Maritime Technology and Society
Vol. 5(2): 214-224, June 2026
doi.org/10.62012/mp.vi.48801

Regular Research Article

Determinants of Operational Performance in Maritime Livestock Transport: A Mixed-Methods SEM–PLS Study from Indonesia

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Abstract: Livestock transportation by sea plays an important role in Indonesia's national cattle supply chain, but to date, it still faces challenges in the form of variability in service quality, driver competence, and the lack of digital monitoring technology on board ships. This study aims to identify the factors that influence the operational performance of government-owned livestock ships (Camara Nusantara 1 to 6) by integrating service quality, technological readiness (based on perception), and the role of crew members/kleder into a single integrated analytical model. A mixed-methods approach was used in this study. The quantitative stage used Structural Equation Modelling–Partial Least Squares (SEM–PLS) with 34 respondents, while the qualitative stage was conducted through in-depth interviews with officials from the Directorate of Traffic and Sea Transportation, Ministry of Transportation. Regulatory variables were measured but excluded from the structural model due to multicollinearity with service variables. The results showed that service quality had a significant effect on operational performance. At the same time, technology, although not yet implemented on livestock ships was the strongest predictor, reflecting stakeholders' expectations for future digitalisation. The role of kleders did not have a statistically significant effect, even though they played a major role in manually monitoring livestock conditions. Qualitative findings reinforce these results by demonstrating inconsistencies in kleders' competencies, limitations in technological infrastructure, and variations in operational implementation between regions. This study contributes to the development of marine livestock logistics systems in Indonesia, while also providing policy recommendations to improve efficiency, safety, and livestock welfare.

Keywords: livestock transport; maritime logistics; SEM–PLS; operational performance; shipping technology; animal welfare; Indonesia

1. Introduction

The transport and distribution of livestock in various regions of Indonesia, especially on the islands, is driven by increasing demand for beef in consumer centres [1]. This has led to an increase in livestock prices in consumer centres compared to prices in producer centres [2]. In production centres, there is a surplus of livestock due to relatively low beef consumption, coupled with low transport costs [3]. Transporting livestock by land and sea involves different protocols and methodologies, including the use of equipment during transit, modes of transport, and various logistical considerations to maintain the quality of livestock from origin to destination [4]. Inefficiencies in the livestock supply chain caused by inadequate transport infrastructure can limit market access and increase livestock costs or prices [5][6]. For example, in areas lacking adequate transport infrastructure, farmers may find it difficult to transport their animals to market efficiently. This can lead to delays, increased costs, and ultimately lower profits for farmers [7]. In addition, poor transport systems can result in low-quality livestock

Received: 2026-02-23; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.48801 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

reaching the market, which impacts both producers and consumers [8].

Specialised livestock transport vessels have been developed to improve animal comfort and reduce weight loss and mortality during transport [3]. These vessels are designed to comply with animal welfare principles, creating comfortable conditions during the journey, while also considering logistical aspects and applicable procedural guidelines [9]. This strategy is expected to help reduce weight loss and livestock mortality due to suboptimal handling during sea transport [10][11].

From an operational perspective, sea transport of livestock allows for more efficient movement of livestock and supports the continuity of shipping schedules from production centres to consumer areas [1][12]. In addition to transportation aspects, clear regulations are also important to facilitate smoother livestock transport operations and enhance collaboration between stakeholders [13][14]. Livestock transport regulations play an important role in ensuring sustainability by maintaining animal welfare, reducing environmental impact, and promoting efficient transport practices.

Technology also plays an important role in improving livestock transport efficiency. Technological innovations enable improved animal welfare, simplified operations, and increased safety in livestock transport. The integration of environmental technology and sustainable monitoring systems can reduce operational impacts and improve efficiency at ports relevant to livestock transport [15]. The application of artificial intelligence (AI) and the Internet of Things (IoT) enables the monitoring of individual livestock behaviour, such as feeding patterns, and provides strategic information for better transport and improved animal welfare [16]. Advanced tracking systems ensure more accurate livestock counting and identification, minimising errors in the supply chain [16]. In addition, innovative container designs tailored for livestock minimise barriers, facilitate movement, and reduce stress on animals during transport [17]. Thus, these new technologies can improve animal welfare and efficiency in the livestock industry.

