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Driving Safety Excellence: Strategies for Minimizing Land Transportation Incidents in the Oil and Gas Industry

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Abstract

The global energy landscape has long relied on the oil and gas sector, a vital industry heavily dependent on an intricate web of pipelines, barges, and diverse transportation networks. This study delves into the pressing safety concerns within the oil and gas domain, specifically addressing transportation-related incidents, which notably exhibit a higher fatality rate compared to other aspects. Employing the Six Sigma methodology, this research endeavors to scrutinize and bolster the safety protocols within the land transportation sector of the UAE's oil and gas industry. Various analytical approaches are utilized to unearth the root causes of these issues, subsequently enabling comprehensive investigations and effective mitigation strategies. Drawing data from the International Association of Oil and Gas Producers (IOGP), committed to curbing land transportation accidents, insights are gathered from a wide spectrum of global oil and gas entities, including local firms in the UAE. Through the application of Six Sigma principles, the findings underscore that human factors, encompassing diverse facets, stand as the primary catalysts behind land-based incidents plaguing the industry. This study signifies a significant step toward identifying and rectifying critical safety concerns, ultimately striving for a safer operational environment within the oil and gas transportation sphere. The results of FMEA identified inadequate training for unusual situations as a major human factor in land transportation incidents, with the highest RPN of 504. After analysis, a significant 57.14% reduction in RPN was achieved, supported by statistical validation confirming the effectiveness of recommended actions in reducing severity and overall risk.

Keyword
Oil and Gas, Lean-Six Sigma, transportation, accident, safety

1. Introduction
Transportation methods differ based on the material to be transported, the material`s physical status, cost, available resources, etc. In the oil and gas industry, most transportation activities are on land using trucks vehicles, or pipelines. Although transport using pipelines is a reasonably safe method, it has had its share of risks throughout history. Factors contributing to pipeline failures have been studied and identified for safer and more effective systems, including corrosion, damage related to equipment and operations, in addition to natural or outside force damage. A clear understanding of historical events will guide successful planning for the future; by investigating several unfortunate disasters resulted from pipeline failure, vandalism was found to be the root cause of pipeline failure, accounting for

43% of fatalities (Biezmaa et al. 2020). Pipeline failure incidents have been taking place for more than 80 years; these events came with cost but also with lessons, which helped in the analyses and contributed to building future pipeline transport systems to prevent the re-occurrence of such disasters. However, safety issues in transportation in this industry do not only revolve around pipelines but also land transportation risks.

According to the Occupational Safety and Health Administration (OSHA), the major safety issues in oil and gas industry within well drilling and service activities are vehicle collisions, caught by/in or between, explosions and fires, falls from heights (FFH), confined spaces, ergonomic hazards, high-pressure lines and equipment, electrical and machine hazards, and finally planning and prevention. Vehicle collisions are at the top of the list of the leading safety issues in this industry. People, materials, equipment, and products must be transported from and to specific wells, which requires spending a lot of time traveling long distances on highways. OSHA approximates that 40% of people killed in the oil and gas industry share the exact reason for death, which is highway vehicle incidents.

Work-related Land Transportation Fatalities Reports from IOGP studied all land transportation fatalities that took place in different oil and gas producer companies from 2000 to 2022, investigating the causal factors of these events, conditions, and actions. The casual aspects are divided into people/acts and process conditions, the study gathered incidents into two categories: fatalities resulting from violent acts and fatalities excluding assaults/ violent acts. For the first quarter of the study, from 2000 to 2005, there was a noticeable increase in fatalities incidents, especially in 2003, while the second quarter witnessed a significant reduction in Motor Vehicle Crash (MVC) reported fatalities incidents, the third quarter violent acts resulted in an observable increase of MVC in 2011, the last quarter which was from 2016 to 2022, MVC fatalities cases begin to reduce. However, in 2021, there was a slight increase in reported cases, which can lead to the conclusion that land transportation incidents in the oil and gas industry are not yet controlled. ADNOC, an oil and gas company in UAE, has also stressed the ongoing existence of land transportation incidents, where the only incidents in the company in 2023 were all concerning land transportation.

Accidents in this industry have severe economic ramifications and immediately endanger people's lives, property, and the environment. Thus, improving the safety system in land transportation mishaps in the oil and gas sector is critical. Accidents are intensified by factors such as inadequate safety protocols, outdated infrastructure, and human error, which underscores the urgency of developing effective safety measures. The paper attempts to answer how to address critical safety issues and enhance the safety system within the land transportation sector of the oil and gas industry.

