Research Article

Implementation of Animal Welfare Standards on Livestock Vessels and Their Impact on Cattle Weight Loss and Financial Benefits

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Abstract | The use of dedicated livestock vessels, such as the Camara Nusantara (CN) fleet, is part of the Indonesian government's strategy to improve the efficiency of inter-island livestock transportation and welfare standards. This study evaluates the implementation of animal welfare principles on CN vessels, assesses their impact on cattle weight loss during transport, and the associated economic benefits. The research was conducted in August 2024 , focusing on cattle shipments from East Nusa Tenggara (ENT) via Tenau Seaport to Samarinda (East Kalimantan) using the CN-5 vessel. Primary data were collected through direct observation, interviews, and physical measurements of 135 randomly selected cattle across three decks (Deck A, B and C) by Slovin's formula with a 7.5% acceptable margin of error. Environmental conditions (temperature and humidity), feed and water provision, and welfare practices were monitored throughout the voyage. Structural adjustments to the vessel, particularly regarding conditions on Deck C, are recommended because this deck showed the most favorable Temperature-Humidity Index (THI)—a metric combining ambient temperature and humidity to assess thermal stress in cattle. Improving feed quality supplied by livestock traders during transport may reduce live weight loss. CN vessel operators should optimize blowers and ventilation systems to maintain humidity and temperature levels conducive to animal comfort, thereby mitigating weight loss. Weight loss was measured pre- and post-transport. A Benefit-Cost Analysis (BCA) and one-way ANOVA were applied to evaluate economic outcomes and differences across decks. The results indicated that implementing animal welfare standards reduced cattle weight loss, which ranged from 4.6% to 7.6%, with an average of 6.3%. Contributing factors included sufficient feed and water, adequate ventilation, and stress management. The BCA result of 1.243 (>1) confirms a positive financial return due to reduced weight loss and lower transport costs. Applying animal welfare principles in livestock transport is crucial to maintain animal performance, safeguard welfare, and ensure economic sustainability within Indonesia's livestock supply chain.

Keywords | Animal welfare, Camara nusantara, Cattle weight loss, Livestock vessel, Financial benefits

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INTRODUCTION

Livestock transportation is crucial to the livestock industry, serving as a vital link between producers and consumers across different regions. In Indonesia, an archipelagic country, sea transportation is the primary means of distributing livestock from production centres to consumer regions inaccessible by land routes. However, maritime livestock transport presents challenges, including extended distances, fluctuating sea conditions, and longer travel times. According to Winarso (2014), extended journeys increase logistical costs and negatively affect animal welfare and health.

One of Indonesia's main issues in sea-based livestock transportation is the limited implementation of animal welfare (AW) principles. This is largely due to the continued use of modified cargo vessels that do not adhere to proper AW standards for inter-island livestock transport. Inadequate transportation conditions can impose psychological and physical stress on animals (Buckham-Sporer *et al*., 2023). Such stress arises from extreme heat, improper handling, movement restrictions, limited access to feed and water, loud noises, overcrowding, and social disruption (Collins *et al*., 2018; Nicol and Scott, 1990). These stressors can lead to weight loss, elevated levels of cortisol, hematocrit, and creatinine in the blood, carcass bruising, and a decline in meat quality, which ultimately affects animal health and market value (Lendrawati *et al*., 2019; Carrasco-Garcia *et al*., 2020; Zanardi *et al*., 2022; Hultgren *et al*., 2022). Furthermore, transporting livestock using vessels not specifically designed for animals results in restricted movement, inadequate ventilation, and insufficient feed and water facilities. Consequently, cattle weight loss during transit can reach 11%–12%, leading to economic losses for farmers and industry stakeholders (Ilham and Yusdja, 2004).

In addition, irregular vessel leasing mechanisms and fluctuating charter costs pose significant barriers to efficient and sustainable livestock distribution (DITJENPKH, 2016). These challenges create uncertainty in livestock shipments from production centres and instability in livestock supply in consumer regions. Such conditions may drive up transportation costs and contribute to market price volatility.

To address these persistent challenges, the Indonesian government launched the Camara Nusantara (CN) fleet—a series of specialized livestock vessels designed to modernize the inter-island distribution of live animals. This national initiative aims to enhance transport efficiency, reduce logistical costs, streamline the distribution chain, and uphold animal welfare (Nugraha *et al*., 2020). Each of the six CN vessels were built under standardized government specifications and are equipped with improved facilities, including enlarged livestock compartments, enhanced ventilation systems, and scheduled feed and water management protocols to mitigate stressors during sea voyages. As government policy increasingly emphasizes evidence-based interventions, a systematic evaluation of the CN vessels is essential to assess their effectiveness in improving animal welfare, reducing weight loss during transport, increasing cost efficiency, and delivering economic benefits to farmers and industry stakeholders. While the present study focuses on CN-5, which operates the Kupang–Samarinda route, its findings are potentially generalizable across the CN due to the vessels' uniform design and operational protocols. Nonetheless, broader research across other vessels and routes remains necessary to validate these conclusions and support scaling efforts fully.

