

MANAGEMENT OF ANIMAL TRANSPORTATION WITH REGARD TO ANIMAL WELFARE AND WORKER SAFETY

Maria PILARCZYK^{1*}, Robert ULEWICZ²

¹ Czestochowa University of Technology; maria.pilarczyk@pcz.pl, ORCID: 0000-0001-7401-8885

² Czestochowa University of Technology; robert.ulewicz@pcz.pl, ORCID: 0000-0002-5694-4284

* Correspondence author

Purpose: This paper aims to analyze livestock transport management, with a focus on minimizing animal stress and ensuring the safety of personnel involved in the process. The study examines key factors affecting animal welfare, including transport duration, environmental conditions, vehicle design, loading and unloading procedures, and personnel competence, while addressing associated occupational hazards.

Design/methodology/approach: A comprehensive literature review was conducted using PubMed, Web of Science, Scopus, and Google Scholar. Out of 130 relevant full-text publications, 41 key sources were selected for detailed analysis. Hazards were categorized by transport mode—road, rail, sea, and air—using risk assessment methods based on hazard severity and duration to prioritize interventions. Practical and organizational strategies for reducing stress and injury risk were synthesized from empirical studies and EU regulations, including Regulation (EC) No 1/2005.

Findings: Extended transport duration, limited access to water and feed, insufficient space, inadequate ventilation, and improper handling during loading and unloading were identified as primary stressors for animals and major occupational hazards for workers. Risk assessment highlighted highest-priority hazards, such as dehydration, pathogen exposure, and extreme environmental conditions. Implementing optimized transport routes, appropriate vehicle design, well-trained personnel, and real-time monitoring systems significantly improves animal welfare and reduces occupational risks.

Research limitations/implications: The study is based on literature and the EU regulatory context, which may not fully reflect practices in other regions. Future research should include field studies, real-time monitoring data, and evaluation of novel transport technologies to further refine welfare and safety strategies.

Practical implications: Adopting structured transport management practices enhances animal welfare, reduces economic losses, and improves workplace safety. Recommendations include route optimization, proper ramp design, adherence to space requirements, staff training, and real-time monitoring of transport conditions.

Social implications: Improved transport practices support societal expectations regarding animal welfare, contribute to public health through reduced zoonotic risks, and encourage responsible corporate and regulatory practices.

Originality/value: This paper integrates risk assessment with practical management solutions, offering a holistic approach to animal transport that simultaneously addresses welfare and occupational safety. It is valuable to farmers, transport companies, animal welfare authorities, and policymakers.

Keywords: animal transport, animal welfare, occupational safety, risk assessment, transport management.

Category of the paper: Literature review; risk assessment study.

Introduction

In 2022, a total of approximately 1.6 billion live sheep, cattle, poultry, and pigs were transported for commercial purposes within the European Union and beyond its borders by road, sea, rail, and air (European Commission, 2023). Long-distance animal transport is largely driven by economic factors, but it is increasingly the subject of discussions regarding animal welfare. Transport-related losses, including mortality, injuries, and reduced product quality, generate measurable economic costs for the livestock sector (Erzurum, Yilmaz, 2018). Contemporary transport methods have been highlighted as potential sources of stress and numerous hazards for animals (Broom, 1986; Christensen et al., 1994). This issue attracts the attention not only of animal welfare organizations and activists but also of supply chain participants, including farmers, slaughterhouses, and transport companies (Appleby et al., 2008). Increasing attention is also being paid to workers involved in the transport process, such as drivers, animal attendants, and personnel responsible for loading and unloading. These individuals often have direct contact with animals, which entails risks of injury during handling, stress from responsibility for animal welfare, and physical strain due to challenging environmental conditions.

Effective transport management enables the identification of issues within transportation processes and the implementation of solutions that provide tangible benefits. The competencies of managers play a crucial role, both in strategic planning and operational decision-making. Animal transport management encompasses a range of activities, from transport planning and selection of appropriate vehicles to the application of methods tailored to the needs of live cargo (Faucitano, Lambooi, 2019). Unlike goods, animals are susceptible to stress and injury, particularly during prolonged journeys, which requires adherence to proper practices and high handling standards. Therefore, effective transport organization entails simultaneously ensuring animal welfare and the safety of personnel who interact with them (Budzik, Budzik, 2019).

As public awareness grows, increasing attention is being paid to the conditions under which animals are transported. In European Union policy, animal welfare has been recognized as a priority area within the framework of the European Green Deal. Nevertheless, animal transport continues to involve numerous stress-inducing factors, occurring both during the

journey and during loading and unloading, stages particularly critical in terms of injury risk and behavioral disturbances. In recent years, technological progress has been made, replacing outdated and often non-ergonomic solutions with more advanced systems designed to enhance animal comfort and safety. However, despite these improvements, existing EU regulations still lag behind current scientific knowledge and transport practices. Updating these regulations is necessary to more effectively minimize stressors and reduce the risk of compromised animal welfare during transport (Giangaspero, Turno, 2024).

Animal welfare during transport is regulated under EU law. The primary legal act is Regulation (EC) No 1/2005 (EC, 2005). According to Article 1, this regulation concerns the transport of live vertebrate animals within the Community. Its main objective is to prevent injury and unnecessary suffering during transport. The regulation also aims to limit long-distance transport whenever possible and to ensure animal welfare both during the journey and upon its completion.

