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RESEARCH ARTICLE

Swiss Cheese Model for Analyzing Freight Car and Bus Traffic Accidents can Lead to the Implementation of Preventive Measures for Traffic Accident Avoidance

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ABSTRACT

Accidents involving goods, cars, and buses have consequences for the vehicles involved and other road users. Such accidents often result in multiple collisions, leading to material losses and even the loss of life. The causes of transportation accidents are usually complex, with numerous interrelated factors contributing to their occurrence. This is illustrated by the Swiss Cheese Model of Accidental Causation, which depicts the organizational hierarchy as a stack of slices of cheese with varying degrees of weakness. Although weaknesses at each level of the organization may not directly cause accidents, they can allow negligence to seep through the cracks and eventually lead to accidents. This study aims to identify the root causes of bus and freight car accidents, focusing on human and facility negligence. The study results reveal that the physical and mental limitations sub-criteria are linked to vehicle maintenance, which requires ongoing attention to spare parts and engine upkeep. In addition, the driver's capabilities must be considered and adjusted accordingly, as exceeding one's limits can lead to driver fatigue and engine damage.

INTRODUCTION

Traffic accidents are prevalent in Indonesia, especially in crowded cities with heavy traffic. The causes of these accidents are varied, ranging from poor road conditions to reckless driving and insufficient law enforcement. It is common to see motorists ignoring traffic signals, speeding, or driving under the influence of alcohol or drugs. Pedestrians and cyclists are also at risk of accidents due to the lack of proper infrastructure and safety measures. Unfortunately, the consequences of these accidents can be severe, with thousands of people losing their lives or sustaining injuries every year. The Indonesian government has acknowledged the severity of the issue and has implemented measures such as increased police patrols, improved road maintenance, and stricter penalties for traffic violations. However, much more needs to be done to ensure the safety of all road users and reduce the number of traffic accidents in the country.

According to research conducted by Hermanto et al. (2021), traffic accidents are currently a significant transportation problem in Indonesia, and reducing their frequency is a matter of ongoing study. Unfortunately, the death rate caused by these accidents remains high, particularly in cases involving freight transportation such as freight cars and buses. These types of accidents often result in significant material and human losses. Various factors contribute to accidents, including humans, facilities, infrastructure, and the environment (Fridayanti and Prasetyanto, 2019).

The number of accidents in Indonesia has been increasing yearly, and the National Transportation Safety Committee (NTSC) is responsible for investigating such incidents. One division of the NTSC, the Road Traffic and Transportation Sub-Committee (RTTSC), specifically investigates road transportation accidents. The NTSC has produced 141 investigation reports from 2007 to 2021, and most accidents involved buses and freight cars, with freight cars accounting for 38% and buses for 60% of the accidents (Transportasi, 2021). Human factors were found to be the primary cause of most accidents involving freight cars and buses, indicating that such accidents are still quite common. Accidents involving freight cars and buses can have severe consequences for other road users, often resulting in head-on collisions, causing material losses and fatalities. One such accident occurred on the Cikopo-Palimanan Toll Road (KM 184 + 300 A) between an Isuzu bus with vehicle number D 7013 AN and a Toyota passenger car with vehicle number B 2918 PKL. The driver's exhaustion and lack of vigilance caused the bus to leave the traffic lane, resulting in 24 victims, including 8 fatalities, 9 minor injuries, and 7 serious injuries. Similarly, driver fatigue resulted in an accident between a tanker truck (B 9154 UEH) and a Toyota Avanza (G 8974 PM) on the Meruya Toll Road in the direction of Tangerang (KM 68 A) (Saputra, 2018; Vulic et al., 2018).

According to data from Raharja (2023), traffic accidents in Indonesia are caused by several factors, including human error (36.36%), infrastructure (36.36%), vehicles (4.55%), and environmental factors (22.73%), as described in Figure 1. Human error, which includes driver error, undisciplined road user behavior, and a lack of safety awareness when driving, is the main cause of traffic accidents in Indonesia. Infrastructure, such as poor road conditions, a lack of traffic signs, and a lack of street lighting, is also a significant cause of traffic accidents. Environmental factors, such as bad weather and slippery road conditions, also play an important role. While vehicle factors account for only 4.55% of traffic accidents in Indonesia, it is essential to ensure that vehicles are well-maintained and safe to use (Malik and Sinha, 2020). This can be achieved through routine vehicle maintenance and paying attention to critical components that can affect driving safety, as shown in the picture below:

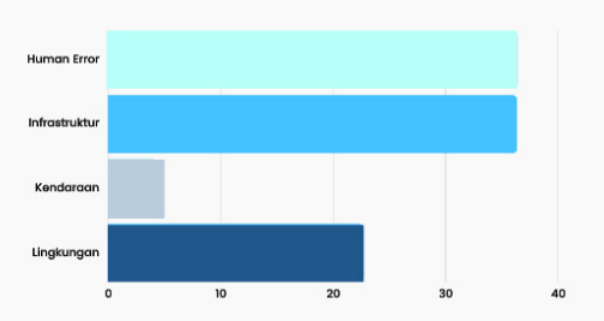

Figure 1: Percentage of factors causing accidents in Indonesia in 2023 (Source: PT Jasa Raharja, 2023)

Accidents within transportation systems are intricate, as they are not solely caused by one factor but interconnected ones (Keramati et al., 2021). This is demonstrated by the Swiss Cheese Model of accident causation, where each slice of cheese with holes represents different organizational ranks with varying weaknesses. Although multiple deficiencies at each level of the organization may not directly

cause accidents (Saidel, 2000; Rachiq et al., 2022), the negligence that seeps through these holes and penetrates all layers can potentially lead to accidents (Saputra et al., 2017). With this background in mind, this study aims to identify the primary causes of bus and freight car accidents in terms of human and facility negligence. By identifying these root causes, accident prevention measures can be more targeted.

