

The characteristics of trucking operators in Table 1 include type of vehicle operated, fleet size, and company experience, which together provide a snapshot of the trucking industry. In terms of vehicle type, the majority of operators prefer medium trucks (5-10 tons) which are used by 45.7% of operators, followed by small trucks (<5 tons) at 28.6%, and large trucks (>10 tons) at 25.7%. The large number of medium-sized trucks indicates that this type of vehicle is considered ideal to meet the needs of freight transportation that requires flexibility, both in terms of load capacity and the ability to cover diverse routes.

Table 1. Characteristics of Truck Transport Operators

Characteristic	Number of Operators	Percentage (%)
Vehicles operated		
- Small truck (<5 tons)	10	28.6
- Medium truck (5-10 tons)	16	45.7
- Large truck (> 10 tons)	9	25.7
The amount of truck operated:		
- 1-10 units	18	51.4
- 11-50 units	12	34.3
- > 50 units	5	14.3
Company Experience:		
- <5 years	7	20.0
- 5-10 years	11	31.4
-> 10 years	17	48.6

In terms of fleet size, the majority of operators operate their fleets on a small to medium scale, with 51.4% of operators having 1-10 trucks, 34.3% having 11-50 trucks, and only 14.3% managing more than 50 trucks. The dominance of operators with small fleets indicates that the industry is still largely comprised of companies with limited capital or transport capacity, which may be more focused on specific market segments. This can pose a challenge when transportation demand increases, especially on major routes or during peak demand periods.

From the perspective of experience, the majority of operators have considerable experience, with 48.6% of them having more than 10 years of experience. This dominant level of experience indicates that most industry players have adapted to market dynamics and effective operational strategies. With longer experience, operators tend to be more reliable in providing responsive and quality services, as well as being better prepared to face challenges and changes in policies within the transportation industry.

4.2. Level of Effect of Decision Factors for Selection of Modes of Goods Transportation

Preference for transportation operators in choosing a mode for the distribution of goods is strongly influenced by several factors. From the analysis of operational cost factors, travel time, and flexibility are included in the category "very influential." Operational costs have a score of 3.26, showing that cost efficiency is a top priority for operators in determining the mode of goods transportation, especially to maintain the sustainability and profit of the company. Travel time and flexibility also have a high level of influence, each with a score of around 3.20 and 3.11. High flexibility makes it easier for operators to accommodate demand that is uncertain, while travel time impacts high operational costs.

Safety and security factors (2.89), policy support (2.77), and ease of loading and unloading (2.37) are included in the "influential" category. Safety and security are important to mitigate risks and protection during the trip, the safer the trip, the higher the influence on the decision to choose a mode for goods distribution by operators. Policy support factors are also no less important, and operator preferences show that government regulations in goods distribution activities should be supported by operational cost subsidy policies, especially fuel costs. High operational costs lead to expensive transportation costs, on the other hand operators do not want to lose the market so they carry out ODOL practices which have an impact on road damage. The ease of loading and unloading factors is also a concern for operators because this factor is related to service time and flexibility. According to operators, the use of rail transportation will actually increase the complexity of the loading and unloading systems because it adds to the handling system.

Finally, the environmental impact factor with a score of 1.74 is in the category "quite influential." Although this factor is not considered a top priority, there is still consideration of the environmental impact in the Decision of the Modes of Goods Transportation. Operators are still considering environmental aspects in the context of sustainability, but the main focus remains on more influential factors such as operational costs, travel time and flexibility. Overall, the operator's perception shows that aspects of cost efficiency and time, security, and policy support are the main basis in determining the right mode of transportation on the Makassar - Pare Pare route. More can be seen in Figure 3.

4.3. Operator Perception of Road and ROLA Transportation Comparison

Based on the operator perception of the ratio between road transportation and ROLA, it shows that 40% of operators on the Makassar - Pare Pare route have the perception that road transport operational costs are more expensive than using the ROLA system. They link the use of the ROLA system with the potential for cost savings, especially in the aspect of fuel and vehicle maintenance. With ROLA, reducing the frequency of vehicle use on the road can reduce fuel costs and maintenance costs. This relationship indicates that the ROLA system will be more attractive to the operator if the tariff can compete with the total operational costs of road transportation, thus providing incentives for the transfer.