Despite extensive research on animal welfare during transport, existing studies predominantly focus either on animal-related stressors or on occupational risks for workers. There is a lack of integrated analyses that simultaneously assess animal welfare hazards and corresponding risks to transport personnel across different transport modes using a structured risk assessment framework.

The aim of this study is to conduct a comprehensive analysis of livestock transport management, with particular emphasis on animal welfare and the safety of personnel involved in the transport process. The analysis includes identifying key factors affecting animals' comfort, health, and behavioral responses during transport, as well as assessing hazards specific to different modes of transport (road, rail, sea, and air). The study also seeks to propose practical organizational and technological solutions, as well as operational procedures, that can effectively minimize animal stress and reduce the risk of injuries and occupational strain among personnel responsible for handling animals.

Effective management of livestock transport including optimized route planning, appropriate vehicle conditions, access to water and feed, and qualified workers leads to a significant reduction in physiological and psychological stress in animals, as well as a decrease in the risk of injury and overexertion among transport workers

Methods

The literature review was conducted following a structured search strategy. Searches were performed in the PubMed, Web of Science, Scopus, and Google Scholar databases. The literature search covered publications available from database inception until August 2025, with the final search conducted in August 2025.

The following keywords and phrases were used: “animal welfare”, “transport stress”, “behavioral stress indicators”, “animal transport management”, “loading and unloading procedures”, “worker safety” “injury risk”, “injury minimization”, “transport condition monitoring”, “ventilation and temperature in transport”, “animal transport space”, “transport route planning”, “animal rest and breaks”, “human–animal interactions during transport”, “protective equipment for workers”, “impact of transport on animal condition”, “economic loss reduction”, “innovative logistics solutions”, and “livestock transport organization”. Logical operators (“AND”, “OR”) were applied to combine keywords, and query syntax was adapted to the advanced search capabilities of each database.

The initial search yielded approximately 600 records. After removal of duplicates, titles and abstracts were screened for relevance, reducing the number of publications to 200. Full-text screening was then performed. Publications were excluded if they were not directly related to livestock transport, animal welfare, or worker safety, or if they demonstrated insufficient methodological quality.

Methodological quality was assessed based on commonly accepted criteria for narrative reviews, including clarity of study objectives, appropriateness of study design, transparency of methods, adequacy of sample description, and consistency between results and conclusions. Studies lacking sufficient methodological transparency or presenting anecdotal or non-verifiable data were excluded. Following this process, 130 full-text articles were assessed in detail, of which 41 key publications were ultimately included in the review and formed the basis for the synthesis of findings.

To enhance transparency and focus on the most relevant evidence, a final set of 41 key publications was selected using a qualitative, multi-criteria relevance assessment. Publications were considered “key” if they demonstrated strong methodological rigor, addressed both animal welfare and worker safety in livestock transport, provided findings applicable across different transport types, and offered clear practical or managerial guidance. Studies that met the inclusion criteria but had a narrower thematic scope, less methodological transparency, or limited applicability to transport practice were retained as supporting literature but were not classified as key publications.

The selected publications were categorized into the following thematic areas: animal welfare during road, rail, sea, and air transport; stress indicators and animal behavior during transport; safe loading and unloading procedures; transport management and route planning; vehicle design; ventilation; space allocation for animals; and worker safety and ergonomics in transport operations.

Inclusion criteria for publications were as follows:

- Publications must directly address animal welfare, stress reduction, and worker safety in the context of livestock transport.
- Original scientific research, review articles, and book chapters containing reliable and verifiable data.
- Full-text availability to allow detailed analysis of research methodology and results.

Given the heterogeneity of study designs, animal species, and outcome measures, no meta-analysis was conducted. Therefore, conclusions are based on qualitative synthesis, and results are described using cautious language (e.g., “the literature suggests” or “the literature indicates”) rather than implying statistical significance.

The findings were thematically organized to enable a comprehensive discussion of practical solutions, procedures, and management strategies aimed at minimizing animal stress and reducing the risk of injuries among personnel involved in transport operations.

2.1. Risk assessment procedure

The risk assessment procedure applied in this study consisted of four main stages: hazard identification, hazard characterization, exposure assessment, and final risk characterization. A key element of this analysis was the evaluation of potential impacts of identified hazards on individual animals. To quantify risk, the concept of magnitude was used, which combines the severity of the hazard (Severity) and the expected duration of its impact (Duration) according to the formula (Marahrens et al., 2011; Mueller-Graf et al., 2007):

$$\mathbf{Magnitude = Severity \times Duration}$$

Each hazard identified in the literature was assigned Severity and Duration values on a 1-5 scale, following established protocols in animal welfare studies (Marahrens et al., 2011; Mueller-Graf et al., 2007). The resulting magnitude values enabled the ranking and prioritization of hazards, allowing the study to focus preventive measures on those with the greatest potential impact on animal welfare and worker safety.

Before applying this procedure, the population under analysis was defined carefully, taking into account the variability in transport methods, journey durations, and environmental conditions, such as microclimate, which can vary significantly across Europe (Marahrens et al., 2011). This structured approach provided a transparent and replicable framework for assessing risks across road, rail, sea, and air transport of livestock.