The novelty of this study lies in its comprehensive evaluation of CN vessels. Unlike previous studies that primarily focused on technical aspects of transportation, this research adopts a multidimensional analysis encompassing technical, animal welfare, and economic perspectives. Moreover, this study compares conditions before and after CN vessel implementation and quantifies the tangible impacts on animal welfare, transportation cost efficiency, and the financial benefits received by farmers and industry actors. Furthermore, this research examines the potential of CN vessels in supporting government policies aimed at improving animal welfare and enhancing the sustainability of the national livestock industry.

MATERIALS AND METHODS

Research Time and Location

This study was conducted in East Nusa Tenggara (ENT) Province, the departure point for cattle shipments via Tenau Seaport, with Jakarta and Samarinda City in East Kalimantan Province as the destinations (Figure 1). The research was carried out on August, 2024 .

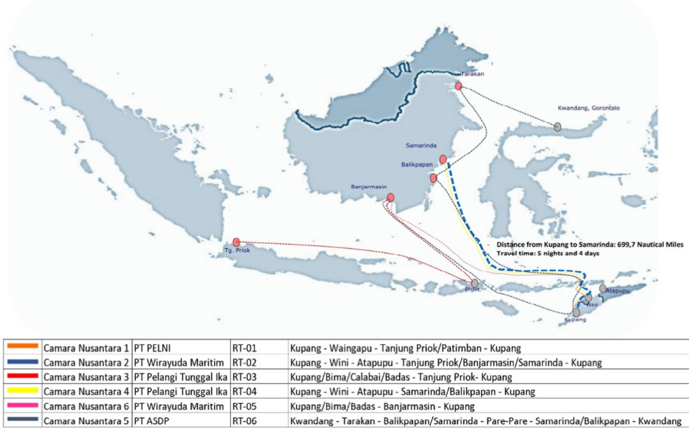

Figure 1: Camara nusantara ship route in 2024.

Types, Sources and Methods of Data Collection

This study utilized both primary and secondary data sources. Primary data included: (a) body weight measurements of cattle before and after transportation, (b) environmental parameters—temperature, humidity, and wind speed—recorded using thermometer, hygrometer, and anemometer, and (c) the frequency of feed and water provision during the voyage. Environmental conditions were measured continuously at one-minute intervals for temperature and humidity, and three times daily for wind speed. Secondary data were sourced from the Directorate General of Sea Transportation, Ministry of Transportation of the Republic of Indonesia, specifically including official records on government livestock shipping subsidy allocations in a year.

To determine the sample size for cattle weight measurement, the Slovin formula was applied using a 7.5% margin of error at a 92.5% confidence level, yielding a statistically representative sample of 135 cattle from a population of 2,100 head. All selected animals were weighed at the Animal Quarantine Facility in Kupang prior to loading and re-weighed at the destination facility in Samarinda. Observations of animal welfare practices were conducted throughout the voyage to capture real-time implementation patterns (Veissier *et al*., 2018).

Although the CN-5 vessel comprises four decks, data collection focused on Decks A, B, and C, with 45 cattle selected randomly from each. This approach ensured proportional representation and facilitated comparative analysis across varying environmental and structural conditions on board (see Figure 2).

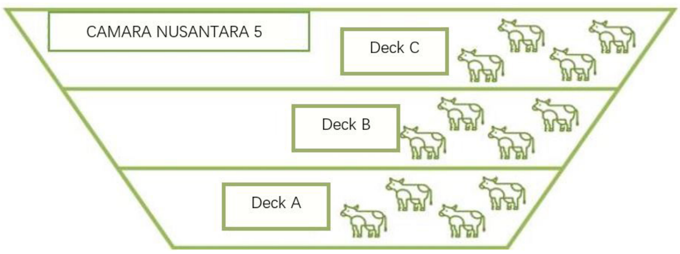

Figure 2: Positions of deck A, B, and C on the Camara Nusantara ship.

Data Analysis

Both quantitative and qualitative descriptive analyses were used to interpret the findings. Quantitative analysis involved tabulation and graphical representation of data, while qualitative analysis focused on descriptive observations regarding cattle conditions during transportation. One-way Analysis of Variance (ANOVA) was conducted to evaluate differences in weight loss across decks. This statistical approach was also applied to compare variations in environmental conditions, such as temperature and humidity, among Deck A, Deck B, and Deck C. The full expression of the ANOVA model used in this study is provided in the Supplementary Data.

The t-test is a widely used statistical hypothesis test to evaluate whether significant differences exist between the means of two or more groups (Kim, 2015). In this study, a t-test was applied to assess differences in cattle weight loss across groups on decks A, B, and C.