1.1 Objectives

The main objective of this paper is to help reduce and ultimately eliminate the number of serious land transportation incidents and fatalities by developing a proper systematic framework for reducing and controlling the number of incidents occurring in the oil and gas sector due to land transportation. The Framework offers an integrated approach and the flexibility to address a wide range of risks, impacts, or threats related to occupational health and safety; thus, the Lean-Six Sigma approach will be used to introduce sufficient analysis of the leading causes behind land transportation incidents and to suggest applicable control strategies for implementation in the safety system of land transportation.

2. Literature Review

The oil and gas industry relies heavily on land transportation for various activities, such as logistics, equipment transportation, and worker commutes. However, the industry is confronted with a significant challenge of minimizing land transportation incidents. There are options available for land-based oil and gas transportation: trucks, railroads, and pipelines. There are more road safety precautions for tanker trucks than mere speed limits. Trucks have an airtight construction, and partitions prevent the liquid from moving backward or forward. Another factor contributing to safer transportation is the tank's design: round for LNG, oval for gasoline and diesel (Marchand 2021). In the past, the railroad was the main mode of transportation for oil. They compete with pipelines nowadays, but they remain a good option because they provide more flexible routes. Spills and inadvertent emissions are a significant problem for oil transportation and storage methods. Tanker spills can contaminate coastal areas, whereas rail and pipeline spills, depending on where they occur, can contaminate wildlife habitats or populated areas (Vanek et al. 2012).

When it comes to transportation, safety is the priority. Tankers face numerous risks at all times, regardless of their size, from the smaller general-purpose tankers carrying refined products to the super tankers that transport crude oil (Goerlandt et al., 2015). One example is Cargo, which by nature is flammable and is bound to release certain gases. Cell phones and cameras are examples of equipment that could potentially explode or catch fire. All electrical devices in general, including power tools, are utilized for maintenance and everyday tasks. Lightning or electrical storms, and cigarettes, have historically resulted in fires and prompted the widespread prohibition of smoking in prohibited areas (Marchand 2021).

The driver is one important aspect of land transportation safety to consider. The three main factors are training, health, and qualifications. When it comes to driving, authorizations and qualifications are crucial. The employer's authorization for the driver to drive for work should be part of the driving-for-work policy and procedures (Janno et al., 2021). Drivers should often participate in training to keep up their knowledge and skills. Refreshing their knowledge of traffic laws is usually advised for drivers, at least annually. Drivers can receive certain fundamental yet required training from outside providers. These instruction programs include fatigue awareness, firefighting or Hazardous Materials (HazMat), first aid, and CPR (Vehicle Safety, 2023).

One other key safety factor for land transportation is the roadways. All types of roads, including freeways, highways, and interstates, are experiencing increased traffic and congestion. Since most existing roads are too old to be repaired or rebuilt, additional work zones will exist in already heavily trafficked locations (Tawfik, M. 2015).

Organizations should design and implement transportation safety measures that best meet the needs of their roadway users in terms of mobility and safety, as the effects and challenges associated with oil fields can vary. Trip planning can be implemented as a transportation safety measure. In addition to, communication between the client company and the transportation contractor, equipment inspection and reporting, securing cargo, weather conditions and mapping routes (Iyer, L., 2021).

Human error can provide serious safety risks in land transportation in the oil and gas industry. These mistakes can happen at several phases, from planning and preparation to actual driving and decision-making on the road. There is an increase in occupational accident figures in different workplaces around the world (YUVKA et al., 2023). According to the International Labour Organization (ILO), in 2014, over 2.3 million fatalities occurred worldwide each year due to occupational accidents and work-related diseases. Several causes contribute to these accidents, but one of the main ones is human error. Human error is an unintended failure to achieve the planned outcomes through action, checking, retrieval, transmission, diagnostic, and decision errors. It refers to a worker's incorrect judgment or behavior at work that hurts the workplace (Dekker, S., 2017). Stated differently, it is an action that results in an emergency, takes lives, harms the environment and property, and interferes with the business operations of any place of employment. Within the Oil and Gas (O&G) industry, human error is the primary cause of more than 70% of accidents (Alkhaldi, M, 2017). The significant impact of these disasters on the workforce, workplace, economy, and society is considerable, given the diverse range of hazardous chemicals and operations associated with the oil and gas (O&G) industry (Alkhaldi, M, 2017). Common human errors can include fatigue: extended workdays and rigorous schedules can cause driver tiredness, which can affect decision-making, response times, and general driving ability, research found that the risk of errors and incidents rises by 13% for 10-hour shifts and 28% for 12-hour shifts compared to 8-hour shifts (Caldwell et al., 2019). Distractions: When a driver is distracted by something other than the road, such as a radio or cell phone, the likelihood of an accident increases (Née et al., 2019). Impaired driving: driving while under the effect of alcohol or drugs can affect drivers' judgment and skills, which can result in collisions. Inadequate training: Inadequate training and lack of experience can lead to poor decision-making and driving methods (Cao et al., 2022). Elvik, R. (2017) studied the relationship between incidents rate and access point density. It was demonstrated that the incidents rate increases by 4% per added access point in the road, which easily describes the possible hazardous impacts potentials based on road infrastructure. Wang, X. *et al.* (2022) explored causation factors behind crash incidents, the study took into consideration several parameters such as vehicle user, road infrastructure, and environment subsystem. Human factors were the highest causes of accidents and yielded to 98.13%. Also, the use of countermeasures can significantly contribute into road accidents reduction and enhance the transportation safety. Cvahte Ojsteršek, T. *et al.* (2023) examined the effects of in-vehicle tasks distraction such as setting the climate, navigational system, and radio frequency. Its was obtained that those tasks can divert visual attention by more than 40% which can highly influence drivers' behavior.

