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Relationship of Vehicle Factors as Causing Factors of Severity of Tanker Car Accidents at PT XYZ in 2022-2023

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Abstract
The three main risk factors causing traffic accidents are categorized into human factors, vehicle factors and environmental factors (Haddon, 1972). This study aims to analyze vehicle factors as the cause of fuel tanker car accidents at PTXYZ during the period 2022–2023 and their relationship to severity. The unit of analysis for this study was 33 investigation reports as secondary data. Univariate analysis was carried out on the description of vehicle factors including: car age, preventive maintenance, pre-trip inspection, braking system, tire condition, electricity, lighting/visibility, and modification, as well as multivariate analysis of ordinal logistic regression to determine the relationship between vehicle factors and vehicle severity (Category N–A), humans (fatal, serious injury, minor injury), and the environment (fuel spill). This study found that the dominant vehicle risk factors and severity were braking system failure (60%), accident severity without injury dominated (81.8%). Most incidents did not result in spills, but 6.1% were fatal. The results of the multivariate analysis indicate that although no vehicle factors are statistically significant at the 95% confidence level, factors such as braking system, steering, tires, engine, and visibility have high positive estimates indicating a tendency to increase crash severity. The findings highlight the need to focus on brake system inspection and maintenance, as well as improve training programs and telemetry monitoring. Recommendations include strengthening preventive maintenance, sharpening pre-trip inspection, and conducting further research with a larger sample to validate the results.

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1. INTRODUCTION

Traffic accidents are a global problem that has multidimensional impacts, both in terms of public health, economy, and development. According to data from the United Nations (United Nations, 2020), every year around 1.3 million people die from traffic accidents, with more than 3,000 deaths occurring every day. Most of the victims are from vulnerable road user groups, such as pedestrians, cyclists, and motorcyclists. In addition, between 20 and 50 million people experience non-fatal injuries that can lead to permanent disability. Traffic accidents are also the leading cause of death in the productive age group of 15–29 years and contribute to economic losses of 1–3% of Gross National Product (GNP) in many countries (World Health Organization, 2015, 2017).

In Indonesia, data from the Indonesian Police Traffic Corps (Korlantas POLRI) recorded that throughout 2017 to 2021 there were 533,626 accidents, resulting in 134,631 fatalities, 61,653 serious injuries, and 620,919 minor injuries, with total material losses of more than

IDR 1.13 trillion (BPS Jakarta, 2021). Previous research by Djaja et al. (2010) revealed that the highest incidence and death rates occurred in the productive age group (26–30 years), especially among motorcyclists, with major contributions from human factors, vehicle conditions such as brakes and lighting, and inadequate road infrastructure.

The risk of accidents becomes much greater when hazardous materials transport vehicles such as oil and gas tankers are involved. In this scenario, the risks include not only vehicle damage or individual injury, but also potential environmental and public safety hazards. Leakage of toxic substances, explosions and fires from tanker accidents can cause a large number of fatalities, even in a single incident (Ghaleh et al., 2019; Ewbank et al., 2019). A report by Concawe (Banner, 2021) also shows that road traffic accidents are the second leading cause of death in the downstream oil and gas industry in Europe, after explosions and fires, with an average of 30 days of Lost Work Time Injury (LWI) per incident.

The risk of tanker accidents is not only high in terms of frequency, but also in terms of the destructive impacts caused, both to humans and the environment. Explosions and fires due to fuel tanker accidents have repeatedly been recorded as causes of mass deaths in various countries. Historical data such as incidents in South Kivu, Nigeria, Pakistan, and the tragic case in Cibubur, Indonesia, confirm that tankers are one type of vehicle with the most potential for fatal accidents. This complexity drives the need to evaluate not only the driver factor as the main cause of accidents, but also the contribution of vehicle factors and operational management.