LITERATURE REVIEW

Traffic accidents involving freight cars and buses can have devastating consequences, resulting in loss of life, injury, and property damage. The Swiss cheese model, initially proposed by James Reason, is useful for analyzing such accidents and identifying preventive measures to avoid them. The model suggests that accidents occur due to a series of failures or holes in the safety system, which align to create a path for the accident to occur. In this literature review, we explore the Swiss cheese model's application in analyzing traffic accidents involving freight cars and buses and the effectiveness of the preventive measures implemented as a result of the analysis.

In Indonesian study Soehodho (2017) described the traffic accidents are a widespread problem that highlights the shortcomings of traffic management and transportation systems. This issue is particularly pronounced in Indonesia, where the number and severity of traffic accidents are alarmingly high, especially in Jakarta, the country's most populous city. Although traffic accidents are caused by a combination of three different factors - human, vehicle, and external factors - human factors have the most significant impact, as evidenced by global statistics. In this context, we aim to identify non-human factors that contribute to the increasing number of traffic accidents in Indonesia, where motorcycle accidents are the most common. To address this issue, we propose three key solutions: the development of public transportation, the improvement of road infrastructure, and the implementation of effective traffic management measures.

A study conducted in Indonesia Mutmainnah et al. (2020) highlighted an increase in ship accidents in Indonesia from 2018 to 2019, with passenger ships being the most common ship type involved. The article emphasizes the importance of understanding the causative factors contributing to these accidents and suggests using the National Transportation Safety Committee's investigation reports to identify them. The paper focuses on analyzing fire/explosion accidents of passenger ships that began in car decks using a new MOP Model that classifies failures into four categories: Man, Machine, Media, and Management.

In another study Sa'diyah and Enggarsasi (2018) explained that traffic serves as an important means of communication within communities and plays a vital role in national development. However, one of the major challenges associated with traffic is the occurrence of accidents. Such accidents usually happen when the transportation infrastructure including roads, vehicles, and supporting facilities fail to keep up with the rapid developments in the community. To address this issue and analyze the prevention measures aimed at reducing accidents within regional police jurisdictions, an empirical juridical approach was utilized in this research, which involved data retrieval and interviews conducted at the East Java Regional Police in Indonesia. The findings revealed that efforts to prevent an increase in accidents in the Regional police are aimed at reducing the factors that cause traffic accidents through three approaches: pre-emptive, preventive, and repressive. These prevention efforts can significantly reduce the number of accidents occurring in Indonesia.

In a study by 6 (2015) discussed the safety issues surrounding school buses in China, which have seen a significant increase in accidents in recent years. The author notes that while research on school bus accidents has been conducted in western countries, there is limited empirical data available in China. The article presents findings from an analysis of 148 school bus accident cases and compares the characteristics and causes of these accidents to those in western countries. The author notes that while many similarities exist, unique temporal and spatial characteristics specific to China also play a role. The article concludes with recommendations to reduce school bus accidents in China, including special traffic services during key periods, increased recognition of school buses, and education for all drivers to be more aware of school buses. The author also suggests restrictions on the use of minibuses as school buses.

Overall, the article provides valuable insights into the challenges of ensuring school bus safety in China and offers practical solutions to address this issue.

Similarly, in a study by Suryoputro et al. (2015). discussed the importance of preventing train accidents in Indonesia and proposes the implementation of the Swiss Cheese Model, a basic accident investigation framework, to identify root causes. The text identifies four factors that should be considered when investigating train accidents in Indonesia and recommends the development of more advanced accident investigation systems to improve understanding. The text suggests that the Swiss Cheese Model could be successfully implemented in Indonesia but notes that obtaining confidential information can be challenging.

Another study by Toto and Limone (2019). described that oad safety is a significant concern for developed and developing countries due to its negative economic impact. Despite various accident analysis approaches, there is an increase in road crashes every year. This study aims to analyze a driving school accident using a system-based accident analysis approach. Data was collected through an interview and a Swiss Cheese Accident Causation Model was used to identify the factors that contributed to the accident.

Jong et al. (2020). presents a comprehensive analysis of the over speed derailment of the Puyuma express train in Yilan, Taiwan, in October 2018, which caused 18 fatalities and 267 injuries. The authors utilized fault tree analysis and a Swiss cheese model to identify potential causes and contributing factors to the derailment. They also introduced modified Swiss cheese models to further demonstrate the causal relationships between the factors and the time-dependent nature of the accident.

The investigation team appointed by the Executive Yuan completed the investigation within two months and presented their findings in a way that was easily understandable by the general public. The results revealed that the ATP system (or PTC) installed in the train cannot guarantee 100% safety, highlighting the importance of reviewing safety culture and corresponding procedures to ensure the safety of railway operations.