In addition to operational costs, travel time also affects the operator's decision to shift to ROLA. Based on Figure 3, the operator sees that the timeliness in shipping can be more guaranteed with ROLA compared to road transportation that is often hampered by congestion (by 29%). Operators who need timeliness, especially in shipping high -value goods or urgent needs, will be more likely to choose ROLA if the travel time can be reduced and the timeliness can be maintained. This shows that positive perceptions of time efficiency can strengthen the interest of operators to adopt ROLA.

Although ROLA can offer efficiency in terms of time, operational flexibility is a challenge. Most operators consider road transportation to have a higher flexibility (far more flexible by 49% and slightly more flexible by 34%) because it can immediately reach the destination location without depending on the schedule as in the ROLA system. However, some operators who are accustomed to road transportation can consider switching if ROLA provides a schedule of departure and arrival in accordance with their operational needs. Therefore, so that the ROLA system can compete, it is necessary to increase the flexibility of the schedule that enables timely delivery according to operator needs.

Security and safety are also a significant factor in considering the transition to ROLA. Operators have the perception that the ROLA system is safer because it reduces the risk of traffic accidents on the highway. Figure 3 shows that operators who prioritize the safety of goods and safety of the driver during the trip tend to be more interested in using ROLA by 46%. If the ROLA system continues to show excellence in aspects of safety and safety, for example with less damage to goods or accident incidents, this positive perception can be a strong attraction for operators who prioritize operational security.

The ease of loading and unloading is also an important consideration for operators, especially those who are accustomed to direct access to the destination location. The analysis shows that although ROLA offers better security and time efficiency, operators feel the loading and unloading process at the station can be an obstacle, especially if infrastructure is inadequate. Truck operators want a fast and non -complicated process.

Finally, environmental impacts show that 60% of operators argue that road transportation is no better than ROLA from environmental aspects. ROLA is an environmentally friendly transportation choice, with lower carbon emissions than road transportation. This positive perception shows that ROLA can be in demand by operators who want to reduce carbon traces and contribute to protecting the environment. If the government provides incentives for low -emission transportation, then this attraction can be even greater and encourage more operators to shift to the ROLA system. The full perception of the operator can be seen in Figure 4.