The conceptual model as developed by Haddon (1972) emphasizes that traffic accidents cannot be separated from the interaction of three main factors: humans, vehicles, and the environment, each of which plays a role in the phase.*pre-event*, *event*, And *post-event*. In the context of hazardous material transportation, vehicle factors have a significant contribution, especially when the safety system is not functioning optimally. A study by Yang et al. (2010) showed that in 322 cases of hazardous material transportation accidents in China, 31.4% were caused by mechanical failures, including brake failures and other vehicle systems.

Furthermore, findings by Hoque and Hasan (2006) reinforce that in heavy vehicles, technical failures such as tire punctures (46%), brake system failures (10%), and steering or light failures (1%) are the dominant causes of accidents. Meanwhile, results from Montero-Salgado et al. (2022) in Ecuador confirm that braking system failures (65.5%) and steering (17.2%) are the vehicle components most frequently associated with serious accidents. All these findings indicate that the technical aspects of the vehicle play an important role in exacerbating the severity of accidents, especially when involving tankers transporting flammable materials.

This condition creates a high urgency to evaluate the technical aspects of vehicles as an integral part of accident prevention efforts, especially in vehicles transporting hazardous materials such as tankers. Of the 14 tanker accident investigation reports released by the National Transportation Safety Committee (KNKT), 78.6% or 11 cases listed vehicle factors as the main or supporting cause. This proportion indicates that vehicles are not just a means of transportation, but also a critical point in the operational safety system. This is further emphasized by Ambituuni et al. (2015), who stated that 70% of accidents in oil and gas transportation by land resulted in loss of cargo, which in turn has the potential to cause spills, fires, or explosions.

Although many studies have been conducted on land traffic accidents in Indonesia, the majority of studies still focus on human factors and driving behavior. Research that specifically examines vehicle factors, especially in the context of high-risk tanker trucks, is still very limited. In fact, failures in critical vehicle systems such as brakes, tires, steering,

and lighting systems have been shown to play a significant role in increasing the severity of accidents. Therefore, this study focuses on exploring the relationship between vehicle technical variables and the severity of tanker truck accidents, which not only affect driver safety but also pose a great risk to public safety and the surrounding environment.

By using a quantitative analytical approach through the method ordinal *logistic regression*, this study aims to provide strong empirical evidence regarding the simultaneous influence of vehicle factors on accident severity, as well as filling the research gap that has not been widely touched in Indonesia, especially in the context of vehicles transporting hazardous materials.

2. RESEARCH METHOD

This study uses a descriptive analytical approach with a retrospective study design, which aims to analyze vehicle technical factors that contribute to the severity of tanker accidents at PT XYZ. This study was conducted by utilizing secondary data sourced from the results of the company's internal accident investigation, allowing researchers to examine the pattern of relationships between variables based on events that have occurred in the past.

The study was conducted from May to June 2024, with data coverage of tanker accidents that occurred in the period from 2020 to 2023 throughout the operational areas of PT XYZ. The unit of analysis in this study is the tanker accident case, where each unit is analyzed based on the technical characteristics of the vehicle and the severity of the accompanying accident.

The data collection process is done by extracting information from documented internal accident investigation reports. This data includes important variables such as vehicle age, braking system condition, steering, tires and wheels, engine, lighting and visibility, vehicle modifications, implementation pre-trip *inspection* (PTI), history preventive *maintenance* (PM), and vehicle managers.

After the data was collected, coding, editing, and screening processes were carried out to ensure the completeness and suitability of the data with the research criteria. The cleaned data were then analyzed in two stages. First, a univariate analysis was carried out to describe the distribution of each variable through descriptive statistics. Furthermore, a multivariate analysis was carried out using the Ordinal Logistic Regression method to evaluate the simultaneous relationship between vehicle variables and accident severity. The variable selection process was carried out using a stepwise forward selection approach, where predictor variables were gradually entered into the model based on their significant contribution to the dependent variable.