Overall, this study provides valuable insights into the causes of railway accidents and emphasizes the need for effective safety measures and systems to prevent future accidents. The proposed process and models can be useful in identifying the immediate causes and contributing factors to accidents and in developing strategies to prevent similar incidents from occurring in the future.

In a study by Underwood and Waterson (2014) explained that the Swiss Cheese Model (SCM) is a widely used accident causation model across various industries. However, a debate exists in the research literature regarding its viability as a tool for accident analysis. Critics argue that it oversimplifies accidents by presenting a sequential view, while proponents maintain that it embodies systems theory. This paper aims to evaluate whether the SCM can provide a systems thinking approach and remain a viable option for accident analysis. To achieve this, the train derailment at Grayrigg was analyzed using the ATSB accident investigation model based on SCM and two systemic accident analysis methods, AcciMap and STAMP. The study compared the analysis outputs and usage of the techniques. The findings showed that each model applied a systems thinking approach. However, the ATSB model and AcciMap presented their findings more concisely, while STAMP more clearly embodied systems theory. The study suggests that while practitioners and researchers must make trade-offs in selecting an analysis method, the SCM remains a viable model for accident analysis.

Similarly, a study by Wu et al. (2019) study focused on the prevention and control of school bus accidents, which can result in severe casualties and negative social impacts. A Bayesian network (BN) model is developed, considering factors such as human error, vehicle failure, environmental impacts, and management deficiencies. Conditional probabilities are obtained based on past school bus accidents in China, while expert knowledge is used to determine probabilities for other nodes. The model estimates the consequences of different accident scenarios by changing the state values of some nodes. Sensitivity analysis identifies "overload" as the most influential factor causing school accidents. The study shows that the integration of Bayesian network and Dempster-Shafer evidence theory is an effective framework for school bus accident assessment, providing more practical analysis for school bus safety. This research

could provide technical support for school bus safety, particularly in developing countries.

Another study by Pranoto et al. (2020) proposes a concept of improving safety engineering by developing a device called SLIFA, which can control the speed and level of safety of trucks and buses by detecting the level of tiredness or sleepiness of the driver. The device measures the driver's condition by looking at the eyes, size of mouth evaporating, and heart rate conditions, and uses a particular scale to determine the fatigue level of the driver. Moreover the proposed device has undergone performance tests on trucks and buses with 122 Nm and 112 Nm torque wheels and 339 HP and 329 HP power values, respectively. The minimum speed of the vehicles is 62 km/h, while the top speed is 70 km/h. With a top speed of 70 km/h, the torque and power of the truck are 135Nm and 370HP, respectively. It also states that the average fuel consumption of the truck before installing SLIFA was 3.43 liters/km, which decreased to 4.2 liters/km after installing SLIFA. The device is said to have functional eligibility and can cut fuel consumption by 81 percent. The paper concludes that developing devices like SLIFA can improve safety engineering and reduce the number of accidents caused by driver negligence. However, it should be noted that this is just a proposed concept, and further research and testing would be required before the device can be implemented on a larger scale.

In conclusion, the Swiss cheese model provides a useful framework for analyzing the factors contributing to traffic accidents involving freight cars and buses. The studies reviewed in this literature review suggest that human factors, including driver behavior and attitude, are often the most significant causes of accidents. Preventive measures proposed by the studies include improving driver training, implementing advanced driving assistance systems, enhancing road and vehicle infrastructure, and strengthening safety culture and management systems. Implementing these measures can lead to a reduction in the number of accidents and ensure safer transportation for both passengers and goods.

RESEARCH METHODS

According to Sugiyono (2020) study, a quantitative research method involves a significant amount of numerical data, from acquisition to interpretation. The transportation analysis approach was utilized in this study's quantitative analysis. The research involved various methods, including the Swiss Cheese Model and the Analytical Hierarchy Process (AHP) method. The study's analysis methods included modeling the contribution of human negligence in an accident event as a Swiss Cheese Model accident causation, which led to the development of dynamic error and latent error (Wiegmann et al., 2022). Active errors typically have immediate effects and are linked to frontline operators, while latent errors have hidden consequences within the system and may only become visible as accidents after an extended period when combined with other factors (Soro et al., 2020). In this case, frontline operators are not the primary cause of accidents, as they only operate a system with deficiencies in its design, installation, maintenance, or management decisions.

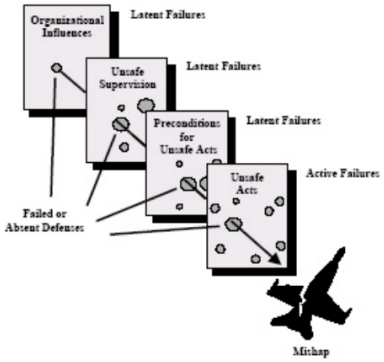

Figure 2: Swiss cheese model (Source: Olson and Raz, 2021)

Olson and Raz (2021) model Figure 2 is a theoretical framework proposed by Kathryn Olson and Avi Raz in their paper titled "Fostering Success in the Workplace: A New Model of Interactive Mentoring." The model provides a useful framework for understanding how mentoring can promote success in the workplace and emphasizes the importance of a collaborative, interactive approach to mentoring. The Swiss cheese model ([3], 2016) categorizes mistakes and their effects into different levels, each with its corresponding sub-levels. Each level is associated with a distinct set of errors and consequences. Here is the breakdown of the levels within the Swiss cheese model.