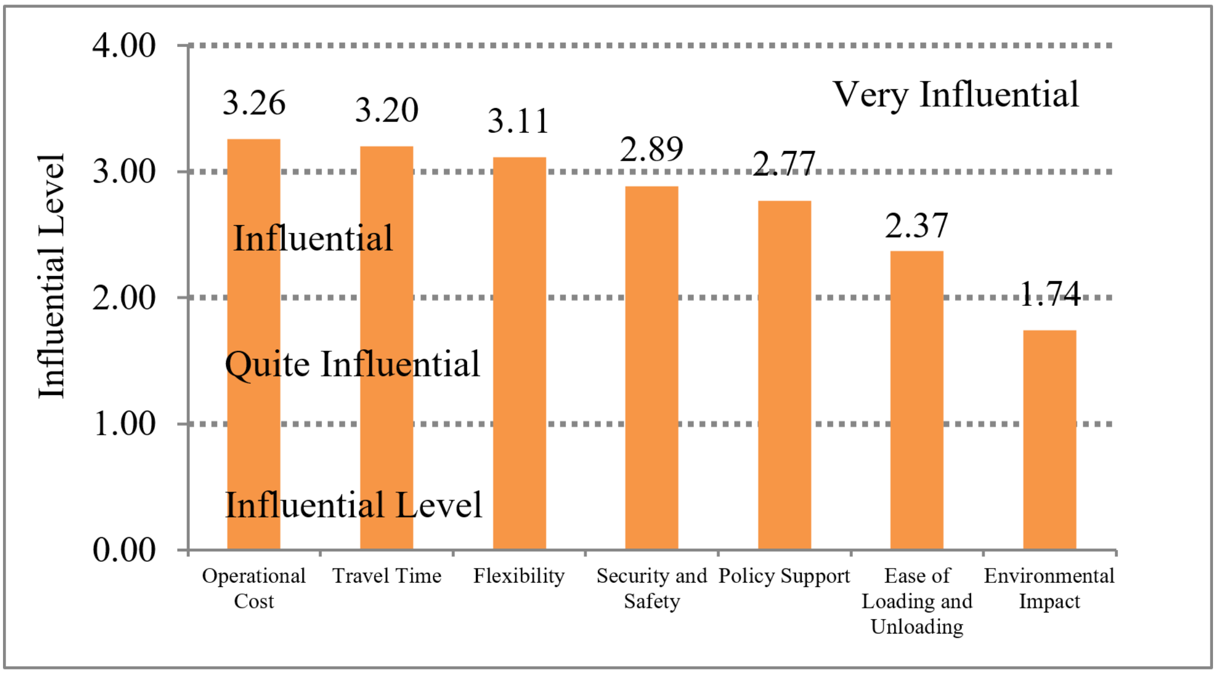
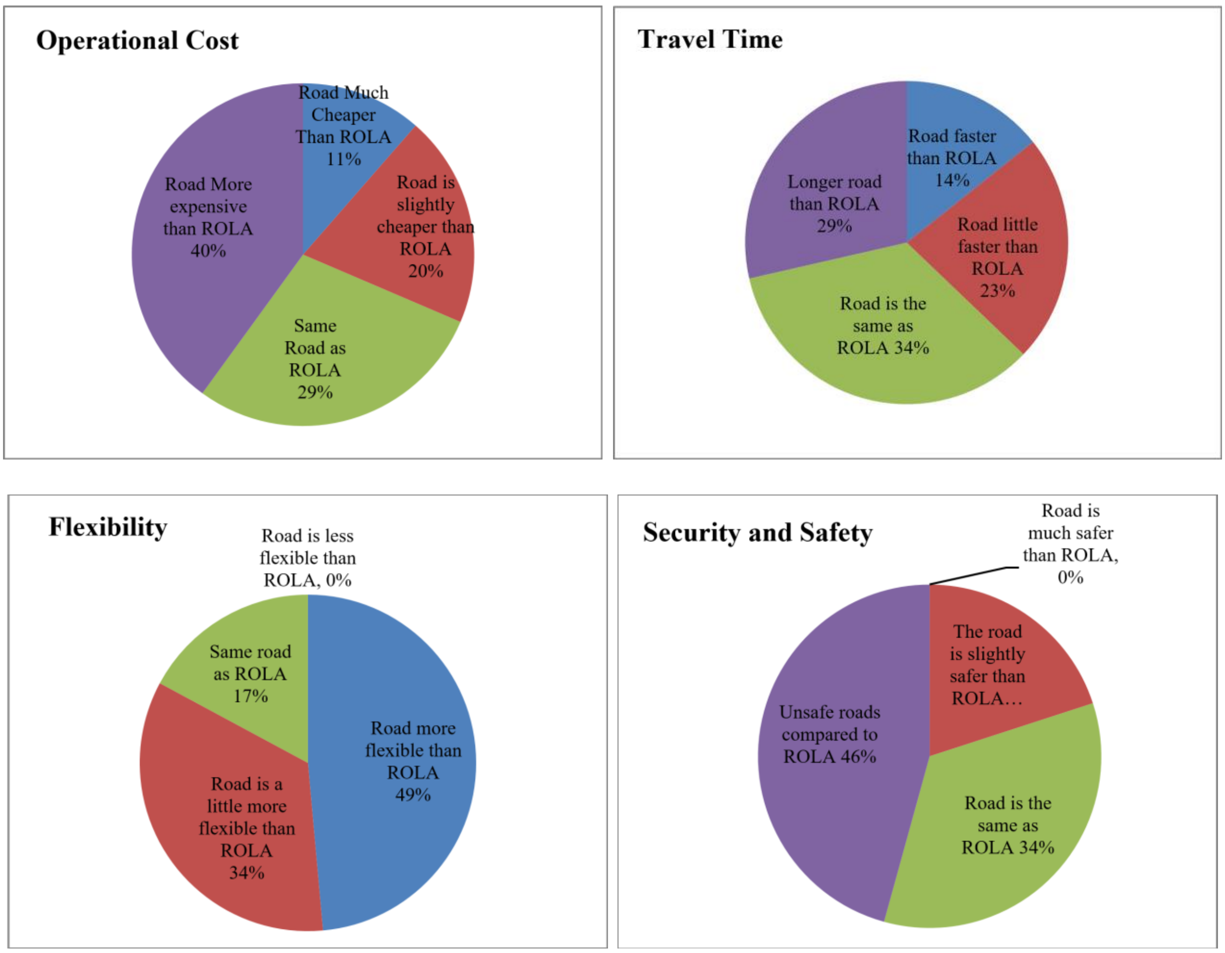