3. RESEARCH LIMITATIONS

This study is limited to PTXYZ's fuel tanker accidents that occurred in 2022-2023, so that any incidents outside that time period are not analyzed. The data sources used are entirely from PTXYZ's internal investigation reports. The focus of the research variables is only on vehicle factors—including vehicle age, preventive maintenance, pre-trip inspection, braking system, tire-wheel condition, electrical, lighting/visibility, and modification—as well as the severity of the accident on vehicles, humans, and the environment, so that the contribution of human and environmental factors as the main causes is not examined. The analysis methods used are limited to univariate descriptions and ordinal logistic regression; advanced statistical models are not used. Because the sample only includes PTXYZ data for a certain period, the results of this study cannot be directly generalized to other fleets or oil and gas companies at different times or contexts.

4. RESULTS AND DISCUSSION

This study analyzes 33 cases of tanker accidents that occurred in the operational environment of PT XYZ during the period 2022 to 2023, with the main focus on identifying the relationship between the technical condition of the vehicle and the severity of the accident. All data analyzed are secondary data from the company's internal documentation, which includes comprehensive details regarding vehicle characteristics and technical factors that have the potential to cause accidents.

Each accident event is analyzed based on variables such as vehicle age, type of tanker, vehicle standardization, preventive maintenance (PM) history, implementation of pre-trip inspection (PTI), and the condition of the braking system, tires, steering, engine, lighting, and visibility, including the presence of structural modifications to the vehicle. In addition, the dimensions of vehicle management are also traced, both by internal parties of the company and third parties as operators.

The severity of accidents is classified ordinally into four categories as follows:

- Category A describes a severe total loss, where no part of the vehicle has any resale value.
- Category B reflects total damage, but still allows some parts of the vehicle to be used as spare parts.
- Category S (Serious) indicates serious damage that requires professional technical attention before the vehicle can be operated again.
- Category N (Normal/Minor) indicates minor damage that does not significantly impair vehicle performance.

Below is data on accident incidents throughout 2022 and 2023.

Table 2. Results of the Investigation of the PT XYZ Tanker Car Accident in 2022 – 2023.

No	Year	Vehicle Factors	Severity Description	Human Severity Category	Spill
Case 1	2022	locking jaw and kingpin	Minor damage, still drivable	Not Hurt	There was no spillage
Case 2	2022	Braking System	Minor damage, still drivable	Not Hurt	There was no spillage
Case 3	2022	Braking System	Total damage, low resale value due to significant damage	Not Hurt	There was no spillage
Case 4	2022	Axle	Serious damage, cannot be driven until repaired	Not Hurt	There was no spillage

No	Year	Vehicle Factors	Severity Description	Human Severity Category	Spill
Case 5	2022	Braking System	Serious damage, cannot be driven until repaired	Not Hurt	There was no spillage
Case 6	2022	Braking System	Serious damage, cannot be driven until repaired	Not Hurt	There was no spillage
Case 7	2022	Braking System	Serious damage, cannot be driven until repaired	Not Hurt	There was no spillage
Case 8	2022	Cab Lock Lever	Serious damage, cannot be driven until repaired	Minor injuries	There was no spillage
Case 9	2022	Braking System	Total damage, cannot be repaired, only for spare parts	Fatality	There was no spillage
Case 10	2022	Cab Lock Lever	Total damage, cannot be repaired, only for spare parts	Fatality	There was no spillage
Case 11	2022	Wheels and Tires	Minor damage, still drivable	Not Hurt	There was no spillage
Case 12	2022	Braking System	Minor damage, still drivable	Minor injuries	There was no spillage
Case 13	2022	Steering	Serious damage, cannot be driven until repaired	Not Hurt	There was no spillage
Case 14	2022	There was a filter	Minor damage, still drivable	Minor injuries	There was no spillage
Case 15	2022	Gearbox (Gear)	Minor damage, still drivable	Not Hurt	There was no spillage