Unsafe acts

There are two main categories of unsafe acts: errors and violations. Errors refer to physical or mental actions that fail to achieve a desired outcome and can be further divided into three subcategories: decision errors, skill-based errors, and perceptual errors. On the other hand, violations indicate a willingness to disregard instructions or rules to accomplish a specific task and are divided into two types: routine and special.

Preconditions of unsafe acts

Unsafe behavior is the leading cause of accidents. When investigating an accident, it is crucial to identify the underlying cause or basis of the dangerous actions, which can be considered the preconditions for such activities. There are two categories of preconditions for unsafe acts: the condition of the operator, which does not meet the required standards, and the work performed by the operator, which also falls short of the standards. The operator's condition is further subdivided into three categories: adverse mental and physiological conditions and physical and mental limitations. On the other hand, substandard work can arise due to inadequate human resource management and a lack of personal readiness.

Unsafe supervision

Unsafe supervision refers to a series of actions that stem from a supervisor's instructions. This type of supervision has four key elements: insufficient oversight, ill-planned operations, failure to address a known issue, and violations by the supervisor.

Organizational influence

Latent errors often need to be made aware of the impact of organizational influence. Failures in the workplace often stem from organizational influences originating from management sources, the work environment, and organizational procedures. It is crucial to recognize this, as decisions made by higher management can affect the supervisory practices in place.

RESULT AND DISCUSSION

Analysis of accident characteristics

Accident characteristics refer to the details and factors contributing to an accident. Analyzing these characteristics can provide insight into the causes of the accident and help identify ways to prevent similar incidents from occurring in the future.

Table 1: Analyzed accident events

Event	Description	Evidence of Accident
AKAP Bus Car Fire (B 7177 BGA).	A bus car with vehicle number B 7177 BGA, majoring in Kalideres-Merak, and operator of vehicle B 7177 BGA, departing from Kalideres Terminal to Merak and carrying 20 passengers, experienced a fire.	
Head-on Collision of Trailer Truck (BK 9991 XA).	On the Bukittingi-Padang National Road, Trailer Truck (BK 9991 XA) was engaged in a head-on collision. When traffic was heavy, the driver used the main brake frequently to slow down the trailer truck, and the RPM was set to 2500 because the engine sounded noisy.	

Cont.....

AKDP bus (Z 7519 AA) was rear-ended by a car.	AKDP Bus with vehicle number Z 7519 AA (hereinafter referred to as the bus car) overtook an Elf car from the left. The bus car hit the traffic cone, then swerved to the right, then to the left, and hit the right rear of a trailer truck.	
Microbus (D 7013 AN) Accident with Passenger Car (B 2918 PKL)	From the direction of Cirebon to Jakarta, there was a private passenger car, the Toyota Rush (hereinafter referred to as a passenger car), travelling with eight passengers. The collision was unavoidable between the passenger car and the microbus.	
Tank trailer truck (B 9154 UEH) collided with Toyota Avanza car (G 8974 PM).	The tank trailer truck arrived at KM 6 on the Jakarta-Tangerang Toll Road. The trailer truck, which was originally travelling in lane 2, switched lanes to lane 1. After that, the trailer truck driver directed the trailer truck to lane 2 again. However, in lane 2 at that time, there was a Toyota Avanza passenger car (G 8974 PM).	

In the investigation conducted by the National Transportation Safety Committee (NTSC), five accident cases involving freight cars and buses were taken as examples for the Swiss cheese analysis (Table 1). The initial analysis revealed several events based on the Swiss Cheese Model analysis levels. Table 2. From the analysis, it was found that the most significant factors causing accidents in freight transportation and bus transportation are vehicle factors and human factors. Vehicle factors could be vehicle damage or system failure, while human factors could be driver error or risky behavior such as drunk driving or driving too fast.

Since vehicle and human factors play a crucial role in freight and bus accidents, measures must be taken to reduce the risk of accidents in these two areas. These measures include improving driver training and supervision, enhancing vehicle maintenance and upkeep, and implementing safety technologies such as emergency braking systems and surveillance cameras to monitor driver behavior.

The below mentioned measures are based on several studies conducted, including:

- Perneger, eta al (2005). study, titled "Using the Swiss Cheese Model of safety incidents, and described that this model has become the dominant paradigm for identifying the different Human, Technical, and Medical errors for safety. This is was survey of a volunteer sample of persons. The study found that factors, health, driver behavior, road conditions, and vehicles contribute to traffic accidents.
- Toto and Limone (2019). “Road transport accident analysis from from a system based accident analysis approach using Swiss cheez Mode” analyzed the factors causing traffic accidents by using the Swiss Cheese Model. The study revealed that driver behavior, road conditions, and vehicles contribute to traffic accidents.
- Eftekhari, et al. (2020) study, titled "Investigating the factors affecting the collison of two Passenger trains” aimed to analyze the factors causing traffic accidents. The study found that factors such as management, individual and environment contribute accident.
- Huang and Liu's (2020) research, "Analysis of traffic accidents based on the Swiss Cheese Model: A Case Study of Beijing," analyzed the factors causing traffic accidents in Beijing using the Swiss Cheese Model. The study found that factors such as driver behavior, road conditions, and vehicles contribute to traffic accidents in Beijing.