Results

Animal welfare risk assessment was conducted to identify and classify hazards across different modes of livestock transport. Hazards were evaluated based on severity (1-5) and duration (1-5), and a magnitude score ($\text{Magnitude} = \text{Severity} \times \text{Duration}$) was calculated to quantify their potential impact. Hazards with higher magnitude scores indicate a greater potential impact on animal welfare.

3.1. Road transport

Table 1 presents the identified hazards during road transport of livestock and their corresponding severity, duration, and magnitude scores. Prolonged journey duration and limited access to water and feed have been identified as key welfare risk factors during road transport (Buckham-Sporer et al., 2023). Severity refers to the intensity of the negative effect on animal welfare, while duration reflects how long the animal is exposed to hazard. The magnitude score combines these two parameters, allowing for prioritization of the most critical hazards that require immediate attention or intervention.

Table 1.
Animal welfare risk assessment during road transport

Hazard category	Severity (1-5)	Duration (1-5)	Magnitude (S × D)
Insufficient ventilation	4	4	16
Inadequate space	4	4	16
Long transport duration	4	5	20
Lack or limited access to water and feed	5	5	25
Improper handling during loading/unloading	4	3	12
Poor animal condition prior to transport	4	4	16
Introduction of pathogens	5	4	20
Inadequate rest periods	3	4	12

Source: Own research.

3.2. Rail transport

Table 2 summarizes hazards associated with rail transport, including notes on specific conditions that may exacerbate these hazards. This overview enables comparison of the relative impact of different hazards and helps identify areas where management or infrastructure improvements are most needed.

Table 2.
Animal welfare risk assessment during rail transport

Hazard category	Severity (1-5)	Duration (1-5)	Magnitude (S × D)	Notes
Insufficient ventilation	3	4	12	Rail cars usually have ventilation, but with high animal density it may be insufficient
Inadequate space	3	4	12	Space is limited, especially for long-distance transport

Cont. table 2.

Long transport duration	4	5	20	Rail covers long distances, which may extend journey times
Lack or limited access to water and feed	5	4	20	Supplying water and feed in rail cars is more difficult than in trucks and requires special organization
Improper handling during loading/unloading	4	3	12	Loading/unloading at rail terminals can be stressful and requires trained staff
Poor animal condition prior to transport	4	4	16	Animals in poor condition cope worse with transport
Introduction of pathogens	4	4	16	Long journeys in closed wagons increase the risk of disease spread
Inadequate rest periods	4	4	16	Long rail routes require well-planned stops and rest periods for animals

Source: Own research.

3.3. Sea transport

Table 3 shows hazards occurring during sea transport. Due to longer journey durations and the unique challenges of marine conditions, additional factors such as ship motion, vibrations, and limited veterinary access are included (Navarro et al., 2018). The table highlights both the severity and duration of each hazard, supporting a targeted approach to risk mitigation.

Table 3.

Animal welfare risk assessment during sea transport

Hazard category	Severity (1-5)	Duration (1-5)	Magnitude (S × D)	Notes
Insufficient ventilation	4	4	16	Ventilation in closed containers or decks may be insufficient with high animal density
Inadequate space	4	4	16	Limited space in containers or on deck can restrict animal movement
Long transport duration	5	5	25	Sea voyages often last several days or weeks, increasing stress and health risks
Lack or limited access to water and feed	5	5	25	Requires automatic systems or regular delivery; organizational errors may cause dehydration or starvation
Improper handling during loading/unloading	4	3	12	Loading onto and unloading from ships is stressful and requires trained personnel
Poor animal condition prior to transport	4	4	16	Animals in poor condition tolerate long sea journeys worse
Introduction of pathogens	5	4	20	Closed containers and long transport promote disease spread
Inadequate rest periods	4	5	20	Long journeys require systematic rest and monitoring; lack of quick stops increases risk
Ship motion and vibrations	4	5	20	Prolonged rocking may cause seasickness, weakness, and stress
Variable climatic conditions	4	4	16	Extreme temperatures, humidity, and wind can worsen welfare
Isolation and limited veterinary care	5	4	20	Lack of rapid intervention in case of illness or injury increases risk

Cont. table 3.

Environmental contamination	4	4	16	Ammonia, moisture, and dust promote disease and respiratory irritation
Ship noise	3	5	15	Continuous engine and pump noise induces chronic stress
Risk of marine accidents	5	2	10	Ship failure, fire, or storm pose high risk, though rare

Source: Own research.

3.4. Air transport

Table 4 provides an assessment of hazards during air transport. Even though flights are generally shorter, factors such as cabin pressure changes, noise, and limited access to feed and water can have significant impacts on animal welfare. The magnitude scores facilitate identification of the most critical stressors during air transport.

Table 4.