Figure 3. Factors of the Effect of Decision Making in the Selection of Modes of Freight Transportation on the Makassar - Pare Pare Route



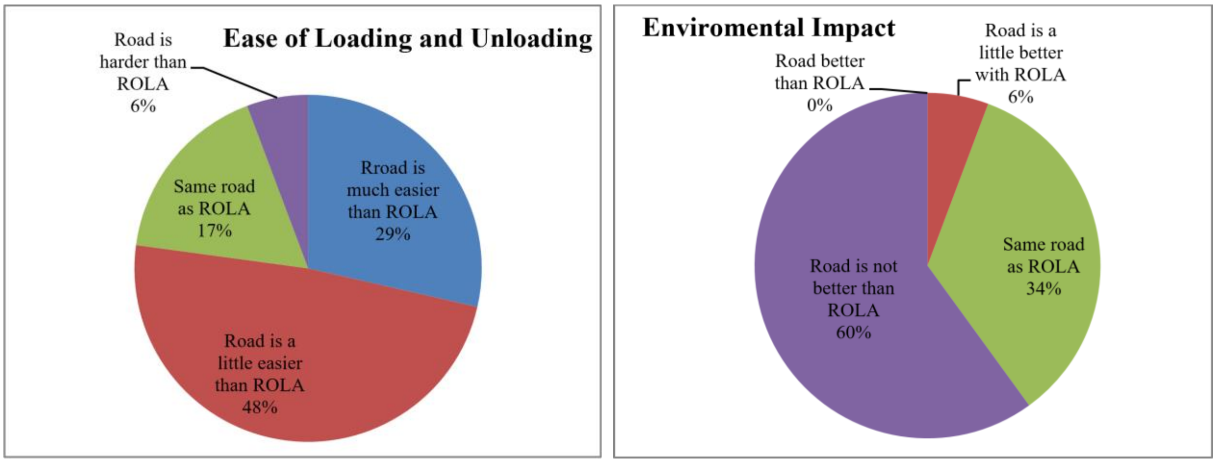


Figure 4. Operator's perception of the ratio of road and ROLA transportation

4.4. Level of Willingness of Truck Operators to Shifting to Using ROLA

Based on the perception of truck transport operators to the ratio between road transportation and ROLA in sub-chapter 4.3, an analysis of the willingness of operators is carried out to shift to use ROLA. The readiness level of the truck operator on the Makassar - Pare-Pare route to shift to the ROLA system shows an attractive pattern. Based on Figure 4, only 11% of operators are very willing and 26% are willing to try ROLA, while 46% are hesitant and 17% are not willing to switch. This shows the doubt of the operator against the ROLA system, which is mostly related to the needs of the operator to maintain efficiency and flexibility in operations. If ROLA does not offer better cost savings and competitive travel time, the truck operator will continue to choose a mode of road that gives flexibility in the route and schedule.

This is in line with the results of research [31] which emphasizes the importance of optimization in the loading process to reduce operational costs. A shorter travel time is one of the main advantages of ROLA, as explained by research [32] which underlines the efficiency of scheduling in container terminals. This efficiency allows a reduction in overall travel time, so it is attractive to operators who prioritize shipping speeds. Research [33] also supports this argument by showing that optimized train formations and scheduling can increase service frequencies and reduce delays. For full the level of willingness of truck operators to move to the ROLA system can be seen in Figure 5.