Table 2: Swiss cheese model

	Layer Swiss Cheese Model			
Accident	Organizational Influences	Unsafe Supervision	Precondition for Unsafe Act	Unsafe Act
Case 1	The Operator of vehicle B 7177 BGA did not pay attention to the fire risk assessment.	Lack of supervision in the main fuse room	Drivers and vehicle crews did not pay attention to the condition of the vehicle before use	Lack of Fire Risk Assessment
	Operator of Vehicle B 7177 BGA did not pay attention to the impact on the equipment used.	Lack of attention to the maintenance of bus equipment		The driver and crew did not pay attention to the fuse room, which was used as a place to put items.
		Lack of supervision on the use of halogen lamps		
Case 2	Operator of Vehicle BK 9991 XA made changes to the technical specifications of the dimensions of the trailer truck and the GVW/JJBB carrying capacity to 23,500 kg, which should be 21,000 kg only.	Lack of attention to truck engine maintenance.	The driver continued to go through road locations that have an inappropriate bend radius.	Lack of driver technique in using brake technique.
	Lack of safety awareness in transporting goods.	Maintenance of spare parts was not supervised properly.	Driver used the wrong braking technique.	Wrong decision-making caused brake failure.
			The driver did not understand the engine rotation speed in the engine braking range (2000–3200 RPM).	
Case 3	Operator of Vehicle Z 7519 AA made drivers work longer hours without thinking about how fatigue can lead to accidents.	Lack of attention to driver working hours	Drivers who experience fatigue	The driver still forced himself to travel in a sleepy condition.
		Lack of attention to rollover potential on bus cars		It was due to the structure of the bus car, which can cause a rollover of the vehicle.
Case 4	There was a change in management of the car ownership that Sakera did not pay attention to.	Lack of attention to the vehicle and the driver.	Driver was driving while sleepy.	Driver still forced to travel in a sleepy condition
	Sakera did not pay attention to the driver's working hours.		Passengers did not use seat belts.	Casualties from collisions due to not using seat belts
	Sakera did not pay attention to the structure of the old vehicle.			
Case 5	The company did not pay attention to vehicles and safety systems when carrying dangerous goods.	Lack of attention to the driver's health and working hours.	The driver does not drive the vehicle at the recommended speed.	The river made movements that caused loss of balance.
			The driver experienced fatigue.	

Table 3: Swiss cheese table specification model

Accident	Organizational Influences	Unsafe Supervision	Precondition for Unsafe Act	Unsafe Act
Case 1	Organizational Process	Inadequate Supervision	Physical/Mental Limitations	Perceptual Error
Case 2	Organizational Climate	Planned Inappropriate Operations	Crew Resource Mismanagement	Skill Based Error
Case 3	Resource Management	Supervisory Violation	Physical/Mental Limitations	Perceptual Error
Case 4	Resource Management	Failed to Correct a Known Problem	Physical/Mental Limitations	Decision Errors
Case 5	Resource Management	Supervisory Violation	Physical/Mental Limitations	Decision Errors

Occasionally, certain tiers within the Swiss Cheese Model analysis (Table 3) may not impact the identifiable causes of an accident, thus making them unnecessary to include in the table. Consequently, the number of columns within the table can be minimized. A comprehensive SWOT analysis was also conducted to determine the plausibility of a bus and freight transportation accident (Table 4).

Table 4: SWOT analysis diagram

SWOT	Explanation
Strength	Large transportation capacity, so it can transport passengers or goods in large quantities
	Wide route network, so it can reach many cities and regions in Indonesia
	Relatively cheaper compared to other transportation such as airplanes
	The speed of delivery of goods can be arranged and scheduled properly
	Large cargo capacity
	Suitable for shipping goods in large quantities and over long distances
Weakness	Vulnerable to accidents
	Delivery times may be disrupted by poor road conditions
	Drivers are tired or under rested, which affects their concentration and reactions while driving
	Drivers who do not understand traffic rules make mistakes while driving
	Poorly maintained and frequently used vehicles to older vehicles that are not replaced regularly
	Overload: Some truck and container drivers tend to exceed the maximum allowable load. This can increase the risk of accidents as the vehicle becomes unstable and difficult to control.
Opportunities	There is an increasing need for the delivery of goods
	Improved technology in freight vehicles
	Addition of a new route network or development of an existing route network
	Lower costs provide an opportunity for a larger number of passengers
	More complete service offerings, such as shuttle and package delivery services
Threats	Increasingly stringent government regulations on safety, exhaust emissions, and vehicle maintenance
	Increased competition from other transportation
	Changing trends and consumer preferences in choosing transportation methods
	Lack of training for freight vehicle and bus drivers in dealing with emergency situations
	High rate of traffic accidents resulting in large material and non-material losses

After conducting a SWOT analysis of bus and freight transportation, it has been determined that several weaknesses and threats compromise traffic safety. These issues include susceptibility to accidents, drivers lacking knowledge of traffic regulations and frequently making mistakes while operating vehicles, inadequate maintenance of old and heavily used vehicles, overloaded vehicles that heighten the risk of accidents, drivers not being adequately trained to handle emergency situations, and high rates of accidents resulting in substantial material and non-material losses. Thus, the government,

transport companies, and the public must unite to take severe and cohesive action to enhance traffic safety in the bus and freight transport industries. This can be achieved through enforcing stringent laws against traffic violations, developing appropriate road infrastructure, acquiring advanced technology and safety equipment like GPS and braking systems, and implementing ongoing training and human resource development programs. By adopting these measures, the risk of traffic accidents will be minimized, and safety for all road users will be improved.