No	Year	Vehicle Factors	Severity Description	Human Severity Category	Spill
Case 16	2022	Braking System	Total damage, low resale value due to significant damage	Not Hurt	Yes, there is a spill of Pertalite
Case 17	2022	Braking System	Minor damage, still drivable	Not Hurt	There was no spillage
Case 18	2022	Braking System	Minor damage, still drivable	Not Hurt	There was no spillage
Case 19	2022	Electrical short circuit - machine	Total damage, low resale value due to significant damage	Not Hurt	There was no spillage
Case 20	2023	Braking System	Serious damage, cannot be driven until repaired	Not Hurt	Yes there is spillage from Manhole seepage
Case 21	2023	Braking System	Minor damage, still drivable	Not Hurt	There was no spillage
Case 22	2023	Braking System	Serious damage, cannot be driven until repaired	Not Hurt	There was no spillage
Case 23	2023	Braking System	Serious damage, cannot be driven until repaired	Not Hurt	There was no spillage
Case 24	2023	Axle	Minor damage, still drivable	Minor injuries	There was no spillage
Case 25	2023	Braking System	Total damage, low resale value due to significant damage	Not Hurt	There was no spillage
Case 26	2023	Braking System	Minor damage, still drivable	Not Hurt	There was no spillage

No	Year	Vehicle Factors	Severity Description	Human Severity Category	Spill
Case 27	2023	Electrical short circuit - machine	Unrepairable, only good for parts	Not Hurt	There was no spillage
Case 28	2023	Electrical short circuit - machine	Unrepairable, only good for parts	Not Hurt	There was no spillage
Case 29	2023	Braking System	Total damage, low resale value due to significant damage	Not Hurt	There was no spillage
Case 30	2023	Braking System	Minor damage, still drivable	Not Hurt	There was no spillage
Case 31	2023	PSV Tank	Minor damage, still drivable	Not Hurt	Yes, there is gas release
Case 32	2023	Braking System	Unrepairable, only good for parts	Not Hurt	There was no spillage
Case 33	2023	Electrical short circuit - machine	Minor damage, still drivable	Not Hurt	There was no spillage

Univariate Analysis

Univariate analysis was conducted to provide a descriptive description of each variable used in this study, both independent variables related to vehicle technical characteristics and dependent variables that describe the severity of the accident, including its impact on vehicles, humans, and the environment. The purpose of this analysis is to understand the distribution and initial pattern of tanker car accidents at PT XYZ during the period 2022–2023.

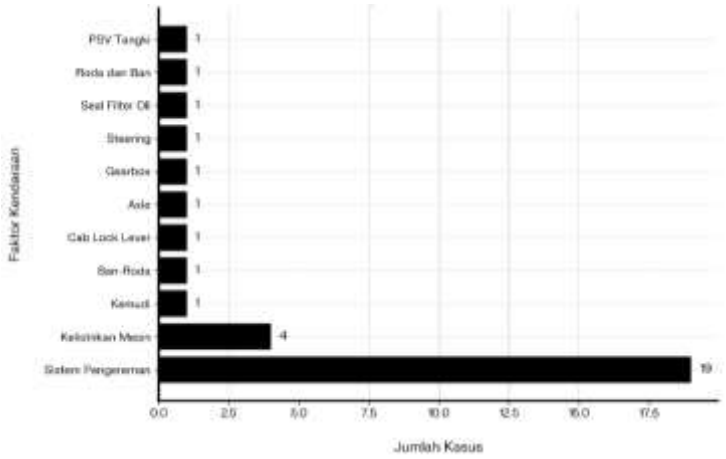

Figure 1. Frequency of Vehicle Factors Causing PT XYZ Tanker Car Accidents (2022-2023)

Vehicle factors are key elements in the safety system of heavy vehicles such as tankers. From the results of the distribution analysis, it was found that the dominant factor causing accidents was the braking system, which was recorded in 19 of the 33 cases. This strengthens previous findings that brake failure is a major contributor to serious accidents in logistics vehicles. In addition, electrical system disturbances in the engine were also identified as the cause in 4 incidents, indicating the importance of routine monitoring of the vehicle's main electrical system.