The government has operated special livestock ships, Camara Nusantara 1 to 6, to improve supply chain efficiency, reduce logistics costs, and ensure animal welfare during long-distance voyages. However, the current operational system still faces various obstacles, including limited ship services, inconsistent livestock maintenance competencies, challenges in implementing regulations, and a lack of digital monitoring technology commonly used in developed countries.

Previous studies have shown the importance of ship facilities such as ventilation, cleanliness, loading and unloading systems, and emergency preparedness as determinants of livestock welfare and smooth sailing operations [12]. In line with global developments, digital transformation in the maritime logistics sector has emphasised the use of health sensors, GPS tracking, monitoring dashboards, and real-time communication systems to improve accuracy and safety. However, Indonesian livestock vessels have not yet implemented these technologies. Health monitoring, feeding, and incident handling processes still rely entirely on livestock handlers [18].

There are several research gaps that have not been widely discussed in the literature. First, there has been no research analysing the determinants of livestock ship operational performance in non-digital conditions. Second, although the technology has not yet been implemented, stakeholders' perceptions of the importance of technology have not been widely studied as a predictive variable. Third, the role of kleder as a key component of manual systems is rarely modelled quantitatively, even though they are at the forefront of livestock monitoring. Fourth, livestock transport regulations have not been empirically tested as independent determinants, mainly because their implementation varies greatly between regions.

This study aims to answer the following questions:

(1) How does service quality affect operational performance?

(2) How do regulations affect operational performance?

(3) How does technology readiness based on perception affect operational performance?

(4) How does the role of kleder affect operational performance?

(5) How do qualitative insights strengthen and explain quantitative findings?

This study provides theoretical contributions through the integration of service, regulation, perceptual technology, and leader role variables

Received: 2026-02-23; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.48801 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

into a single empirical model, as well as practical contributions for governments and ship operators in designing policies to improve the efficiency and digitalisation of livestock transportation.

2. Materials and Methods

This research adopts a mixed methods design to examine the operational performance of livestock vessels in Indonesia. The mixed methods approach was selected to provide a comprehensive understanding of both the quantitative and qualitative dimensions of livestock transportation. Quantitative data were utilized to evaluate operational indicators such as vessel capacity, transportation volume, route characteristics, voyage frequency, loading efficiency, and service performance. Meanwhile, qualitative information was employed to capture operational challenges, management practices, stakeholder perspectives, and logistical constraints affecting livestock shipping operations. By integrating these two approaches, the study aims to generate a more holistic assessment of vessel performance and its contribution to the national livestock distribution system.

The research process consisted of data collection, data analysis, and interpretation stages. Secondary data were obtained from government reports, transportation statistics, port records, and relevant institutional publications related to livestock transportation. In addition, qualitative insights were gathered through document analysis and a review of operational reports and policy documents concerning maritime livestock logistics. The quantitative data were analyzed using descriptive statistical techniques to identify operational trends and performance characteristics, while qualitative findings were examined through thematic analysis to identify recurring operational issues and strategic improvement opportunities. The integration of quantitative and qualitative results enabled the study to formulate a comprehensive evaluation of livestock vessel operations and provide recommendations for enhancing the efficiency, reliability, and sustainability of maritime livestock transportation in Indonesia.

2.1 Quantitative Component

A structured questionnaire using a five-point Likert scale measured four independent variables—Service Quality (X1), Regulation (X2), Technology (X3), and kleder (X4)—and one dependent variable, Operational Performance (Y). The sample consisted of 34 respondents selected through simple random sampling. Respondents included government employees, ship crew members, livestock handlers, shipping company staff, and livestock producers. Each of the variables above has several indicators, as in the following table.