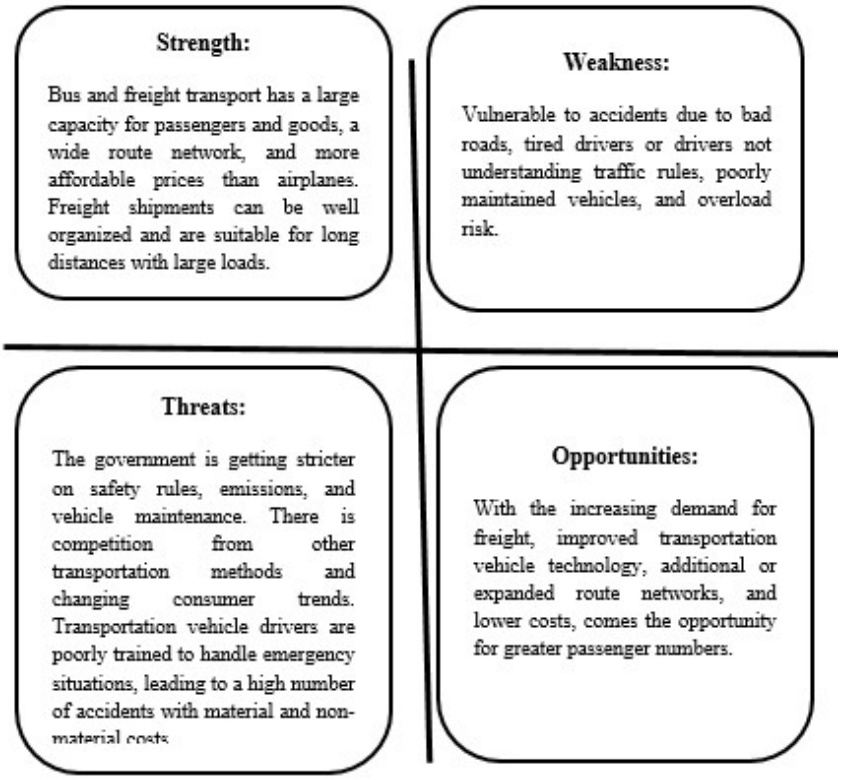

Figure 3: Rational of SWOT

SWOT analysis is a powerful tool that helps organizations identify their strengths, weaknesses, opportunities, and threats. It is a rational process that involves an assessment of both internal and external factors affecting the organization's current and future performance Figure 3. The Swiss Cheese Model layer and SWOT can be analyzed to calculate the sub-criteria for a deeper understanding. This approach involves reducing the number of columns in the table to focus more on the actual causes of accidents. To determine decision-making priorities, the Analytic Hierarchy Process (AHP) method can be used to assess the significance of the relationship between the degree of negligence and the occurrence of an accident. The proportion of different AHP levels can provide insight into the interrelationship between accident-causing factors. The sum for each sub-criteria in the Swiss Cheese Model layer can be calculated to obtain more specific information about the elements with the most significant impact on the occurrence of accidents. This information can be leveraged to develop more effective and efficient strategies for accident prevention. Thus, analyzing the Swiss Cheese model with the AHP method and computing the number of sub-criteria in each layer can help to understand the factors that cause accidents and create better accident prevention strategies, as demonstrated in Table 5.

Calculating the number and percentage values of sub-criteria in each Swiss Cheese Model analysis layer is crucial for determining the next stage's handling priority. The Analytic Hierarchy Process (AHP) method can aid in selecting the most effective action or strategy to address the factors identified in the Swiss Cheese Model analysis.

Table 5: Number of swiss cheese model layer sub-criteria

Sub-Criteria in Case	Total	Percentage
Organizational Process	2	10%
Resource Management	3	15%
Inadequate Supervision	1	5%
Planned Inappropriate Operations	1	5%
Supervisory Violation	2	10%
Failed to Correct a Known Problem	1	5%
Physical/Mental Limitations	4	20%
Crew Resource Mismanagement	1	5%
Perceptual Error	2	10%
Skill Based Error	1	5%
Decision Errors	2	10%
Total	20	100%

Analysis of handling priorities

The first step is to identify the number of relevant sub-criteria from the Swiss Cheese Model to establish the priority for handling freight and bus transportation accidents. The analysis is then based on the results of the National Transportation Safety Committee (NTSC) in the field, as observed in the five cases used in this study. An analytical hierarchy process (AHP) analysis was performed using Expert Choice software to produce more accurate and objective results. Thus, the priority of handling can be determined by comparing the relative weight of each causal factor that has been identified, as recommended by NTSC, so that the most appropriate and effective decision can be made in dealing with the problem of freight and buses.