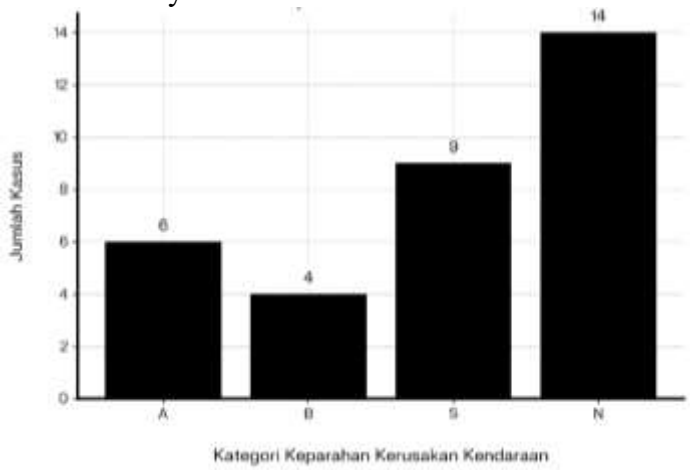

Figure 2. Distribution of Severity Levels of PT XYZ Tanker Car Accidents (2022-2023)

The distribution of vehicle damage severity is classified into four categories, namely A (total damage without resale value), B (total damage with remaining spare part value), S (severe damage but still repairable), and N (minor damage). The analysis results show that category N dominates with 14 incidents, followed by category S with 9 incidents. Category A recorded 6 incidents, and category B only 4 incidents.

The dominance of categories N and S indicates that most accidents are still on a light to medium scale, without total damage. However, the existence of 6 cases of category A indicates a serious incident that has an impact on total damage to the vehicle as a whole. This is an important signal to increase control over vehicles that are old or rarely rejuvenated with critical components. Category B, although the number is the smallest, still shows that total damage still occurs and has the potential for large material losses.

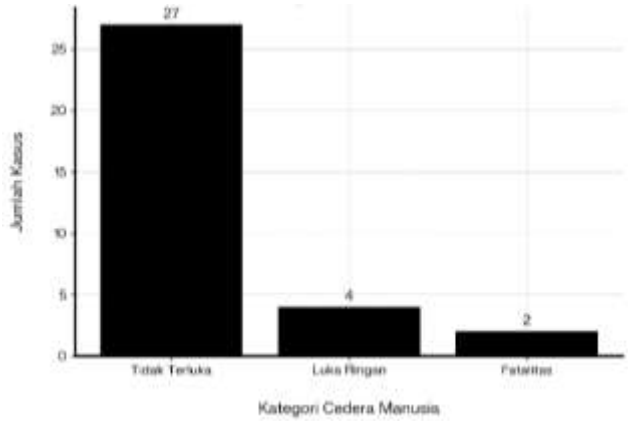

Figure 3. Distribution of Human Injury Severity Levels in PT XYZ Tanker Car Accidents (2022-2023)

In addition to vehicle damage, the study also observed the severity of the driver or crew. Of the total 33 accidents, 27 cases (81.8%) did not result in injury ("No Injury" category), while 4 cases (12.1%) resulted in minor injuries, and 2 cases (6.1%) resulted in death.

This distribution indicates that the majority of accidents do not have a direct impact on life safety, but the number of fatalities remains a critical concern, especially since tankers carry hazardous loads. This finding is consistent with studies by Imran et al. (2022) and Hasan et al. (2021) which show that heavy vehicles tend to have cabin structures that are able to protect drivers in minor to moderate accidents, but still require additional layers of protection to reduce fatalities in severe accidents.