The financial benefits of using a dedicated livestock vessel were evaluated through the Benefit-Cost Analysis (BCA) method (Boardman *et al*., 2018). This approach assessed the financial feasibility of subsidized livestock transportation by comparing transportation costs, the impact of weight loss, and government-provided subsidies. The BCA formula applied in this study is shown below:

$$BCA = \frac{Total\ weight\ loss\ (Rp) + Transport\ cost(Rp)}{Total\ Goverment\ Subsidy\ (Rp)}$$

Where;
Total weight loss (Rp) refers to the monetary equivalent of cattle weight reduction during transport;
Transport cost (Rp) refers to the logistical expenses associated with livestock shipping;
Total government subsidy (Rp) denotes the financial support allocated for livestock vessel operations.

If the BCA value exceeds 1, the CN-5 livestock vessel demonstrates financial benefits. Conversely, if the BCA value is 1 or lower, this transportation system is deemed financially unfeasible. This method refers to the guidelines of Boardman *et al*. (2018), which outline cost-benefit analysis techniques for public policy decision-making.

RESULTS

Animal Welfare Principles on CN Vessels

Animal welfare is a critical consideration throughout the livestock industry, from upstream to downstream operations. It encompasses physical and psychological well-being, which are closely linked to their living conditions. These include animals' ability to exhibit natural behaviours, physical comfort, the absence of disease, and freedom from hunger (Giangaspero and Turno, 2024). This study presents the findings of an observational study on several practices and conditions during cattle transportation using the CN-5 vessel, which serves as a model for implementing animal welfare principles. Although the CN-5 vessel comprises four decks, only Decks A, B, and C were used for cattle placement and thus included in the sampling. Deck D, which functions as the engine room, was excluded from the study due to its non-relevance to animal transport.

Availability of Feed and Drinking Water

Research findings indicate that feed availability on board the Camara Nusantara 5 (CN-5) vessel is generally sufficient. The types of feed provided include corn stalks, rice straw, and dried natural grasses. On average, each animal received one bundle of feed weighing between 2.5 and 3 kg per feeding, with a frequency of three times daily—morning, noon, and evening. Leftover feed was collected and repurposed as bedding material, enhancing animal comfort and reducing the risk of injuries caused by rigid or slippery ship flooring. Feed quality analysis showed that the hay provided contained crude protein (CP) levels ranging from 1.73% to 2.14%. The results of the analysis can be seen in the table below (Table 1).

Table 1: The results of feed samples.

No	Test Parameters	Unit	Sample 1	Sample 2
1	Water Content	% DM	9.47	8.62
2	Ash	% DM	15.17	4.65
3	Crude Protein	% DM	2.41	1.73
4	Crude Fat	% DM	1.35	1.13
5	Crude Fiber	% DM	45.58	54.61
6	Calsium	% DM	1.45	0.7
7	Phospor	% DM	0.12	0.19

* The analysis was carried out at the feed quality testing and certification center, Indonesia. * % DM, percentages on a dry matter basis.

Environmental Conditions

The study results indicate that the onboard environmental conditions varied across decks, likely influencing differences in cattle weight loss during transport. The open deck (Deck C) generally provided a better environmental condition than the more enclosed Deck A and B, particularly in term of air circulation, temperature, and humidity. These findings are consistent with Mason *et al.* (2007), who reported that ventilation systems and the level of fresh air exposure significantly impact stress levels and animal welfare during transportation.

Table 2: Average temperature, humidity and THI.

Deck	Temperature (^{0}C)	Humidity (%)	Average THI
A	31.99	67.33	84
B	29.44	71.26	81
C	28.82	70.19	79

Source: Primary data, 2024.

Table 2 presents the average recorded temperatures during transport. The analysis revealed that the temperature on Deck C was lower than that on Deck A and Deck B. Deck C benefited from better ventilation, facilitating optimal air circulation and contributing to a more stable ambient temperature, thereby reducing thermal stress in the cattle. Conversely, animals housed on Deck A and B were exposed to higher temperatures, which may have led to increased basal metabolic rates and more significant energy expenditure for thermoregulation.

As presented in Table 2, Deck A maintained humidity within the optimal range, facilitated by blowers and additional ventilation on both the port and starboard sides of the vessel. This ventilation design enabled the removal of excess moisture, preventing the accumulation of humidity that could endanger animal welfare. Conversely, Decks B and C recorded higher humidity levels despite having access to outside air. This increase is likely associated with seawater evaporation, a common phenomenon during maritime transport (Petherick and Phillips, 2009). Elevated humidity increases the risk of skin infections, respiratory diseases, and metabolic disorders in cattle, especially when combined with high temperatures and suboptimal ventilation.

Table 2 shows the humidity levels recorded during transport on the livestock vessel CN-5 across the observed decks. Among the three analyzed decks, Deck A recorded the lowest relative humidity at 67.33%, while Decks B and C exhibited humidity levels of 71.26% and 70.19%, respectively. These findings demonstrate that Decks A, B, and C humidity levels remained within normal ranges. This aligns with the statement of Suprayogi *et al.* (2017), who reported that optimal pen humidity ranges from 60–80%.