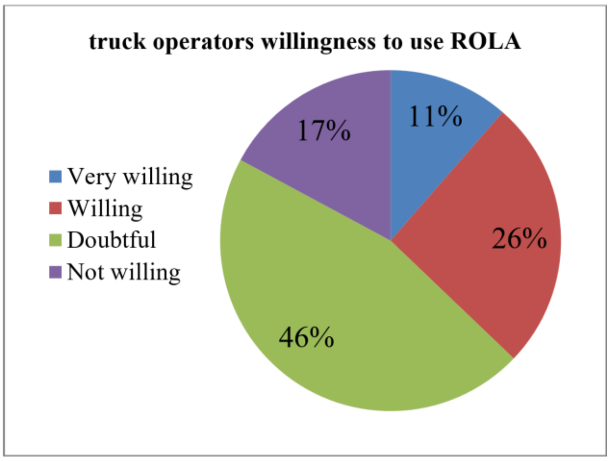


Figure 5. The willingness of truck operators to shifting to the ROLA system

In terms of safety and safety, ROLA has the potential to reduce the risk of accidents and driver fatigue on a long journey. Research [34] strengthens this by emphasizing the importance of safety evaluations in high-speed train operations to mitigate risk. Data on lower accident rates on rail modes than road modes shows valid reasons for operators who place a high priority on safety to consider the transition to ROLA. In addition, the ease in the loading and unloading process can be added value, because the efficient ROLA system is expected to speed up logistics flow. However, it is necessary to adapt to new procedures that might slow down some operators who have been accustomed to loading and unloading conventional trucks.

From an environmental perspective, ROLA can reduce carbon emissions compared to road modes, in line with findings [35] which highlight opportunities for energy savings and environmental conservation through rail operational improvement. Although the potential for environmental impact reduction is an advantage, operators may require additional incentives to encourage the transition. Overall, operator readiness to shifting is very dependent on how well ROLA is able to meet its needs economically and operationally. To attract more operators, efforts that can be made are to increase the efficiency of ROLA in terms of costs, time, and increased flexibility.

4.5. Analysis of Factors Affecting Operator Decisions Turning to the ROLA System

This analysis aims to determine the factors that influence the willingness of operators to shift to the ROLA system. The dependent variable is the level of operator's willingness (Y), and the independent variable consists of seven factors that are considered relevant, namely operational costs (X_1), flexibility (X_2), travel time (X_3), security and safety (X_4), policy support (X_5), ease of loading and unloading (X_6), and environmental impacts (X_7). Each variable can be seen in Table 2. Variable descriptive statistics.

Table 2. Variable descriptive statistics

Variables	Minimum	Maximum	Average
Y	1.00	4.00	2.25
X_1	2.00	4.00	3.45
X_2	2.00	4.00	3.35
X_3	2.00	4.00	3.20
X_4	2.00	4.00	3.00
X_5	1.00	4.00	2.60
X_6	1.00	4.00	2.30
X_7	1.00	3.00	1.55

Table 2 shows the minimum, maximum, and average distributions of the variables analyzed. The average value of the willingness of the operator to shifting to the ROLA (Y) system is 2.25. Meanwhile, the independent variable with the highest average is X1 (operational costs), which shows the cost factor has a high distribution level among respondents, followed by other variables with an average value that is quite varied.

The initial model of multiple regression analysis was obtained from the analysis results in Table 3, with the resulting equation as follows:

$$\mathbf{Y = 7.2507 - 0.3959X_1 + 0.1607X_2 - 1.1932X_3 - 0.1039X_4 - 0.2494X_5 + 0.3331X_6 - 0.1037X_7}$$

Table 3. Multiple Regression Analysis Results

Variables	koefisien	std. error	t-Statistik	p-value
Const	7.2507	1.025	7.073	0.000
X_1	-0.3959	0.192	-2.062	0.062
X_2	0.1607	0.197	0.817	0.430
X_3	-1.1932	0.193	-6.175	0.000
X_4	-0.1039	0.169	-0.614	0.551
X_5	-0.2494	0.225	-1.108	0.290
X_6	0.3331	0.232	1.434	0.177
X_7	-0.1037	0.215	-0.482	0.638

The coefficient of determination (R^2) is 0.808, which means that around 80.8% of the variation of the willingness of the operator (Y) can be explained by the independent variables (X_1 to X_7). This model shows a pretty strong relationship between the dependent and independent variables. From this result, it can be seen that the variables X_1 (operational costs) and X_3 (travel time) have a significant coefficient at the 10% level (with the P value for X_1 approaching significant at 0.062, and X_3 is significant at 0,000). That is, these two variables are the main factors that influence the willingness of operators to move to the ROLA system.