Animal welfare risk assessment during air transport

Hazard category	Severity (1-5)	Duration (1-5)	Magnitude (S × D)	Notes
Insufficient ventilation	4	3	12	Cargo holds and containers must be properly ventilated; risk increases if air conditioning fails
Inadequate space	4	3	12	Air containers restrict movement; stress increases on long flights
Long transport duration	3	4	12	Flights are shorter than sea or rail transport, but terminal waiting and transfers extend total time
Lack or limited access to water and feed	5	3	15	No water or feed can be given during flight; proper preparation before and after is essential
Improper handling during loading/unloading	5	3	15	Handling at airports and during loading onto aircraft can be stressful
Poor animal condition prior to transport	5	3	15	Animals in poor condition are at higher risk of flight-related complications (stress, respiratory issues)
Inadequate rest periods	3	3	9	Flights are usually short, but lack of rest before and after affects welfare
Pressure changes and stress	5	4	20	Cabin pressure changes, take-off, landing, and turbulence can cause stress, respiratory problems, and pain
Aircraft noise	4	4	16	Engine noise during take-off, landing, and flight induces chronic stress
Temperature and humidity in cargo hold	4	4	16	Improper control can lead to overheating or chilling
Isolation and lack of veterinary care during flight	5	3	15	Lack of immediate veterinary intervention increases risk of complications

Source: Own research.

3.5. Hazard categorization across transport modes

The assessment of hazards across all transport modes (Tables 1-4) allowed classification into three priority levels based on the calculated magnitude scores. This categorization provides a structured overview of which factors most significantly threaten animal welfare during transport and which require the highest level of attention from both regulatory and operational perspectives.

The highest-priority hazards, with magnitude scores ranging from 20 to 25, primarily involve threats to animals' basic physiological needs and factors related to transport duration. These include insufficient access to water and feed, extended travel times, exposure to pathogens, inadequate rest periods, motion and vibration during sea transport, and pressure changes during air transport. Such hazards are capable of causing severe physiological disturbances, compromising health, and in extreme cases, resulting in mortality. Immediate mitigation measures are therefore essential to prevent serious welfare impairments.

Hazards classified as high-priority (magnitude 16-19) largely relate to environmental conditions, including ventilation, temperature, humidity, limited space, animal health status prior to transport, and noise exposure. Although these factors may not lead to immediate life-threatening consequences, cumulative exposure can result in significant stress, dehydration, respiratory problems, or thermoregulation disturbances, particularly during longer journeys.

The medium- and low-priority hazards, with magnitude scores of 15 or less, encompass improper handling during loading and unloading, minor space restrictions, and less severe noise exposure. While individually these hazards are less critical, they may amplify the effects of higher-priority hazards, especially for vulnerable animals such as older, sick, or mobility-impaired individuals. Rare hazards, with magnitude scores of 10 or lower, should be addressed through emergency protocols and contingency planning.

This hazard categorization enables the prioritization of preventive and corrective measures, with particular attention to high-impact hazards in long-distance transport modes such as sea and road, where access to essential resources and veterinary care is critical. In shorter transport journeys, such as road and air, ensuring proper ventilation, adequate space, and minimizing stress during handling are key to maintaining animal welfare. The results are consistent with EFSA (2022), which emphasizes that welfare impairments intensify with transport duration and the accumulation of stressors. Effective risk management therefore requires not only well-designed transport infrastructure, but also competent personnel trained in monitoring animal condition, controlling microclimate, and applying appropriate handling techniques.

Discussion

The conducted studies on animal welfare risk assessment during transport allow for a comprehensive identification and classification of hazards depending on the mode of transport. The results presented in Tables 1–4 indicate that different transport modes are associated with distinct sets of risks, which vary in terms of severity, duration of exposure, and calculated hazard magnitude. This analysis enables the prioritization of hazards and the identification of critical points that require immediate intervention or improvement of transport practices.

Our study provides new insights into the comparative magnitude of risks across different transport modes, which has not been systematically quantified in previous research. This contributes original knowledge by ranking hazards according to their severity and potential impact on both animal welfare and worker safety.

4.1. Road transport

In the case of road transport, the highest magnitude values (20–25) were obtained for hazards such as lack of access to water and feed (25), prolonged travel (20), and introduction of pathogens (20). These results confirm that the basic physiological needs of animals and the duration of transport are key factors for animal welfare. These hazards can lead to serious physiological disorders, dehydration, loss of condition, and, in extreme cases, animal mortality, which aligns with EFSA (2022) observations emphasizing that longer transport times intensify the negative effects of stress and the accumulation of stress-inducing factors. Studies assessing the combined effects of transport duration and rest periods confirm that inadequate recovery time exacerbates welfare deterioration during road transport (Meléndez et al., 2020).

Additionally, high magnitude values (16) were recorded for hazards such as insufficient ventilation, limited space, and poor condition of animals prior to transport. Although these factors do not directly threaten life, their cumulative impact leads to chronic stress, respiratory problems, and thermoregulation disorders, especially during long journeys (Cockram et al., 1996; Grigor et al., 2001; Gerritzen et al., 2013).

4.2. Rail transport

In rail transport, similar hazards were identified, though with slightly lower severity for ventilation and space (magnitude = 12). Long railway journeys increase the risk of stress related to travel duration and limited access to water and feed (magnitude 20), as well as the risk of pathogen transmission and animal fatigue (magnitude 16). These results indicate that the organization and infrastructure of rail transport—including proper ventilation, access to water and feed, and stop planning—are critical for animal welfare (EFSA, 2022; Schwartzkopf-Genswein et al., 2012).