Figure 3: Average temperature and humidity during transportation (Deck A).

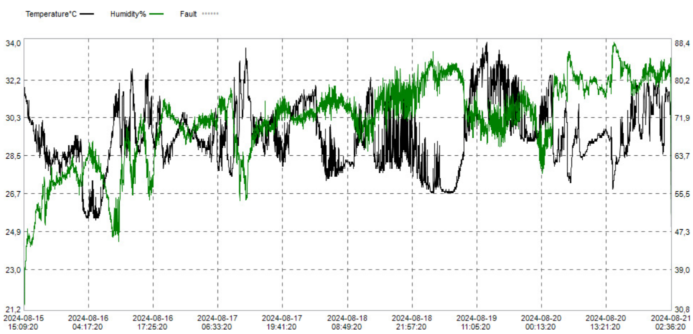

Figure 4: Average temperature and humidity during transportation (Deck B).

To better understand environmental variations during transport, Figures 3, 4, and 5 present visualizations of the average temperature and humidity on each Deck. The horizontal axes in Figures 3, 4, and 5 indicate the sailing days and the times at which air temperature and humidity measurements were taken. The left vertical axis represents air temperature (°C), while the right vertical axis represents relative humidity (%). Temperature trends over time are illustrated with black lines, whereas humidity trends are shown with green lines.

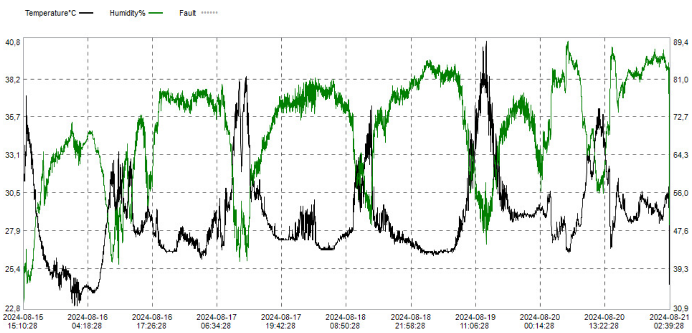

Figure 5: Average temperature and humidity during transportation (Deck C).

Data analysis revealed that Deck A recorded the highest THI value (84), followed by Deck B (81) and Deck C (79). A THI value exceeding 80 indicates suboptimal thermal conditions that may compromise animal comfort, potentially leading to heat stress and more significant live weight loss than other decks. In contrast, the THI value on Deck C suggests a more favourable environment for animal welfare during transport. Statistical analysis using one-way Analysis of Variance (ANOVA) confirmed a significant difference in the mean THI values across the decks ($P \leq 0.05$).

Weight Loss Impact During Transportation

This study's results showed that before transportation, the average body weight of cattle was 278.08 ± 38.85 kg, with the heaviest animal weighing 392 kg and the lightest 194 kg. After a five-day sea voyage aboard the Camara Nusantara vessel (CN-5) from Kupang (East Nusa Tenggara) to Samarinda (East Kalimantan), the average body weight decreased to 260.94 ± 39.37 kg, with the heaviest animal weighing 374 kg and the lightest 157 kg. Overall, there was an average weight loss of 6.27 ± 3.80%, reflecting the impact of long-distance travel and the ship's environmental conditions on animal welfare and transportation efficiency.

Table 3: Average weight loss.

Deck	Body Weight (kg)		Weight Loss (kg)	% Weight Loss
	Before	After		
A	268.31±30.74	247.98±30.05	20.33±10.56	7.58
B	284.73±49.29	266.49±49.95	18.24±8.52	6.61
C	281.20±31.06	268.36±32.26	12.84±8.78	4.62
Mean	278.08±38.85	260.94±39.37	17.14±9.79	6.27

Source: Primary data, (2024).

Details of weight loss by deck are presented in Table 3. These findings indicate variations in weight reduction across the observed decks, with Deck A experiencing the highest weight loss (7.58%), followed by Deck B (6.61%) and Deck C (4.62%). These differences are likely attributable to varying environmental factors, stocking densities, and ventilation systems on each deck.

Statistical analysis using one-way ANOVA revealed a significant difference in body weight loss among the three decks ($p \leq 0.05$). This finding indicates that deck location contributes to variations in weight loss, which may be attributed to environmental conditions within the vessel, such as air circulation and humidity. Deck A experienced the highest weight loss (7.58%), likely due to inadequate air circulation or higher stocking density than the other decks. Conversely, Deck C exhibited the lowest weight loss (4.62%), suggesting that the conditions on this deck were more favourable for animal welfare. These results demonstrate that optimizing ventilation can significantly reduce transport-induced stress and minimize weight loss in cattle during maritime transport.