To ensure the validity of the model, several statistical assumption tests are carried out, namely:

- The normality test (Shapiro-Wilk Test) shows a p-value of 0.360, greater than 0.05. This indicates that residuals are normally distributed, which meets the assumptions of linear regression.
- Heteroscedasticity Test (Breusch-Pagan Test): The P-value of 0.547 shows the absence of heteroscedasticity in data, so that the residual variance does not depend on the independent variable.
- Autocorrelation Test (Durbin-Watson Test): Durbin-Watson value of 2,253 close to 2, indicating the absence of autocorrelation between residuals.

To determine the most optimal regression model, a comparison of the entire combination of independent variables is conducted. The results in Table 4 show that the combination of variables X_1 (operational costs) and X_3 (travel time) produces the best model with an adjusted R^2 of 0.731.

$$\mathbf{Y = 7.2507 - 0.3959X_1 - 1.1932X_3}$$

Table 4. Optimum models

Variables	Coefisien	Std. Error	t-Statistik	P-Value
Const	7.2507	0.874	8.297	0.000
X_1	-0.3959	0.189	-2.091	0.057
X_3	-1.1932	0.191	-6.244	0.000

Models with variables X_1 and X_3 as the main predictors are the most efficient models in explaining the willingness of operators to shift to use the ROLA system. Specifically, the negative coefficient of X_1 shows that an increase in operational costs tends to reduce the willingness of operators to move to the ROLA system. Conversely, X_3 (travel time) which also has a negative coefficient shows that the longer the travel time, the lower the willingness of the operator to use ROLA.

4.6. Sensitivity of Mode Transfer

The results of sensitivity analysis show a change in the level of willingness of road transport operators to move to the ROLA system based on the percentage of decreased operational costs and travel time. When ROLA's operational costs are cheaper up to 20% than road transportation, there is a significant increase in the willingness of operators to move. At this level, 57% of the operators stated "very willing" and "willing," while uncertainty (doubt) and rejection (not willing) reduced up to 26% and 17% respectively. This indicates that the greater the operational cost savings, the higher the willingness of the operator to shift to ROLA, and with this tendency, it is clear that the cost incentive is a strong factor in operator decision making. Simulation Sensitivity Aspects of operational costs can be seen in Figure 6.

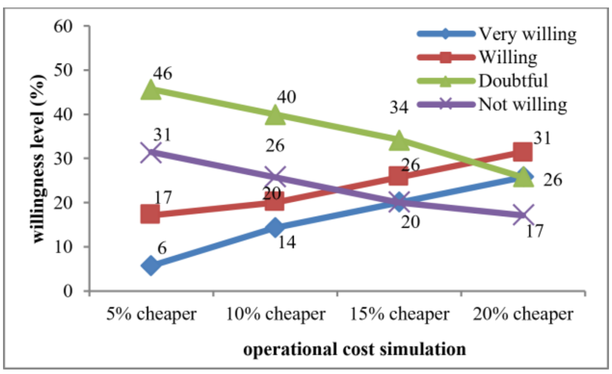


Figure 6. Sensitivity The willingness of mode transfer based on aspects of operational costs

Whereas based on the aspect of travel time, when ROLA is faster up to 120 minutes than road transportation, the willingness to move reaches its peak of 65% of the operator stating "very willing" and "willing," and only 6% "not willing", while 29% still "doubtful". A significant reduction in travel time increases the willingness of operators to switch, showing that the aspect of time greatly affects the operator's decision, especially in large time savings. Simulation Sensitivity aspects of travel time can be seen in Figure 7.