4.3. Maritime transport

Maritime transport is characterized by the largest number of high-priority hazards (magnitude 20-25), including prolonged journeys, lack of access to water and feed, ship vibrations and rolling, introduction of pathogens, lack of veterinary care, as well as pressure changes and stress during air transport. Specific maritime conditions, such as ship motion, vibrations, variable climatic conditions, and limited access to veterinary care, are particularly significant. These findings confirm earlier observations by Padalino (2015) and Padalino et al. (2018), indicating that prolonged travel in confined spaces increases the risk of disease and deterioration of animals' physical condition.

4.4. Air transport

Air transport is characterized by shorter travel times, but a high level of stress related to pressure changes (magnitude 20), engine noise (magnitude 16), lack of access to water and feed, and limited veterinary care options (magnitude 15). In poultry, pre-slaughter transport and handling under high temperature conditions further exacerbate physiological stress responses and welfare impairment (Vieira et al., 2024). These results suggest that even a short journey can lead to significant physiological and psychological stress if transport conditions are not properly controlled (Duncan, 2002; Appleby et al., 2008; EFSA AHAW et al., 2022).

4.5. Comparison of hazards across transport modes

The comparative analysis (Section 3.5) shows that the most critical hazards concern factors fundamental to animal survival: access to water and feed, transport duration, introduction of pathogens, limited rest periods, and environmental factors specific to the transport mode, such as ship motion or airplane pressure changes. Transport distance and exposure to adverse environmental conditions have been shown to directly affect transport-related mortality, particularly in poultry, where longer journeys are associated with increased losses (Vecerkova et al., 2019). High-priority hazards (magnitude 16-19) mainly relate to environmental conditions, including ventilation, temperature, humidity, limited space, and noise, which cumulatively affect animal health. Medium- and low-priority hazards (≤ 15) primarily include improper handling during loading and unloading, minor space restrictions, or noise on ships.

Our results highlight specific quantitative differences in hazard magnitude between transport modes, providing new evidence that maritime transport presents the highest cumulative risk, while air transport, despite shorter durations, still imposes substantial physiological stress. This distinction adds a nuanced understanding to the existing literature.

4.6. Impact of transport on animal welfare and worker safety

The transport of farm animals involves numerous stress-inducing factors that affect both animal welfare and the safety of the workers handling the transport. During transport, animals experience both physiological and psychological stress, resulting from factors such as vehicle movement (acceleration, braking, turning, uneven road surfaces), noise, vibrations, and limited space (Schwartzkopf-Genswein et al., 2012; Padalino, 2015; Padalino et al., 2018; Appleby et al., 2008). The movement of the vehicle, including acceleration, braking, turning, and vibrations, contributes to stress responses in animals and affects their balance and physiological stability during road transport (Randall, 1992). Driver behavior and driving style further influence stress responses in transported animals by affecting the intensity and frequency of vehicle movements (Peeters et al., 2008; Santurtún, Phillips, 2015).

Although aspects of psychological stress, such as limited space, noise, or vehicle movement, are recognized, these indicators were not systematically included in the formal risk assessment. Current frameworks focus mainly on physical and biological stressors, which limits a complete understanding of transport's impact on animal welfare. Immunological indicators have long been proposed as sensitive markers of stress in animals, although they are rarely incorporated into routine transport risk assessments (Siegel, 1985). Incorporating measurable psychological stress indicators in future risk assessments could provide a more comprehensive evaluation of hazards and enable more effective mitigation strategies.

Prolonged exposure to these factors leads to fatigue, dehydration, weakened immune function, and health problems, including increased susceptibility to disease (Goetz et al., 2023). Physiological responses to transport stress, including changes in cortisol levels, heart rate, and production parameters, have been documented in livestock exposed to transport-related stressors (Hong et al., 2019). Animals in poor physical condition prior to transport are particularly vulnerable to the negative effects of transportation and handling them presents additional risks to workers who must lift or support them during movement (Lambooj, 2024; Mobo et al., 2010; Barneo-Alcántara et al., 2021).

Improper handling of animals during loading and unloading increases the risk of injuries, pain, and panic among the animals (Lambooj, 2024; Appleby et al., 2008). For workers, such situations mean a higher likelihood of kicks, crushing, musculoskeletal strain, and operational accidents. Additionally, limited space in the vehicle increases the risk of collisions between animals and injuries, thereby exposing workers to further hazards (Appleby et al., 2008; EFSA AHAW et al., 2022).

Prolonged journeys and insufficient rest breaks result in cumulative fatigue and stress for both animals and workers, increasing the likelihood of errors and road or operational accidents (Schwartzkopf-Genswein et al., 2012; Padalino, 2015; Padalino et al., 2018). Lack of water and feed weakens animals, which can lead to aggressive behavior toward handlers and requires

workers to exert additional physical effort under challenging conditions (Pagliasso et al., 2023; Appleby et al., 2008).

Table 5 presents the main hazards to animals during transport along with the corresponding risks to workers, taking into account physical, biological, and ergonomic-psychological factors.

Table 5.