The Associated of Economic Benefits

According to data from 2023, the average price of live cattle in Samarinda, the destination area, was recorded at IDR 61,019 per kilogram. During the same period, 23,869 head of cattle were transported using the CN-5 livestock vessel on the Tenau-ENT to Samarinda, East Kalimantan route. One key financial advantage of utilizing the CN livestock vessel is reducing cattle body weight loss during transportation.

Previous studies reported that cattle transported by conventional cargo vessels experienced an average body weight loss of 18.5% (Sujadi, 2019). In contrast, research on the CN-5 livestock vessel demonstrated an average weight loss of only 6.27%. This indicates that using the CN-5 livestock vessel reduces weight loss by 12.23% compared to cargo vessels. This difference has significant economic implications for livestock traders, as the final body weight of cattle upon arrival directly affects their market value. Assuming an average cattle weight of 278 kg, as reported in this study, the financial benefit derived from the reduced weight loss when using the CN livestock vessel amounts to approximately IDR 49,518,851,496. This reduced weight loss reflects improved transportation efficiency and translates into direct financial gains for traders.

In addition to minimizing body weight loss, this study also identified that the CN livestock vessel offers financial benefits through lower transportation costs. The average shipping cost using conventional cargo vessels on the Tenau-ENT to Samarinda-East Kalimantan route is approximately IDR 2,000,000 per head. The regulated fare for the CN livestock vessel, as stipulated in Minister of Transportation Regulation No. 76 of 2019 and Minister of Transportation Decree No. 260 of 2019, is set at IDR 771,600 per head on the same route. Therefore, the cost difference between cargo vessels and the CN livestock vessel is IDR 1,228,400 per head. Given the 23,869 cattle transported by the CN vessel in 2023, the cumulative financial benefit from reduced transportation costs amounts to IDR 29,320,679,600.

Overall, the total financial benefit of the CN livestock vessel, calculated from reduced body weight loss and savings in transportation costs, reaches IDR 78,839,531,096. To assess the economic feasibility of this policy, the financial benefits are compared with the government subsidy allocated to the CN livestock vessel in 2023, which amounted to IDR 63,426,377,000. Utilizing the Benefit-Cost Analysis (BCA) method, the benefit-cost ratio is calculated as follows:

$$BCA = \frac{Total\ weight\ loss\ (Rp) + Transport\ cost (Rp)}{Total\ Goverment\ Subsidy\ (Rp)}$$

$$= \frac{78{,}839{,}531{,}096}{63{,}426{,}377{,}00\ 0}$$

$$= 1{,}243$$

DISCUSSION

Animal Welfare Principles on CN Vessels

In Indonesia, livestock handling during transportation has yet to fully adhere to established animal welfare standards. This is evident in practices observed while loading animals onto vessels, throughout the journey, and during the unloading process, all of which still exhibit significant shortcomings. In response to these issues, the government has introduced improvements in livestock transportation systems, particularly for inter-island transport using CN livestock vessels. Traditionally, inter-island cattle transport has relied on cargo ships not specifically designed for livestock carriage. As a result, their design and handling procedures fail to meet animal welfare standards.

Availability of Feed and Drinking Water

The provision of feed and drinking water during livestock transport is crucial for maintaining for animal welfare and physiological stability throughout the journey. Prolonged hunger is strongly associated with compromised animal welfare during transportation and can lead to specific physiological changes (Giangspero and Turno, 2024). The proximate analysis results presented in Table 1 represent the average chemical composition of the mixed roughage provided to cattle on board the Camara Nusantara 5 (CN-5) livestock vessel. The feed consisted of a heterogeneous blend of corn stalks, rice straw, and dried natural grasses, as distributed and consumed in practice. The reported values, including CP content ranging from 1.73% to 2.14%, correspond to the nutritional profile of the total mixed feed.

While the provision of feed three times daily was intended to maintain physiological balance, it is important to acknowledge that the CP content of 1.73–2.14% is critically low when compared to the recommended dietary requirements for ruminants undergoing transport stress, which typically range from 7% to 12% CP depending on age and condition (NRC, 2016). These low CP levels, although common in tropical fibrous forages, may be inadequate for maintaining muscle metabolism and immune function during prolonged voyages.

Furthermore, it should be noted that feed intake was not measured directly at the individual level. Instead, data were based on recorded feed provision schedules and estimated group-level consumption. This limitation could introduce bias, particularly if stress-related anorexia influenced access to feed. Future studies should consider integrating indirect intake estimation methods (e.g., residual feed analysis or marker-based assessments) to improve accuracy.

Continuous feed availability and a consistent feeding schedule during transport helped maintain metabolic balance. Feed deficiencies during transit can lead to hepatic glycogen depletion as the animal shifts to alternative energy sources, resulting in a negative energy balance, as indicated by elevated concentrations of non-esterified fatty acids and β-hydroxybutyrate in the blood (Earley and O'Riordan, 2006; Ginane *et al*., 2015).