Table 1. Research Variables

No	Variabel	Code	Indicator
1	Service Quality	X1.1	Loading and Unloading Facilities
		X1.2	Loading and Unloading Safety
		X1.3	Ship Cleanliness During Transport
		X1.4	Livestock Comfort During the Journey
		X1.5	Ventilation and Air Circulation Systems
		X1.6	Animal Waste Management
		X1.7	Availability of Feed and Water During Transport
		X1.8	Animal Health Facilities (Veterinarians, Animal Medicines) Available
		X1.9	Routine Animal Check-ups During the Journey
		X1.10	Disease Transmission Management During the Journey
		X1.11	Emergency Treatment Facilities During the Journey
		X1.12	Small Livestock Weight Loss
		X1.13	The Crew Has a Rest Area on the Ship
		X2.1	Regulations regarding livestock transportation are clear and easy to understand.
		X2.2	Oversight of livestock welfare regulations during sea transportation.
		X2.3	Implementation of regulations regarding maximum capacity.
		X2.4	Regulations regarding livestock safety during transportation.

Received: 2026-02-23; Accepted: 2026-06-05
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No	Variabel	Code	Indicator
		X2.5	Livestock sea transportation licensing procedures are too complicated.
2	Regulation	X2.6	Sanctions for violating livestock transportation regulations.
		X2.7	Regulations governing the use of technology.
		X2.8	Regulations change frequently.
		X2.9	Regulations help improve shipping efficiency.
		X2.10	Government regulations in managing livestock sea transportation.
		X2.11	There are obstacles in implementing government regulations.
		X2.12	Socialization of regulations regarding livestock transportation is quite good.
		X3.1	Technology for monitoring livestock health
		X3.2	Technology to assist in monitoring livestock during transit
		X3.3	Use of applications to book livestock cargo space
		X3.4	Information technology helps improve livestock safety
		X3.5	Tracking technology (GPS) to monitor vessel position
3	Technology	X3.6	Communication technology used between vessels and livestock farmers
		X3.7	Information technology to improve the efficiency of livestock sea transportation
		X3.8	Technology helps in handling problems or emergency incidents
		X3.9	Training on technology use has been provided to vessel operators
		X3.10	Access to technology use in livestock transportation
		X3.11	Livestock health measuring technology
		X3.12	Technology integration can reduce operational costs
		X4.1	The kleder keeps weighs the animals during quarantine.
		X4.2	The kleder keeps weighs the animals upon arrival at the ship's destination.
		X4.3	The kleder helps improve livestock safety.
		X4.4	The kleder keeps helps improve livestock safety during loading and unloading.
		X4.5	The kleder keeps prepares livestock food and water during quarantine.
		X4.6	The kleder keeps prepares livestock food and water during transport.
4	Kleder	X4.7	The kleder keeps monitors livestock health and reports it to health officials.
		X4.8	The kleder keeps always cleans up livestock waste during transport.
		X4.9	The kleder keeps assists in handling problems or emergency incidents.
		X4.10	The kleder keeps coordinates with health officials if any animals are sick.
		X4.11	The kleder keeps reports the livestock's position during the journey to the animal owner.
		X4.12	Livestock transport training has been provided to the keeper.
		X4.13	The communication tools used by the kleder and breeders are adequate
		Y1.1	jarang terjadi cidera pada ternak selama pengangkutan
		Y1.2	Waktu perjalanan kapal ternak tepat waktu
		Y1.3	Kapal berhenti di pelabuhan tepat waktu
5	Operational	Y1.4	Kapal datang dan berangkat selalu tepat waktu
	Performance	Y1.5	Hewan ternak yang diangkut sesuai batas maksimal (550 ekor Sapi)
		Y1.6	Tarif kapal ternak pemerintah lebih murah dibandingkan kapal swasta
		Y1.7	Adanya Koordinasi antara pihak pengangkut dan peternak dalam memastikan kelancaran proses pengiriman ternak

SEM–PLS version 4 was used to analyze both the measurement model (validity and reliability) and the structural model (path coefficients and R^2 values). SEM–PLS was chosen due to its suitability for small samples and complex reflective models.

2.2 Qualitative Component

To support and contextualize the quantitative findings, in-depth interviews were conducted with officials from the Directorate of Traffic and Sea Transportation. This qualitative component was intended to obtain institutional perspectives on the implementation, management, and operational challenges of livestock vessel services in Indonesia. The interviews provided additional explanations for patterns identified in the quantitative data, particularly those related to vessel utilization, service continuity, route performance, and the effectiveness of livestock transportation programs.