Figure 4: Weighting criteria in the selection of handling priorities

Figure 4 illustrates that the physical and mental limitations criterion holds the highest weight of 0.203, or 20.3%, of the total criteria. This criterion plays a significant role in accidents involving freight cars and buses, often caused by human error, such as drivers' exhaustion or lack of focus due to irregular working hours. The resource management criterion holds the second-highest weight of 0.162 or 16.2%. Resource management, including human and vehicle resources, significantly affects accident occurrence. Companies often pressure drivers to work longer hours, leading to exhaustion and inadequate attention to vehicle maintenance, resulting in issues like bad brakes. The "failed to correct a known problem" criterion holds the lowest weight of 0.046 or 4.6%. This criterion rarely causes accidents, and if the issue has been corrected and checked, accidents should not occur. In scientific terms, these factors are linked to the concept of human factors engineering (HFE) or ergonomics, which focuses on humans when designing systems or products for increased safety and efficacy. HFE principles such as appropriate working hours, driver training and monitoring, and regular vehicle maintenance can address physical and mental limitations and resource management, ultimately reducing accident risk and improving road safety.

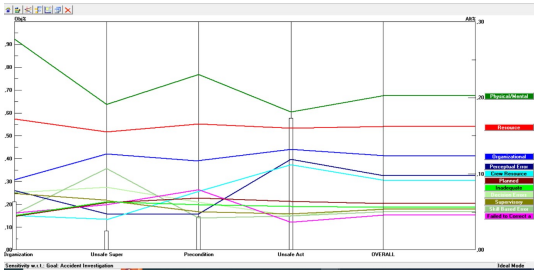

Figure 5: Accident priority handling performance chart

The text describes the Accident Priority Handling

Performance Chart (Figure 5), highlighting several factors contributing to traffic accidents. These factors are prioritized and targeted as part of a strategy to reduce the number of accidents. The chart identifies physical and mental limitations, resource management, organizational processes, and failure to correct a known problem.

- The physical/mental limitation factor relates to drivers' physical and mental conditions affecting their ability to drive safely. Conditions such as poor health or fatigue can cause drivers to lose control of their vehicles, while stress or psychological disorders can impair their concentration and focus while driving.
- Resource management covers managing resources in the transportation context, including budget, human resources, and equipment. Inadequate resources can lead to a lack of vehicle maintenance, driver training, and supervision, all of which can contribute to accidents.
- Organizational process factors include policies and procedures in transportation management, such as regulatory systems, internal organizational policies, and operating standards. Inadequate policies and procedures, such as those related to timing or risk assessment, can lead to driver error and accidents.
- The "failure to correct a known problem factor refers to the inability to address a general problem, such as leaving a vehicle with a technical problem unrepaired. Prioritizing the resolution of these factors can be achieved by improving vehicle maintenance, improving driver training and supervision, and implementing appropriate policies and procedures in transportation management.

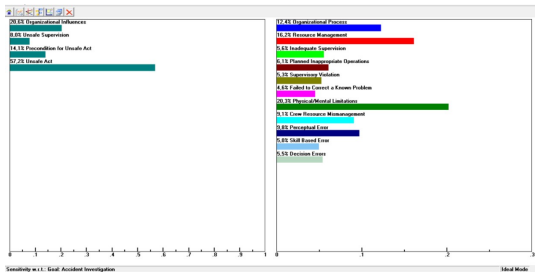

Figure 6: Dynamic chart of accident priority handling options

In Figure 6, a dynamic graph displays accident priority handling options based on the highest criteria of accident causes taken from NTSC data through five cases used in the study. The cases analyzed were organizational influences, unsafe supervision, and preconditions for dangerous and hazardous acts. The analysis found that the cause of the accident with the highest value was a hazardous act caused by unsafe and dangerous behavior that can lead to work accidents, injury, and death.

A head-to-head comparison was conducted to prioritize the three causes of accidents with the highest weight to determine the best solution. The graph in the figure presents the comparison results, revealing that the best option to deal with accidents is to improve driver behavior and reduce the risk of vehicle system failure. This can be achieved by improving driver training and supervision and conducting regular vehicle maintenance and upkeep. These efforts are expected to reduce the risk of accidents and improve freight and bus transportation safety.

Figure 7: Head to head organizational process and resource management

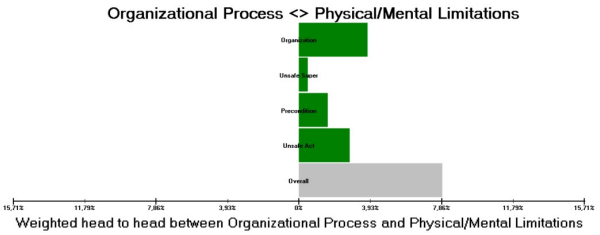

Figure 8: Head to head organizational process and physical/mental

Limitations

The findings from Figure 7 indicate that resource management has a higher value of 3.93% in improving road safety. Meanwhile, based on the analysis in Figure 8, the physical or mental limitation factor provides a more significant advantage of 7.86%

compared to organizational processes. Therefore, the top priorities to reduce accidents and enhance road safety are as follows:

- Address drivers' physical and mental limitations by improving their health and physical condition and providing more intensive training.
- Improve resource management to optimize resources such as time, manpower, and equipment by enhancing work processes' efficiency and effectiveness and ensuring appropriate utilization of existing resources.
- Enhance organizational processes to increase work efficiency and effectiveness, including better supervision and training and identifying and addressing potential problems.