In addition to feed management, an efficient water supply system is essential to prevent dehydration and reduce transport-induced stress. The CN-5 vessel features a water distribution system that is superior to those on conventional cargo ships, ensuring regular access to drinking water. Prolonged thirst can cause dehydration, leading to adverse effects, including behavioral changes, when animals are deprived of water for more than 12 hours during transport (Nielsen *et al*., 2022). Study results show that each animal received an average of 25.4 litres of water per day, administered in three sessions aligned with the feeding schedule. Adequate and consistent water intake prevents dehydration, which could otherwise lead to reduce feed intake, metabolic disturbances, and increased oxidative stress (Grandin, 2019).

However, several challenges affecting the water distribution system on the CN-5 were identified, potentially impacting water availability for the animals. These include low water pressure and a limited number of drinking stations. Under certain conditions, uneven water distribution can hinder some animals from receiving sufficient water, increasing the risk of dehydration, reducing feed intake, and disrupting electrolyte balance. Insufficient hydration can negatively impact physiological performance, leading to weight loss due to fluid deficits and decreased metabolic efficiency (Mitlohner *et al*., 2001).

The findings of this study highlighted that improved feed and water management on board the CN-5 significantly enhances animal welfare and transport efficiency. A well-structured feeding and watering schedule helps maintain the physiological stability, reduces stress levels and minimizes economic losses due to weight shrinkage during transport. Despite existing technical limitations in water distribution, optimizing the system such as increasing water pressure, adding drinking stations, and implementing hydration monitoring systems-can further enhance livestock transport effectiveness in the future.

Environmental Conditions

Temperature fluctuations can disrupt metabolic homeostasis in livestock, ultimately affecting body weight retention during transport. Previous studies have confirmed that exposure to high temperatures during transportation increases fluid loss and oxidative stress in cattle (Mitloehner *et al*., 2001). These findings also indicate that cattle exposed to more stable experiencing more stable temperatures with controlled humidity exhibit lower weight loss percentages than those subjected to extreme temperature fluctuations.

Cattle transported from Kupang, East Nusa Tenggara (ENT), predominantly consist of Bali cattle, a local breed with physiological adaptations to the region's hot and arid tropical climate. Bali cattle have evolved to tolerate high temperatures and low rainfall conditions, making them well-suited for the extreme environment of ENT (Rahayu *et al*., 2016). The optimal temperature range for Bali cattle lies between 24°C and 30°C. Although they can withstand higher temperatures than temperate-region cattle, prolonged exposure to extreme heat still poses risks to their welfare and productivity. According to FAO (2011), the normal ambient temperature range for cattle is 18–24°C, with critical temperatures starting at 27°C. Literature indicates that at 25°C, cattle exhibit increased respiration and sweating rates while rectal temperatures rise at 26°C. Beyond these thresholds, cattle are likely to experience heat stress (McDowell *et al*., 1969; Bianca, 1962). Heat stress occurs when livestock fail to maintain homeothermy (Buckham-Sporer *et al*., 2023). According to Nielsen *et al*. (2022), the maximum permissible temperature during transport is 27°C, with a relative humidity of 80%.

Prolonged exposure to high temperatures may result in heat stress, characterized by an increased respiratory rate, greater water intake, and the release of stress hormones such as cortisol. Previous research has shown that chronic heat stress in cattle can reduce feed efficiency and cause electrolyte imbalance, ultimately leading to weight loss during transport (Gaughan *et al*., 2010; Mahrunisa et al., 1999).

In addition to temperature, ambient humidity plays a critical role in determining livestock health and welfare during transport. Humidity levels are influenced by the ship's internal temperature, ventilation systems, and seawater evaporation throughout the voyage. Excessively high and low humidity can have a negative impact on cattle, particularly in terms of thermal stress, skin health, and overall welfare. Overall, the combination of high temperature and humidity contributes to an increased THI, a key indicator for assessing livestock's risk of heat stress (Dikmen and Hansen, 2009). Therefore, optimizing the ship's ventilation and cooling systems is essential to mitigate the adverse effects of transport on cattle health and productivity.

The lower humidity on Deck A is attributed to the optimal performance of the ventilation system, with all blowers on both sides of the vessel operating effectively to ensure better airflow. In contrast, Decks B and C exhibited higher humidity levels despite being more open and having greater access to external airflow. Seawater evaporation can explain this phenomenon, which increases air moisture around the more exposed areas. Thus, although natural ventilation was expected to be more effective on these decks, evaporation effects appear more dominant, leading to higher humidity levels.

The environmental conditions on each vessel deck were monitored throughout transport to evaluate their impact on animal comfort and welfare. These variables were measured using standardized equipment to ensure accurate and reliable data collection. In this study, the THI was employed as the primary indicator for assessing the environmental conditions on each deck. THI integrates temperature and humidity into a single numerical value that reflects the level of thermal stress experienced by the animals.