Received: 2026-02-23; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.48801 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

The interviews focused on several key themes, including livestock ship operations, livestock transportation services, livestock monitoring systems, competency standards for livestock handlers or Kleders, and the implementation of relevant regulations. Attention was given to how livestock vessels are managed in practice, how animal welfare is maintained during transportation, how monitoring and reporting mechanisms are applied, and how human resource competency affects service quality. The qualitative information obtained from these interviews was analyzed thematically to identify recurring issues, policy implications, and operational improvement opportunities. These findings were then integrated with quantitative results to provide a more comprehensive understanding of livestock vessel performance and governance.

3. Results

The quantitative analysis was conducted using IBM SPSS Statistics and SmartPLS 4. The results include descriptive statistics, measurement model assessment, structural model evaluation, and qualitative findings obtained from in-depth interviews with stakeholders involved in livestock transportation services.

3.1. Descriptive Statistics

A total of respondents representing government institutions, livestock transportation operators, and related stakeholders participated in this study. The demographic characteristics of the respondents are presented as follows.

In terms of gender, the majority of respondents were male (94.1%), while female respondents accounted for only 5.9%. This composition reflects the dominance of male personnel in maritime transportation and livestock logistics activities.

Regarding educational background, most respondents held a bachelor's degree (64.7%), followed by diploma holders (17.6%) and respondents with other educational qualifications (17.7%). The relatively high proportion of respondents with tertiary education indicates that the participants possessed adequate knowledge and professional experience related to livestock transportation services.

Based on age distribution, 41.2% of respondents were younger than 30 years, 35.3% were between 30 and 40 years old, and 23.5% were over 40 years old. This distribution demonstrates a balanced representation of younger and more experienced professionals within the livestock transportation sector.

In terms of occupation, respondents were equally divided between public and private sectors. Approximately 50% were government employees from central and regional agencies, while the remaining 50% consisted of livestock vessel crews, livestock handlers (*Kleders*), livestock farmers, and shipping company personnel involved in livestock vessel operations. This balanced representation provides perspectives from both regulatory and operational stakeholders.

3.2. Measurement Model Assessment

The measurement model (outer model) was evaluated to assess the validity and reliability of the indicators used to measure the latent constructs. Indicators with outer loading values greater than 0.70 were considered to satisfy the requirements of convergent validity and reliability.

For the Operational Performance construct, the strongest indicator was the effectiveness of coordination between transport operators and livestock farmers in ensuring the smooth delivery of livestock. This finding highlights the importance of stakeholder coordination in maintaining transportation efficiency and operational continuity.

For the Livestock Ship Service construct, several indicators demonstrated strong validity and reliability, including loading and unloading facilities, loading and unloading safety procedures, vessel cleanliness during transportation, livestock comfort throughout the voyage, and the adequacy of ventilation and air circulation systems. These indicators collectively represent the quality of services provided during livestock transportation.

The Technology Application construct was measured through indicators related to livestock health monitoring technology, onboard livestock monitoring systems, communication technologies used between vessel operators and livestock owners, operator training in technology utilization, and accessibility to technological tools supporting livestock transportation activities.

Received: 2026-02-23; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.48801 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

The high loading values obtained indicate that technology plays an important role in enhancing operational effectiveness.

For the Role of Kleders construct, the most significant indicators included livestock weighing during quarantine and upon arrival, supervision of livestock safety during loading, unloading, and transportation, provision of feed and drinking water during transport, livestock health monitoring and reporting, emergency handling capabilities, coordination with veterinary and health authorities, communication of livestock status to owners, and participation in livestock transportation training programs.

Overall, the outer model assessment confirmed that all retained indicators contributed significantly to their respective constructs. Therefore, the measurement model met the established requirements for convergent validity and composite reliability according to SEM-PLS standards.

3.3. Structural Model Assessment

The structural model (inner model) was evaluated to determine the influence of the independent variables on operational performance. The results obtained from SmartPLS 4 are presented in Figure 1.