The oil and gas industry must achieve driving safety excellence to minimize the risk of land transportation incidents. This literature review highlights the importance of implementing comprehensive safety programs, leveraging technological advancements, and promoting collaboration and industry-wide initiatives to enhance driving safety in the sector. The oil and gas industry can mitigate risks and protect its workforce, assets, and reputation by adopting strategies.

3. Methods

The study focuses on developing a proper systematic framework for reducing and effectively controlling the number of incidents occurring in the oil and gas sector due to land transportation. The lean-six sigma approach was utilized to introduce sufficient analysis of the main causes behind the noticeable increase in land transportation accidents in the oil and gas industry in recent years. Additionally, applicable control strategies are suggested for implementation in the safety system of land transportation. The following steps show the sequences of lean-six sigma tracked to achieve desired objectives:

Step 1: Define the problem. In this stage, a pareto chart was developed to monitor the frequency of primary causes that led to possible land transportation incidents, followed by fishbone analysis to highlight each factor of the most frequent primary causes.

Step 2: Measure the process. FMEA analysis was performed to assess the potential risk associated with potential operations and possible corrective action to be made to avoid major and fetal land transportation incidents.

Step 3: Analyze the process. FMEA analysis was executed to present a deep understanding of the factors affecting the land transportation performance and provide a measurable improvement in corrective actions planned.

Step 4: Implement improvements. Suggested strategies based on pervious analyses were recommended to positively alter land transportation safety operations.

Step 5: Control the operation. Long-term control techniques were proposed to emphasize the importance of maintaining improved and safe land transportation operations.

3.1 Fishbone Analysis

A Pareto chart was employed to determine the frequency of factors contributing to violating safety protocols, resulting in a spike in land transportation incidents within the oil and gas industry. The five most frequent reasons were extracted from the Pareto chart for further investigation. As depicted in the Pareto chart, these prevalent factors predominantly fall under the categories of human factors and organizational errors. Subsequently, a fishbone analysis was conducted for each of these causes to comprehend the underlying impacts of each reason. Each reason was dissected and linked to various factors, including individual, organizational, and other significant elements, to shed light on each factor's potential influence and its contribution percentage to the core challenge at hand.

3.2 FMEA analysis

A detailed failure mode and effect analysis was performed for both phases separately in the define and measure phase of the lean-six sigma approach. The FEMA analysis presented in the measure phase shed light on the possible causes behind highlighted factors from fishbone analysis that arise and work together to form a possible land transportation incident. It demonstrates the failure modes of land transportation operations and the contributing factors to them, along with the effects and consequences generated by specified failure modes. Also, it provides the causes affecting the occurrence of identified failure modes. For the measure phase, a detailed occurrence of such factors and causes were demonstrated after coupling it with corrective actions and possible prevention approaches. Figure 1. describes the detailed operations of FMEA analysis.