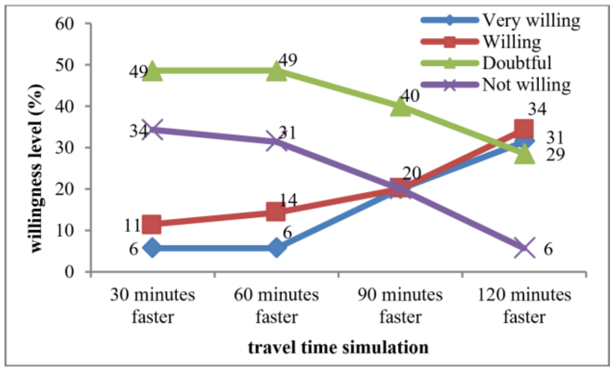


Figure 7. Sensitivity The willingness of mode transfer based on aspects of travel time

From these two aspects, it appears that both operational cost incentives and travel time have a positive impact on the willingness of operators to move to the ROLA system. However, the reduction in travel time from 90 minutes to 120 minutes has a greater impact than operational cost incentives by 15% to 20%. This shows that faster travel time is a major consideration for operators in the transfer decision to the ROLA system.

4.7. Research Implication

The implementation of the ROLA system on the Makassar – Parepare route has the potential to significantly increase the efficiency of logistics distribution. With a decrease in operational costs by up to 20% through ROLA, transport operators tend to be more willing to move, which leads to savings in distribution costs. This is in line with research [24],[23] which explains that in the long run, this reduction in costs can increase the competitiveness of logistics companies while strengthening supply chains in areas that require the distribution of goods with more efficient price. In addition, the speed offered by the ROLA system provides great potential for the timeliness of shipping goods, in this study, where the operator shows a high willingness to move during the trip time can be shortened for up to 120 minutes. This shows that the ROLA system, through travel time optimization, can reduce delays in shipping and support on-time distribution needs in regions with high logistics demands.

This study also shows that the adoption of the ROLA system can have an impact on reducing road infrastructure loads. The transfer of transportation from the highway to the ROLA system will help maintain the condition of the road from damage caused by many to-traffic Odol vehicles on the national road of South Sulawesi Province. This is in line with research [30], [29] which found that with a significant reduction in road traffic burden, road maintenance budgets can be saved and allocated for other more urgent needs, or for development of additional infrastructure that can support logistics in strategic areas.

The results of this study can guide the government and stakeholders in developing policies for the widespread implementation of the ROLA system. For example, providing incentives to transport operators shifting to ROLA or integrating with subsidized policies can encourage adoption. Additionally, investment in infrastructure supporting ROLA operations can target other potential areas in Indonesia. This approach aims to create a more efficient, energy-efficient, and sustainable logistics distribution system [28].

5. Conclusions

The study shows that most operators, namely 63% are still "doubtful" and "not willing" to shift from road transport to ROLA; however based on sensitivity analysis, lower operating costs are 15% -20%, and more travel time Fast (90-120 minutes) has the potential to increase the willingness of truck operators to shift from road transport to ROLA. In addition, ROLA's excellence in terms of safety, reducing carbon emissions, and logistics efficiency is a factor that supports operator preferences to switch. Nevertheless, the main challenge faced is the low operational flexibility and the complexity of unloading which affects the interests of some operators to adopt this system.

The realization of ROLA implementation on the Makassar–Parepare route requires infrastructure readiness, policy support, and collaboration between truck operators and railway service providers. The development of efficient loading and unloading terminals, along with economic incentives such as operational subsidies, can enhance ROLA's competitiveness. Key challenges, including operational flexibility and loading/unloading time, can be addressed through optimized scheduling and terminal facilities.

Two crucial aspects that must be considered are cost and travel time. To make ROLA more economically competitive, this can be achieved through subsidies, tariff adjustments, and operational efficiency. Additionally, in terms of travel time, competitiveness with trucks can be enhanced by optimizing train schedules, minimizing delays in the loading and unloading process, and improving intermodal connectivity. Strategy, ROLA implementation can strengthen the logistics competitiveness of the South Sulawesi region and increase the contribution of the transportation sector to the goals of sustainable development.

The limitation of the research is that it still focuses on the perspective of truck operators without involving other stakeholders, such as the owner of the goods, regulators, and railroad service providers, which can provide a more comprehensive view. For further research, it is recommended to conduct a comparative study of the development of the cost and time simulation model to evaluate the operational efficiency of ROLA compared to other modes of transportation in various scenarios.

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