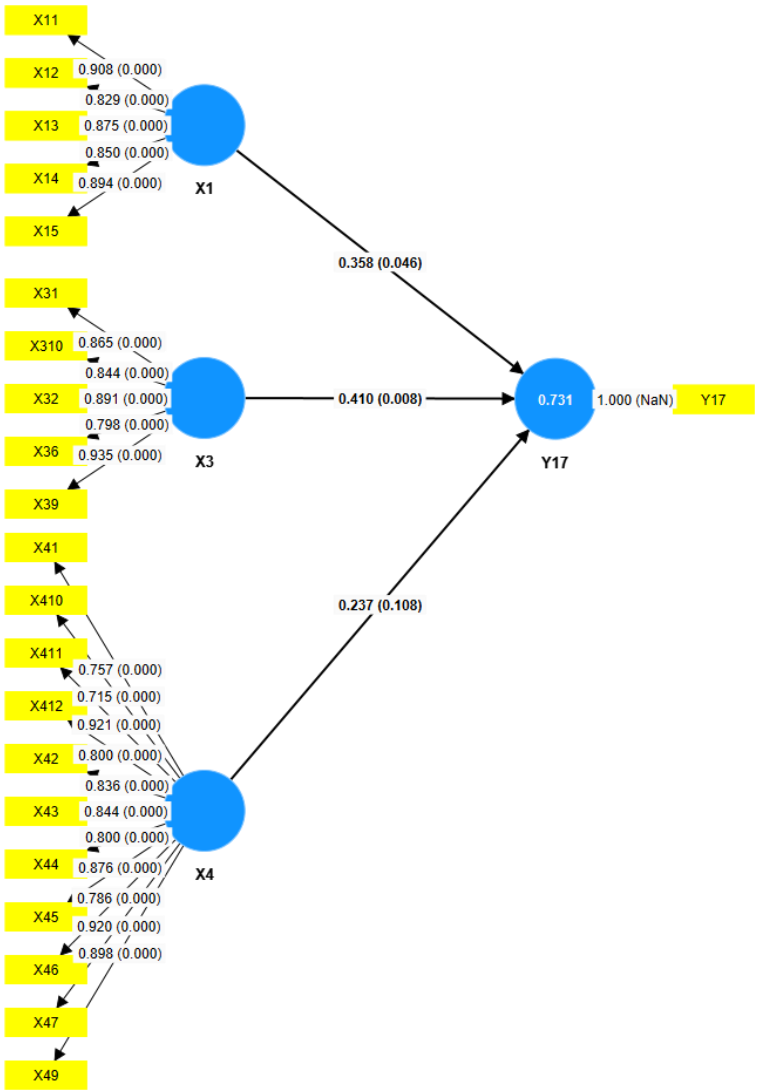

Figure 1. Structural Model Results.

The analysis revealed that Livestock Ship Service Quality has a positive and statistically significant effect on operational performance (β = 0.358; p = 0.046). This result indicates that improvements in service quality, including loading facilities, cleanliness, safety, and livestock comfort, contribute directly to better operational outcomes.

The Technology Application variable exhibited the strongest influence on operational performance (β = 0.410; p = 0.008). This finding suggests that technological adoption, including

Received: 2026-02-23; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.48801 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

monitoring systems, communication technologies, and livestock health tracking tools, plays a critical role in improving the efficiency and effectiveness of livestock transportation services.

In contrast, the Role of Kleders showed a positive but statistically insignificant relationship with operational performance (β = 0.237; p = 0.108). Although livestock handlers contribute to animal welfare and operational support, their direct impact on overall operational performance was not sufficiently strong to achieve statistical significance in the current model.

The coefficient of determination (R^2 = 0.731) indicates that 73.1% of the variance in operational performance can be explained by the variables included in the model. This result demonstrates substantial explanatory power and suggests that service quality, technology application, and the role of Kleders collectively provide a strong explanation of livestock vessel operational performance. It should be noted that the Regulation variable was excluded from the final structural model due to multicollinearity issues. The variable exhibited a Variance Inflation Factor (VIF) value greater than 5, indicating a high correlation with the service quality construct and potentially affecting the stability of the model estimates.