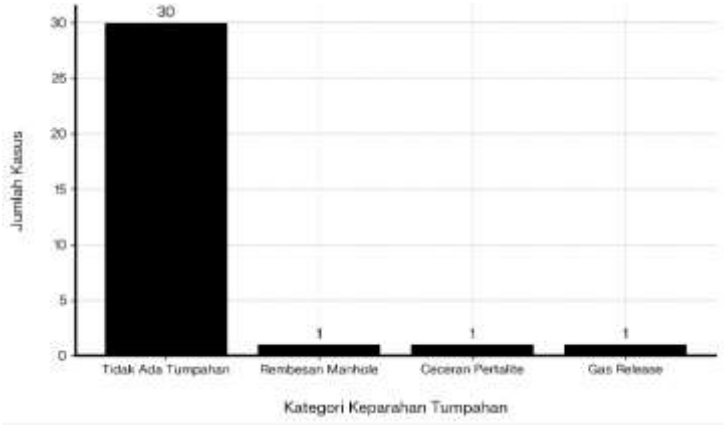

Figure 4. Distribution of Spill Severity Levels in PT XYZ Tanker Car Accidents (2022-2023)

Tanker accidents not only cause material losses and human safety, but also have the potential to cause environmental damage due to oil or gas spills. From the analysis, it can be seen that more than 30 of the 33 cases did not involve spills, indicating that the majority of accidents were structural and did not cause cargo leakage.

However, there were 3 cases of spills with different types, namely: seepage from manholes, pertalite spills, and gas releases. Although the number is small, the existence of these cases indicates the vulnerability to hazardous material leaks, which have the potential to trigger explosions or fires, especially if they occur in dense environments or near heat sources. Therefore, technical handling of cargo storage systems and safety connections must be the focus of tanker vehicle inspections.

Multivariate Analysis

Multivariate analysis in this study was conducted using the Ordinal Logistic Regression (OLR) method to evaluate the simultaneous influence of various vehicle factors on three main outcomes: vehicle crash severity, human impact severity, and spill severity. The selection of this method is based on the ordinal nature of the dependent variable, which classifies events into several ordered levels of severity. The following are the results of multivariate analysis using *Ordinal Logistic Regressions*.

In the analysis of the influence of vehicle factors on the severity of tanker car accidents, it was found that none of the variables were statistically significant at the 95% confidence level. However, variables such as braking system, steering, tires, engines, and visibility had high positive coefficient estimates indicating a tendency for increased severity of vehicle damage, with *estimate* Braking (17,414), Steering (14,905), Tires/Wheels (16,776), Engine (16,291), and Lighting/Visibility (18,260).

In the influence of vehicle factors on human severity, there are no statistically significant variables, but some variables such as braking and steering actually show a negative coefficient direction that is not in accordance with the theory. This indicates a limitation in the amount of data.

Meanwhile, in the influence of vehicle factors on the severity of the spill, all variables are also not statistically significant and many coefficients are inconsistent with the theory, possibly due to unbalanced data distribution or small sample size. Therefore, further research is needed with a larger sample.

5. CONCLUSION

This study reveals that vehicle technical factors play an important role in determining the severity of tanker accidents, both in terms of vehicle damage, impact on humans, and potential environmental hazards such as fuel spills. Based on the results of univariate analysis, it was found that the dominant factor causing tanker accidents at PT XYZ during 2022–2023 was braking system failure (60%), followed by electrical failures and other technical components such as steering and tires1. Most accidents resulted in minor to moderate damage to vehicles (categories N and S), with 81.8% of incidents not causing human injuries and the majority of incidents not causing spills, although there were still cases of fatalities and spills that had the potential to harm the environment.

The results of multivariate analysis using the ordinal logistic regression method showed that no statistically significant relationship was found between vehicle factors, human severity, vehicles, or the environment. However, the direction of the coefficients and estimates indicate the potential relationship of several vehicle factor variables.

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