Implementing these recommendations is expected to reduce the risk of accidents and improve road safety.

Theoretical implication of study

The theoretical implications of this study could be extended to broader discussions of safety management and organizational safety culture. The Swiss Cheese Model of Accidental Causation used in this study is widely recognized in safety management, and it has been applied in various industries to identify the potential causes of accidents and to develop preventive measures. The model suggests that accidents occur when multiple factors align and that the likelihood of an accident can be reduced by identifying and mitigating weaknesses at each level of the organizational hierarchy.

The study's focus on human and facility negligence highlights the importance of a safety culture within an organization. Safety culture refers to the shared values, attitudes, beliefs, and practices that influence the safety-related behavior of individuals within an organization. By addressing issues related to vehicle maintenance and driver capabilities, the study emphasizes the need for organizations to prioritize safety and establish a strong safety culture.

Furthermore, the study highlights the importance of ongoing attention to safety-related issues. Safety is not a one-time event or a fixed outcome but a continuous process requiring ongoing attention and effort. This study demonstrates that neglecting safety-related issues at any level of the organizational hierarchy can lead to a chain of events that eventually result in an accident.

This study's theoretical implications extend beyond transportation safety to broader discussions of safety management and organizational safety culture. By emphasizing the importance of identifying and mitigating weaknesses at every level of the organizational hierarchy, the study underscores the need for organizations to prioritize safety and establish a strong safety culture to prevent accidents and promote the well-being of employees and stakeholders.

Practical implication of this study

The practical implications of this study are significant for transportation safety and accident prevention. Based on the study's findings, several practical implications can be drawn:

Regular vehicle maintenance: The study highlights the importance of ongoing attention to vehicle maintenance to prevent accidents involving freight cars and buses. Transportation companies must prioritize regular vehicle maintenance and allocate adequate resources to ensure that vehicles are in good condition.

Driver training: The study identifies driver capabilities as a critical factor in accident prevention. Therefore, transportation companies should prioritize training to ensure drivers have the necessary skills and knowledge to operate vehicles safely. This could include training on safe driving practices, fatigue management, and vehicle maintenance.

Safety culture: The study emphasizes the importance of safety culture in accident prevention. Transportation companies should establish a strong safety culture that prioritizes safety and encourages employees to report safety-related issues. This could include regular safety audits, training programs, and employee engagement initiatives.

Risk management: The Swiss Cheese Model of Accidental Causation used in this study highlights the need to identify weaknesses at every level of the organizational hierarchy to prevent accidents. Therefore, transportation companies should prioritize risk management and establish procedures for identifying and mitigating potential risks.

Multi-sector approach: The study highlights the potential consequences of accidents involving freight cars and buses for other road users. Therefore, transportation companies should collaborate with

other stakeholders, including government agencies, to develop and implement effective accident prevention measures.

Consequently, this study's practical implications underscore the need for transportation companies to prioritize safety and establish a culture of safety to prevent accidents and promote the well-being of employees and stakeholders. By implementing these practical implications, transportation companies can reduce the risk of accidents and improve safety outcomes.

Limitations and future research directions

Sample size: The study may have a limited sample size, and the results may need to be more generalizable to other settings or populations. Data availability: The study may have relied on existing data, and there may have been limited access to data on factors not included in the analysis.

Subjectivity: The Swiss Cheese Model of Accidental Causation used in this study is subjective, and there may be limitations in its application to transportation accidents.

Future research directions

Qualitative research: Future studies could employ qualitative research methods to explore transportation workers' and other stakeholders' experiences and perceptions regarding accident prevention and safety culture.

Longitudinal studies: Longitudinal studies could examine changes in safety-related behavior and practices over time and assess the impact of interventions designed to improve safety outcomes.

Multilevel analysis: Future studies could employ multilevel analysis to examine the interaction between individual and organizational factors in accident prevention and safety culture.

Comparative studies: Comparative studies could examine differences in safety-related behavior and practices across different types of transportation systems and industries to identify best practices and areas for improvement.

Technological advancements: Future research could explore the potential of new and emerging technologies, such as automated vehicles and artificial intelligence, to improve safety outcomes and prevent transportation accidents.

Furthermore, future research directions could address the limitations of this study and further develop our understanding of transportation safety and accident prevention. By exploring new research avenues, we can improve the effectiveness of interventions to improve safety outcomes and reduce the incidence of accidents in the transportation sector.

CONCLUSION

The research revealed that traffic accidents resulting in fatalities or minor injuries are caused mainly by facility or vehicle factors and human factors. The Swiss Cheese Model analysis identified physical and mental limitations as the sub-criteria with the highest number related to vehicle maintenance and driver ability. To avoid driver fatigue and engine damage, regular maintenance is necessary for vehicle parts and engines and adapting driver abilities to their limitations. The AHP analysis also highlighted physical and mental limitations as the top priority for solving the accident problem. Therefore, regulations or policies are required to supervise and impose operational restrictions on goods vehicles and passenger cars. Based on these findings, the recommended priorities and strategies for solving the accident problem are 1) physical and mental limitations, 2) resource management, and 3) organizational process. However, more research is necessary to reinforce these conclusions and provide more robust evidence.

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