3.4. Qualitative Findings

The qualitative findings obtained from interviews with officials from the Directorate of Traffic and Sea Transportation provided important contextual insights into the quantitative results. The interviews revealed that livestock monitoring activities are still predominantly conducted using manual procedures. Most operational monitoring relies on visual inspection and manual reporting by vessel crews and livestock handlers. This condition limits the ability of operators to obtain real-time information regarding livestock conditions during transportation.

Furthermore, the study found that advanced technological systems such as livestock health sensors, automated ventilation monitoring systems, environmental alarm systems, and livestock tracking devices have not yet been widely implemented on Indonesian livestock vessels. The absence of such technologies may explain the significant positive effect of technology application identified in the quantitative analysis, indicating substantial opportunities for future operational improvements through digitalization.

Another important finding concerns the competency of livestock handlers (*Kleders*). Interview participants indicated that the knowledge, skills, and practical experience of Kleders vary considerably among operators and regions. Although training programs have been implemented, differences in competency levels remain a challenge for maintaining consistent service quality and animal welfare standards.

Overall, the qualitative findings support the quantitative results by highlighting technology adoption and service quality as critical factors influencing livestock vessel performance. The findings also suggest that future improvements should focus on strengthening digital monitoring systems, standardizing livestock handling competencies, and enhancing operational management practices to improve the efficiency and sustainability of livestock transportation services in Indonesia.

4. Discussion

The findings of this study demonstrate that service quality plays a significant role in determining the operational performance of livestock transportation vessels in Indonesia. The positive and significant relationship identified in the SEM-PLS analysis indicates that improvements in loading and unloading facilities, onboard cleanliness, ventilation systems, animal comfort, and transportation safety contribute directly to more effective vessel operations. These findings are consistent with previous studies emphasizing that service quality is a critical determinant of transportation performance and logistics efficiency [19]–[21]. In the context of livestock transportation, adequate animal welfare facilities and operational services are essential not only for maintaining animal health but also for reducing transportation risks and operational disruptions [14], [22].

A particularly noteworthy finding is the strong influence of the technology application variable on operational performance. Although advanced technologies are not yet widely implemented on Indonesian livestock vessels, technology emerged as the most influential predictor in the model. This result should be interpreted as reflecting stakeholder expectations rather than actual technological

Received: 2026-02-23; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.48801 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

performance. Respondents from both government and private sectors perceive that technological innovations have substantial potential to improve transportation operations. Technologies such as livestock health monitoring systems, digital communication platforms, environmental sensors, automated ventilation controls, and real-time tracking systems are expected to improve operational coordination, enhance punctuality, reduce incident risks, strengthen monitoring capabilities, and increase regulatory accountability [23]–[27].

The qualitative findings further support this interpretation. Interviews revealed that livestock monitoring is still conducted manually and that most vessels lack digital monitoring systems, health sensors, ventilation alarms, and livestock tracking devices. Consequently, stakeholders view technology as a strategic solution for overcoming existing operational limitations. Similar findings have been reported in previous studies, which argue that digitalization can significantly improve transparency, operational control, and decision-making within transportation and logistics systems [28]–[30]. In this context, technology functions not only as an operational tool but also as a catalyst for the modernization of Indonesia's livestock transportation sector.

In contrast, the role of the *Kleder* was found to have a positive but statistically insignificant effect on operational performance. This result does not imply that *Kleders* are unimportant; rather, it suggests that their contribution is more closely associated with livestock welfare than with broader operational performance indicators. *Kleders* play a critical role in feeding, watering, monitoring animal health, handling emergencies, and ensuring the well-being of livestock during transportation [18]. However, these responsibilities primarily influence animal welfare outcomes rather than operational indicators such as voyage efficiency, scheduling performance, loading speed, or transportation productivity [12], [31].

Another factor that may explain the insignificant relationship is the variability in *Kleder* competency levels observed during the qualitative investigation. Interviews indicated that training opportunities, operational experience, and technical capabilities differ substantially among personnel. The absence of nationally standardized competency requirements and certification schemes may contribute to inconsistent performance among *Kleders*, thereby reducing the measurable influence of this variable within the structural model [18]. Strengthening training systems and establishing competency standards may therefore enhance the contribution of *Kleders* to livestock transportation performance in the future.