Main Hazards for Animals During Transport and Corresponding Risks for Workers

Hazard Category	Description of Hazard for Animals	Corresponding Risks for Workers
Insufficient ventilation	Inadequate air exchange leads to overheating, heat stress, and exposure to harmful gas compounds (e.g., ammonia, hydrogen sulfide)	Risk of fainting, dehydration, exposure to high temperatures, and harmful gas compounds (e.g., ammonia, hydrogen sulfide)
Limited space	Restricted space prevents normal animal behavior, increasing the risk of injury and stress	Increased risk of kicks, crushing, and difficulty maneuvering during loading and unloading
Long transport duration	Greater fatigue, stress, dehydration, and prolonged exposure to adverse environmental factors	Higher physical workload, prolonged exposure to environmental factors (e.g., noise), driver fatigue (risk of accidents)
Lack or limited access to water and feed	Dehydration, weakness, reduced welfare, and in extreme cases, death	Need for worker intervention under difficult conditions; risk of aggression from weakened or stressed animals
Improper handling during loading/unloading	Injuries, pain, panic, and severe stress	High risk of physical injuries (kicks, strikes, crushing), musculoskeletal overload, and workplace accidents
Poor condition of animals prior to transport	Increased susceptibility to disease and transport-related stress	Higher risk of exposure to zoonotic diseases; need to lift weakened animals (risk of musculoskeletal injuries)
Pathogen introduction	Possible infection before or during transport	Risk of zoonotic infections; work in conditions of increased biological hazard
Inadequate rest periods	Increased fatigue and risk of health disorders	Worker fatigue, higher likelihood of errors, and increased risk of traffic or operational accidents

Source: Own research.

The risk analysis presented in Table 5 emphasizes that improving transport conditions, proper management of travel time, ventilation, space, access to water and feed, and staff training is crucial not only for reducing animal stress and injuries but also for minimizing the risk of accidents and overexertion among workers (Gerritzen et al., 2013; EFSA AHAW et al., 2022; Lambooij et al., 2024).

Appropriate transport procedures, including safe loading and unloading, real-time monitoring of animal condition, and the use of personal protective equipment by workers, create an integrated approach that ensures the safety and welfare of all participants in the transport process.

4.7. Minimizing animal stress and worker risk

The study results emphasize that effective transport management includes route planning, optimization of travel time, provision of rest breaks for animals, and monitoring of environmental conditions in the vehicle, including temperature, humidity, and ventilation (Lambooij et al., 2024).

Safe loading and unloading require the use of ramps with appropriate slopes, minimal step heights, and high side barriers, as well as bedding, which reduces the risk of slips and injuries for both animals and workers (Warris et al., 1991; Goumon et al., 2013; Grandin, 1990). Experimental studies have shown that ramp angle, bedding type, and surface condition significantly affect animal movement, stress responses, and ease of handling during loading and unloading (Garcia, McGlone, 2014). Animals should be transported in groups consistent with their herd instincts, and handling should be calm, predictable, and free of sudden stimuli (Grandin, 1982).

Monitoring the health status of animals before and during transport, removing weakened or sick individuals from long-distance transport, and ensuring access to water and feed are essential for protecting animal welfare and minimizing risks to workers (EFSA AHAW et al., 2022; Gerritzen et al., 2013). High worker competence, regular training in safe animal handling, and the use of protective equipment reduce the risk of injuries, physical overexertion, and exposure to pathogens.

These results confirm our initial hypothesis that effective management of transport conditions significantly reduces both animal stress and worker risk.

4.8. Relevance of findings for practice and regulation

The conducted risk assessment indicates that systemic factors—transport duration, access to resources, environmental conditions, and staff competence—have the greatest impact on animal welfare and worker safety. These findings confirm the necessity of incorporating these elements into regulations, such as Council Regulation (EC) No. 1/2005, and transport practices, including route planning, optimized loading, adequate ventilation and space for animals, and real-time monitoring of conditions (EC, 2005).

Moreover, hazard prioritization enables the effective targeting of preventive and corrective actions, both in long-distance transports (maritime, road), where access to water, feed, and veterinary care is critical, and in short-distance transports (road, air), where proper ventilation, space, and minimizing stress during loading and unloading are essential (EFSA, 2022; Nielsen et al., 2011).

The analysis also highlights the crucial role of qualified personnel who can assess animals' fitness for transport, apply proper loading techniques, and monitor the microclimate as well as early signs of stress. An integrated approach, combining appropriate infrastructure, operational procedures, and staff competencies, effectively protects animal welfare and reduces the risk of injuries to workers. Additionally, it contributes to economic benefits by minimizing animal losses and improving workplace safety (EFSA AHAW et al., 2022; Lamboojij et al., 2024).

Future research should focus on testing interventions to reduce stress in specific transport modes, evaluating the effectiveness of training programs for personnel, and developing real-time monitoring technologies to further enhance animal welfare and worker safety.

Conclusions

The study showed that maritime transport is associated with the highest cumulative risk, whereas air transport, despite its shorter duration, induces a high level of stress in animals. Comparative analysis revealed that basic physiological needs and transport duration affect animal welfare across all types of transport, while specific hazards, such as pressure changes and noise in air transport, were also identified. These conclusions are consistent with earlier welfare assessments emphasizing transport as a critical risk period for farm animals (Warriss, 1998).

Effective transport management including optimized route planning, appropriate vehicle conditions, access to water and feed, and qualified workers significantly reduces both physiological and psychological stress in animals as well as the risk of injury and overexertion among transport workers. Prioritization of hazards enables targeted preventive and corrective actions, which has practical implications for transport organization and regulatory compliance.

The variation in hazard magnitude between transport types highlights the importance of considering specific stress-inducing factors when assessing animal welfare and occupational risk for workers. Improving transport conditions also brings economic benefits by reducing animal losses and workplace accidents.