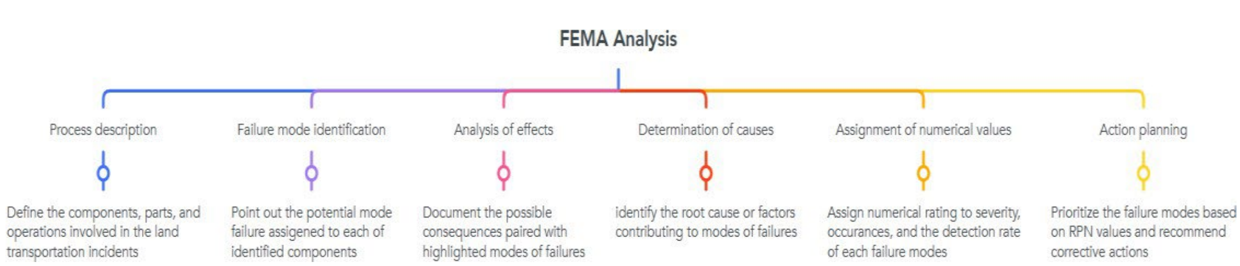


Figure 1. FEMA analysis operations

4. Data Collection

The data used in the study were collected from the International Association of Oil and Gas Procedures; the association provides access to the procedures and safety operations held in oil and gas companies around the globe. The data employed in the study were taken from documented land transportation incidents in recent years. The cases considered included the different regions of the globe and mainly focused on major and fetal land transportation incidents; since the occurrence of those cases slightly increased in recent years, the study aimed to use the data and propose sufficient improvement to the leading causes. Figure 2 from IOGP presents the work-related land transportation fatalities in a specified domain of 22 years.

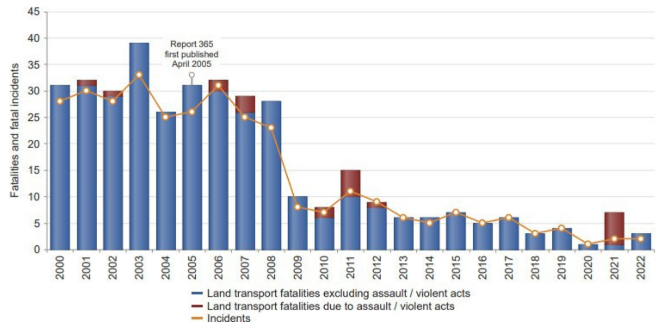


Figure 2. Work-related Land Transportation Fatalities Reported to IOGP

5. Results and Discussion

5.1 Application of Lean Six-Sigma

The study followed the approach of lean six-sigma to propose potential improvements and enhancements to the major and fetal land transportation incidents occurring due to human errors and organizational errors in the oil and gas sector. As mentioned in pervious sections, lean six-sigma consists of five phases. Each phase identifies a specific point in the targeted process. The results obtained from each phase of six-sigma reads as follows:

Step 1: The data collected from the oil and gas association were gathered and sampled to identify the frequency of causes led to major and fetal land transportation, the cases under consideration are the cases from the year of 2018 to 2022, since the sudden increase of land transportation incidents occurred in this domain. A pareto chart was executed to map the proposed causes behind land transportation incidents. Figure 3. presents the pareto chart and frequencies of main reasons which are lack of awareness, failure to follow procedures, inadequate training, inadequate supervision, failure to use PPE, and poor leadership. Those reasons contribute to more than 75% of land transportation happening in the oil and gas sector.

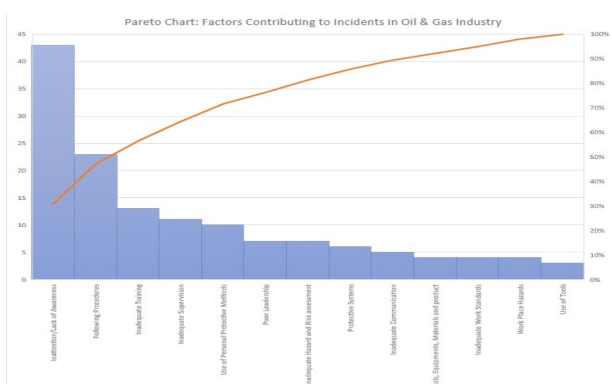


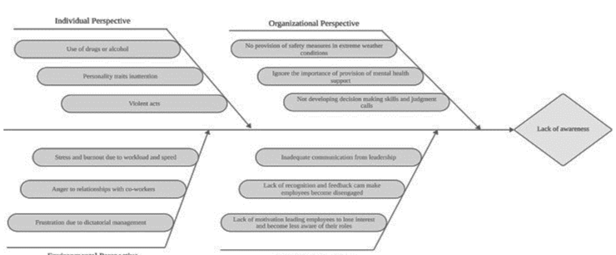
Figure 3. Pareto chart for main reasons behind fetal and major incidents

The highlighted causes from the pareto chart were taken further for detailed fishbone analysis, each one of the causes was broken into small parts to identify possible triggers behind the main cause. Figure 4. shows lack of awareness cause split into four categories which are organizational, individual, leadership, and environmental perspectives.