An interesting result concerns the exclusion of the regulation variable from the final structural model due to multicollinearity issues. The high Variance Inflation Factor (VIF) suggests that regulatory aspects are strongly embedded within existing service practices and therefore cannot be statistically distinguished as an independent construct. This finding implies that regulations currently operate indirectly through service implementation rather than as a separate determinant of operational performance. In practice, compliance with regulations is reflected in operational procedures, safety standards, animal welfare requirements, and service delivery mechanisms.

This finding differs from previous studies suggesting that regulatory frameworks can function independently through an Independent Regulatory Dimension (IRD), even within non-digital operational environments [32]. In the Indonesian livestock transportation context, however, regulations appear to be closely integrated into service activities, making it difficult to separate their effects from service quality itself. This result highlights the need for future digital governance systems that enable regulatory compliance, monitoring, and enforcement to be measured independently from operational service performance.

Overall, the findings suggest that the future development of livestock transportation in Indonesia should prioritize service quality enhancement and digital transformation. While maintaining adequate animal welfare standards remains essential, investments in monitoring technologies, communication systems, and digital operational management are likely to generate the greatest improvements in transportation performance. At the same time, strengthening *Kleder* competencies and developing more measurable regulatory mechanisms may further support the modernization and sustainability of the livestock shipping sector.

Received: 2026-02-23; Accepted: 2026-06-05
doi.org/10.62012/mp.vi.48801 | e-ISSN: 2828-6669 p-ISSN: 2828-7010

5. Conclusions

This study investigated the factors influencing the operational performance of livestock transportation vessels in Indonesia using a mixed-method approach combining SEM-PLS analysis and qualitative interviews. The results indicate that service quality and technology application are the primary determinants of operational performance. Among the examined variables, technology application emerged as the strongest predictor, reflecting stakeholders' expectations regarding the transformative potential of digital technologies in improving livestock transportation services.

The study also found that the role of the Kleder has a positive but statistically insignificant effect on operational performance. Although Kleders contribute substantially to livestock welfare and onboard animal management, their influence is concentrated at the animal-care level rather than on broader operational performance indicators. Furthermore, variations in competency levels among Kleders may reduce the consistency of their contribution across different transportation operations.

Another important finding is the exclusion of the regulation variable from the structural model due to multicollinearity. This result suggests that regulatory requirements are currently embedded within service delivery practices rather than functioning as an independent operational mechanism. Consequently, service quality becomes the primary channel through which regulatory compliance influences operational outcomes.

From a practical perspective, this study provides a scientific basis for the modernization of Indonesia's livestock transportation system. Policy priorities should include gradual digitalization of livestock vessels, implementation of real-time monitoring systems, improvement of communication technologies, enhancement of *Kleder* competencies through standardized training programs and strengthening of regulatory monitoring mechanisms.

Several limitations should be acknowledged. First, the sample size was relatively small (n = 34), which may limit the generalizability of the findings. Second, the technology construct was evaluated based on stakeholder perceptions rather than actual implementation and performance data. Third, the study focused primarily on organizational and operational factors and did not explicitly examine environmental or infrastructure-related variables.

Future research should involve larger samples and broader stakeholder representation. Studies may also evaluate the actual impact of digital technologies after implementation, compare operational performance between government-operated and privately operated livestock vessels, develop competency models for *Kleders*, and incorporate additional variables such as port infrastructure, weather conditions, biosecurity measures, animal welfare indicators, and logistics network performance.

Author contributions: AB; Conceptualization, Designing the study, and data analysis: IAT; data collection: IR; Correction of data analysis: SS; data collection: FU; correction of writing language: SSi; correction of writing language.

Competing interests: The authors declare that they have no competing interests.

Acknowledgments: We would like to thank all parties who have contributed to the completion of this research, especially the Directorate of Traffic and Sea Transportation, Directorate General of Sea Transportation, Ministry of Transportation, for their assistance. Thank you also to the respondents who have been willing to assist us in collecting data so that this research can be completed.

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Received: 2026-02-23; Accepted: 2026-06-05
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