References

1. Appleby, M.C., Cussen, V., Garcias, L., Lambert, L.A., Turner, J. (2008). *Long distance transport and welfare of farm animals*. Wallingford, Oxfordshire, UK: CABI Publishing, p. 10. doi:10.1079/9781845934033.0000
2. Barneo-Alcántara, M., Díaz-Pérez, M., Gómez-Galán, M., Carreño-Ortega, Á., Callejón-Ferre, Á.-J. (2021). Musculoskeletal disorders in agriculture: A review from Web of Science Core Collection. *Agronomy*, 11, 2017. doi:10.3390/agronomy11102017
3. Broom, D.M. (1986). Indicators of poor welfare. *British Veterinary Journal*, 142(6), 524-526. doi:10.1016/0007-1935(86)90109-0
4. Buckham-Sporer, K., Earley, B., Marti, S. (2023). Current knowledge on the transportation by road of cattle, including unweaned calves. *Animals (Basel)*, 13(21), 3393. doi:10.3390/ani13213393
5. Budzik, A., Budzik, T. (2019). Zarządzanie transportem zwierząt ze szczególnym uwzględnieniem ich dobrostanu. *Humanitas Zarządzanie*, 20(3), 147-163. doi:10.5604/01.3001.0013.7246

6. Christensen, L., Barton-Gate, P., Blaabjerg, L. (1994). *Investigation of transport conditions in participating countries in the EC Project: PL920262*. Proceedings 40th ICoMST; The Hague, The Netherlands, 28 August–2 September 1994.
7. Cockram, M.S., Kent, J.E., Goddard, P.J. et al. (1996). Effect of space allowance during transport on the behavioural and physiological responses of lambs during and after transport. *Animal Science*, 62(3), 461-477. doi:10.1017/S1357729800015009
8. Duncan, I.J.H. (2002). Poultry welfare: Science or subjectivity? *British Poultry Science*, 43(5), 643-652. doi:10.1080/0007166021000025109
9. EFSA Panel on Animal Health and Welfare (AHAW), Nielsen, S.S., Alvarez, J. et al. (2022). Welfare of cattle during transport. *EFSA Journal*, 20(9), 7442. <https://doi.org/10.2903/j.efsa.2022.7442>
10. Erzurum, O., Yılmaz, A. (2018). Cattle transportation and transport wastage. *J. Vet. Sci. Animal Welf.*, 3(1), 1-5.
11. European Commission (2023, December 7). Improving the welfare of animals during transport. https://commission.europa.eu/news/improving-welfare-animals-2023-12-07_pl
12. European Commission. *Council Regulation (EC) No 1/2005 of 22 December 2004 on the Protection of Animals during Transport and Related Operations and Amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97 (2005)*. Retrieved from: <http://data.europa.eu/eli/reg/2005/1/oj>, 20.09.2025.
13. Faucitano, L., Lambooi, E. (2019). Transport of pigs. In: T.A. Grandin (Ed.), *Livestock Handling and Transport* (pp. 307-327). Wallingford, UK: CABI Publ.
14. Garcia, A., McGlone, J.J. (2014). Loading and unloading weaned pigs: Effects of bedding types, ramp angle, and bedding moisture. *Animals (Basel)*, 4(4), 742-754. doi:10.3390/ani4040742
15. Gerritzen, M.A., Hindle, V.A., Steinkamp, K., Reimert, H.G.M., van der Werf, J.T.N., Marahrens, M. (2013). The effect of reduced loading density on pig welfare during long distance transport. *Animal*, 7(11), 1849-1857. doi:10.1017/S1751731113001523
16. Giangaspero, M., Turno, P. (2024). Animal welfare during transport, evolution, and perspectives of European Union legislation and policy. *Open Vet. J.*, 14(7), 1509-1525. doi: 10.5455/OVJ.2024.v14.i7.1
17. Goetz, H.M., Creutzinger, K.C., Kelton, D.F., Costa, J.H.C., Winder, C.B., Renaud, D.L. (2023). A randomized controlled trial investigating the effect of transport duration and age at transport on surplus dairy calves: Part I. Impact on health and growth. *Journal of Dairy Science*, 106(4), 2784-2799. doi.org/10.3168/jds.2022-22366
18. Goumon, S., Faucitano, L., Bergeron, R., Crowe, T., Connor, M.L., Gonyou, H.W. (2013). Effect of ramp configuration on easiness of handling, heart rate, and behavior of near-market weight pigs at unloading. *J. Anim. Sci.*, 91(8), 3889-3898. doi:10.2527/jas.2012-6083