Generally, thermoneutral conditions are achieved when the THI is below 72, indicating the absence of stress symptoms. Mild stress occurs at THI values between 72–79, moderate between 80–89, and severe between 90–99, as defined by Dikmen and Hansen (2009) and supported by subsequent literature (Veissier *et al*., 2018; Dimov *et al*., 2020).

The findings indicate that insufficient air circulation on Deck A was the primary factor contributing to the elevated THI and poorer environmental conditions than the other decks. One of the significant consequences of suboptimal ventilation is the accumulation of ammonia gas, which originates from the decomposition of animal faeces and urine during transit. Elevated ammonia levels impair respiratory health, exacerbate physiological stress, and increase livestock risk of upper respiratory tract infections (Jones *et al*., 2019). Ammonia buildup may also reduce feed intake, resulting in more severe live weight loss during transportation. This study highlights that adequate ventilation and air humidity management are crucial to ensuring animal welfare during maritime transport. Improving the ventilation system, particularly on Deck A, is essential to mitigate heat stress and enhance the efficiency of livestock transport aboard the CN-5 vessel.

Free from Pain, Injury and Disease

Based on research findings, the presence of veterinary medical and paramedical personnel conducting health examinations during transportation and the availability of medications on board ensures that the animal welfare aspect—specifically, livestock being free from pain, injury, and disease—is adequately met. According to the established procedures on board, veterinary medical personnel and paramedics typically conduct monitoring twice daily, in the morning and evening. This aligns with Matthews *et al*. (2016), who emphasized the importance of such monitoring for the early detection of health issues and timely intervention. Additionally, quarantine facilities are available to isolate sick animals, preventing disease transmission. This policy is consistent with best practices in livestock management, as the segregation of sick animals increases the likelihood of recovery (Broom, 2019).

Free from Unnecessary Fear and Stress

Research findings indicate that several factors contribute to unnecessary fear during transportation, including loud noises from blowers and ship engines. Creating a calm environment in the holding pens and minimizing loud noises around the farm can provide a comfortable condition for livestock, ensuring they remain free from fear (Yuliati, 2019).

Behavioral Freedom of Livestock During Transport

This study also evaluated the implementation of animal welfare practices by measuring the available movement space for livestock during transport on the CN-5 vessel. Several studies have indicated optimal stocking density is achieved when animals are not overcrowded and can still lie down during the journey (Tarrant, 1990; Buckham-Sporer *et al*., 2023). Increased stocking density has been associated with elevated stress levels, higher heart rates, more significant injuries and bruising, and reduced carcass weight (Tarrant, 1990). Measurements conducted in this study revealed that the cattle transported on CN-5 had an average floor space of 2.45 m^2 per head across the three main decks observed during the voyage. This relatively low stocking density allows the animals to express natural behaviours, a key indicator of animal welfare during transport. Adequate space availability enables cattle to stand steadily, rest comfortably, and perform the minimal movements necessary to maintain balance during sea transit.

Nevertheless, in practice, the cattle were tied to the pen rails to facilitate management and minimize the risk of injury due to vessel movement. This restriction of movement is considered necessary to maintain order, given that the dynamic conditions of maritime transport can increase the risk of slips or collisions between animals. However, despite these limitations, the animals retained a certain degree of flexibility to move within confined boundaries. They could sit or lie on the pen floor, which may help reduce stress and discomfort during the journey. A study by Grandin (2019) reported that sufficient movement space during transport directly correlates with reduced physiological stress in livestock, ultimately minimizing weight loss and promoting health stability during transit.

Weight Loss Impact During Transportation

Suboptimal transportation processes can induce physiological and metabolic stress in livestock, contributing to body weight loss and reduced carcass quality (Pantur *et al*., 2023). Body weight loss during transport can be classified into two categories: shrinkage due to the excretion of faeces and urine and shrinkage resulting from fluid loss within animal tissues (Coffey *et al*., 2015). According to Pantur *et al*. (2023), weight loss in livestock during transportation is generally caused by several factors, including limited feed intake, suboptimal air circulation, high stocking density, and inefficient pre-loading, loading, accommodation, and unloading processes. In addition to environmental conditions, several other factors influence body weight loss in livestock, such as handling procedures, previous feeding regimens, initial conditioning, feed additives, and the type of forage provided (Coffey *et al*., 2015; Malindo *et al*., 2023).

Weight loss during transportation is closely related to physiological stress, which leads to reduced muscle glycogen levels, fluid loss, and decreased carcass quality (Lawrie, 1991). The findings of this study indicate that the weight loss of cattle transported using the CN-5 livestock vessel (6.27%) was significantly lower than that of cattle transported using conventional cargo vessels. These results are consistent with Sujadi (2019), who reported that specialized livestock vessels such as the CN-5 can reduce body weight loss to approximately 7–12%, compared to conventional cargo vessels, where weight loss can reach up to 18.5%.