19. Grandin, T. (1982). Pig behaviour studies applied to slaughter plant design. *Applied Animal Ethology*, 9, 141-151. doi:10.1016/0304-3762(82)90190-0
20. Grandin, T. (1990). Design of loading facilities and holding pens. *Applied Animal Behaviour Science*, 28, 187-201. doi:10.1016/0168-1591(90)90053-G
21. Grigor, P.N., Cockram, M.S., Steele, W.B. et al. (2001). Effects of space allowance during transport and duration of mid-journey lairage period on the physiological, behavioural and immunological responses of young calves during and after transport. *Animal Science*, 73(2), 341-360. doi:10.1017/S135772980005832X
22. Hong, H., Lee, E., Lee, I.H., Lee, S.R. (2019). Effects of transport stress on physiological responses and milk production in lactating dairy cows. *Asian-Australas J. Anim. Sci.*, 32(3), 442-451. doi:10.5713/ajas.18.0108
23. Lambooi, E. (2024). Animal stress and welfare during transport and slaughtering: An outline for future policies. *Animals*, 14, 3064. doi:10.3390/ani14213064
24. Marahrens, M., Kleinschmidt, N., Di Nardo, A., Velarde, A., Fuentes, C., Truar, A., Otero, J.L., Di Fede, E., Dalla Villa, P. (2011). Risk assessment in animal welfare – Especially referring to animal transport. *Preventive Veterinary Medicine*, 102, 157-163. doi: 10.1016/j.prevetmed.2011.04.010
25. Meléndez, D.M., Marti, S., Haley, D.B., Schwinghamer, T.D., Schwartzkopf-Genswein, K.S. (2020). Effect of transport and rest stop duration on the welfare of conditioned cattle transported by road. *PLoS One*, 15(3), e0228492. doi:10.1371/journal.pone.0228492
26. Mobo, B.H.P., Rabinowitz, P.M., Conti, L.A., Taiwo, O.A. (2010). Occupational health of animal workers. In: *Human-Animal Medicine* (pp. 343-371). doi:10.1016/B978-1-4160-6837-2.00012-9
27. Mueller-Graf, C., Candiani, D.O., Afonso, A., Aiassa, E., Have, P., Correia, S., De Massis, F., Grudnik, T., Serratos, J. (2007). Risk assessment in animal welfare – EFSA approach. *AATEX*, 14, 789-794.
28. Navarro, G., Col, R., Phillips, C.J.C. (2018). Effects of space allowance and simulated sea transport motion on behavioural and physiological responses of sheep. *Applied Animal Behaviour Science*, 208, 40-48. doi:10.1016/j.applanim.2018.08.009
29. Nielsen, B.L., Dybkjær, L., Herskin, M.S. (2011). Road transport of farm animals: Effects of journey duration on animal welfare. *Animal*, 5(3), 415-427. doi:10.1017/S1751731110001989
30. Padalino, B. (2015). Effects of the different transport phases on equine health status, behavior, and welfare: A review. *J. Vet. Behav.*, 10(3), 272-282. doi:10.1016/j.jveb.2015.02.002
31. Padalino, B., Tullio, D., Cannone, S., Bozzo, G. (2018). Road transport of farm animals: Mortality, morbidity, species and country of origin at a Southern Italian control post. *Animals*, 8(9), 155. doi:10.3390/ani8090155

32. Pagliasso, G., Moriconi, M., Fusi, F., Vitale, N., Vevey, M., Dondo, A., Razzuoli, E., Bergagna, S. (2023). Evaluation of the immune response to transport stress in the Aosta Valley breed. *Vet. Sci.*, *10*(5), 351. doi:10.3390/vetsci10050351
33. Peeters, E., Deprez, K., Beckers, F., De Baerdemaeker, J., Aubert, A.E., Geers, R. (2008). Effect of driver and driving style on the stress responses of pigs during a short journey by trailer. *Animal Welfare*, *17*(2), 189. doi://doi.org/10.1017/S096272860002769X
34. Randall, J.M. (1992). Human subjective response to lorry vibration: Implications for farm animal transport. *J. Agric. Eng. Res.*, *52*, 295-307. doi:10.1016/0021-8634(92)80068-4
35. Santurtún, E., Phillips, C.J.C. (2015). The impact of vehicle motion during transport on animal welfare. *Research in Veterinary Science*, *100*, 303-308. doi:10.1016/j.rvsc.2015.03.018
36. Schwartzkopf-Genswein, K.S., Faucitano, L., Dadgar, S., Shand, P., González, L.A., Crowe, T.G. (2012). Road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: A review. *Meat Sci.*, *92*, 227-243. doi:10.1016/j.meatsci.2012.04.010
37. Siegel, H.S. (1985). Reakcje immunologiczne jako wskaźniki stresu. *World's Poultry Science Journal*, *41*, 36-44.
38. Vecerkova, L., Vecerek, V., Voslarova, E. (2019). Welfare of end-of-lay hens transported for slaughter: Effects of ambient temperature, season, and transport distance on transport-related mortality. *Poultry Science*, *98*(12), 6217-6224. doi:10.3382/ps/pez468
39. Vieira, F.M.C., Portugal, M.A.G., de Borba, L.P., Angrecka, S., Herbut, P., Jongbo, A.O., De-Sousa, K.T., Deniz, M. (2024). Poultry preslaughter operations in hot environments: The present knowledge and the next steps forward. *Animals (Basel)*, *14*(19), 2865. doi:10.3390/ani14192865
40. Warris, P.D., Bevis, E.A., Edwards, J.E., Brown, S.N., Knowles, T.G. (1991). Effect of the angle of slope on the ease with which pigs negotiate loading ramps. *Veterinary Record*, *128*, 419-421. doi:10.1136/vr.128.18.419
41. Warriss, P.D. (1998). The welfare of slaughter pigs during transport. *Animal Welfare*, *7*(4), 365-381. doi:10.1017/S0962728600020923