The results of this study reinforce previous findings emphasizing the importance of transport management in safeguarding animal welfare and mitigating economic losses due to body weight reduction (Sujadi, 2019). Therefore, further research is warranted to explore optimal strategies for improving the onboard environment, including ventilation design enhancements and optimizing feed and water provision during transit. These strategies are expected to improve livestock transportation efficiency, reduce transport stress's impact, and minimize body weight loss during sea voyages.

The Associated of Economic Benefits

BCA value of 1.243 (>1) indicates that the CN livestock vessel program is financially viable under current conditions, which include government subsidies. These findings affirm that the livestock vessel subsidy program effectively reduces transportation costs and directly contributes to increasing profit margins for livestock businesses. Furthermore, the results of this study align with previous research demonstrating that improved livestock transportation systems can reduce animal stress, minimize body weight loss, and enhance the efficiency of livestock supply chains (Grandin, 2019).

From a policy perspective, the findings of this study support the continuation of livestock transportation subsidies, highlighting their benefits in stabilizing meat prices and promoting animal welfare during transport. Nevertheless, further improvements are necessary to optimize logistics systems, enhance animal welfare standards onboard livestock vessels, and conduct additional studies to explore the potential expansion of routes and fleet size to broaden the program's benefits.

A basic sensitivity analysis was conducted to evaluate the financial feasibility of the program without subsidies. In Scenario 1 (with subsidies), the total financial benefit—estimated at IDR 78.8 billion—exceeded the government's 2023 subsidy allocation of IDR 63.4 billion, resulting in a BCA of 1.243. In Scenario 2 (without subsidies), the BCA value fell to 1.00, suggesting that without public support, the program's economic viability would be marginal. If operational costs were to rise above current subsidy levels, the BCA would drop below the break-even point, rendering the initiative financially unsustainable.

These findings emphasize the critical role of government subsidies, especially in the early implementation phase. However, to ensure long-term sustainability, the program must pursue cost-reduction strategies. These may include optimizing vessel capacity, enhancing feed logistics, scaling up operations for better economies of scale, and leveraging public–private partnerships (PPPs) to share financial burdens and stimulate investment.

It is important to note that the financial benefits assessed in this study are limited to direct economic gains from reduced live weight loss during transport. Broader economic impacts—such as decreased veterinary treatment costs, improved animal performance post-transport, or increased compliance with contractual specifications—were not included in this analysis and warrant future investigation. Future studies should incorporate probabilistic sensitivity analysis (e.g., Monte Carlo simulations) and long-term financial modeling to evaluate program sustainability under variable market and operational conditions.

CONCLUSIONS AND RECOMMENDATIONS

This study indicates that the specialized livestock vessel Camara Nusantara 5 (CN-5) facilitates improved implementation of animal welfare practices in alignment with key recommendations outlined in the World Organisation for Animal Health (WOAH) Terrestrial Animal Health Code (Chapter 7.2), particularly regarding feed and water availability, thermal stress management, and injury prevention. These practices contributed to reducing live weight loss during cattle transport from Kupang to Samarinda to 6.27%, compared to the 18.5% typically recorded on conventional cargo vessels lacking dedicated livestock infrastructure. Improving feed quality supplied by livestock traders during transport may reduce live weight loss. Structural adjustments to the vessel, particularly regarding conditions on Deck C, are recommended. The Benefit-Cost Analysis (BCA) result is 1,243, assessing the benefits of reduced live weight loss and lower livestock transportation costs against the government subsidies, indicates feasibility with a BCA value greater than 1. The comprehensive application of animal welfare principles during livestock transportation using Camara Nusantara vessels is essential to minimize negative impacts on animal performance, welfare, and financial losses.

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NOVELTY STATEMENTS

This study provides the first integrated evaluation of animal welfare implementation, environmental conditions, and economic outcomes aboard Indonesia's specialized livestock vessel, Camara Nusantara-5. It uniquely combines physiological data (cattle weight loss), environmental metrics (temperature-humidity index), and financial analysis (Benefit-Cost Analysis) to assess the impact of maritime transport on cattle welfare and performance. The findings demonstrate that improved vessel design and welfare practices significantly reduce live weight loss (average 6.27%) compared to conventional cargo vessels (18.5%), leading to measurable financial benefits. This multidisciplinary approach offers new evidence supporting national livestock transport policy, with implications for improving animal welfare standards and cost-efficiency in inter-island shipping systems.

AUTHOR'S CONTRIBUTIONS

Conceptualization and Methodology: T. Melasari, B. Guntoro, M.A.U. Muzayyanah and N. Ilham.
Investigation: T. Melasari, B. Guntoro, N. Ilham.
Data Curation: T. Melasari, B. Guntoro, N. Ilham and M.A.U. Muzayyanah. Writing – Original Draft Preparation: T. Melasari, M.A.U. Muzayyanah and R. Malindo.
Writing – Review and Editing: B. Guntoro, M.A.U. Muzayyanah, N. Ilham and N.H. Qui.

SUPPLEMENTARY MATERIAL

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.aavs/2025/13.7.1586.1596

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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