Those perspectives include sub-categories that highly contribute to the mentioned categories which eventually affect the human factor error initiated by lack of awareness. In Figure 5. the use of individual proactive reason rise from several categories such as management perspective which is linked to inadequate supervision and inadequate program on the use of safety system. Figure 6. presents insufficient training which resulted from various factors such as lack of personal knowledge, inadequate training level to each position, and inadequate training program to new employees. Figure 7. demonstrates factors like insufficient oversight and quality management, Absence of transparent communication, and inability to address breaches of ethical safety standards that strengthen the human factor error of ineffective leadership. In Figure 8. Insufficient supervision was detected due to reasons such as insufficient training and a resources shortage in terms of staff. Figure 9. presents abandonment of procedures which were activated due to multiple reasons such as unsafe driving behavior, neglecting pre-task vehicle checklist, and lack of rigorous accountability procedures.

Step 2: A failure mode and effects analysis (FMEA) were performed to present the potential of risk associated and failure modes included in the primary sub-factors of main causes. In the measure phase of six-sigma, performance measurement of current operation should be executed, therefore, FMEA analysis executed to measure the performance of land transportation of oil and gas sector. The measurements were based identifying possible failure modes, and measuring the probability of such failure happening in the system along with potential consequences that could arise due to the mentioned failure modes in land transportation safety system. Table 1. Shows the FMEA analysis obtained based on the subfactors extracted from fishbone analysis. As it shown, the highest risk priority of 504 was achieved by ignoring training for unusual condition factor which is mainly triggered when experiencing extreme weather conditions. The second highest risk priority of 384 was obtained from lack of adherence to driving standards which initiate in drivers by engaging in irresponsible behavior and actions during task execution. The risk priority number can easily be an indicator to the hazardous factors arising from common human error in land transportation. It is a resultant of the severity of the cause, the probability of occurrence, and the frequency of failure detection.

Step 3: In the analyze stage of six-sigma, an additional part was added to FMEA analysis to measure the potential of corrective action suggested. The possibility of failure modes, and probability along with consequences that may arise due to the main failure modes after implementation of improvements were presented. Table 2 shows the updated FMEA analysis with proposed calculations of prevention actions. After implementing the recommended actions to avoid failure modes of the factors, the risk priority number reduced significantly which shows the possibility of avoiding hazardous situation by adopting suitable safety action and controlling the process. As stated, ignoring training for unusual situations yielded the highest risk priority number, however, the actions executed decreases the risk priority number by 57.14%. The highest reduction in risk priority number was obtained by Failure to prioritize investment in leadership development and drivers training factor which yielded a reduction of 92% which remarkably shows the promising outcomes of the suggested corrective action.



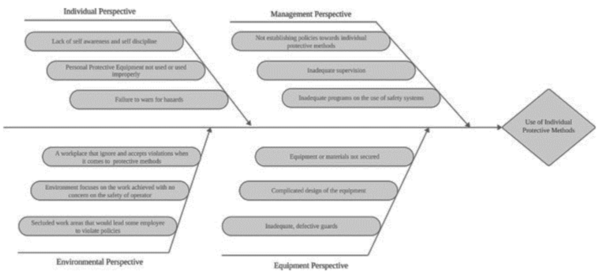


Figure 4. Fishbone analysis of lack of awareness cause
methods cause

Figure 5. Fishbone analysis of use of individual proactive

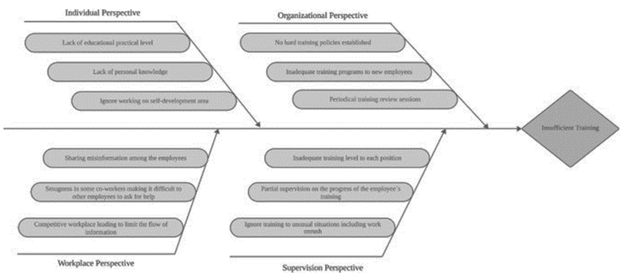


Figure 6. Fishbone analysis of insufficient training cause
cause

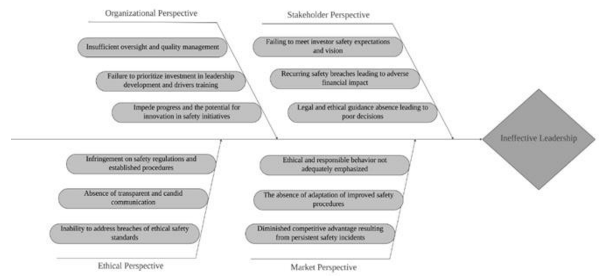


Figure 7. Fishbone analysis of ineffective leadership

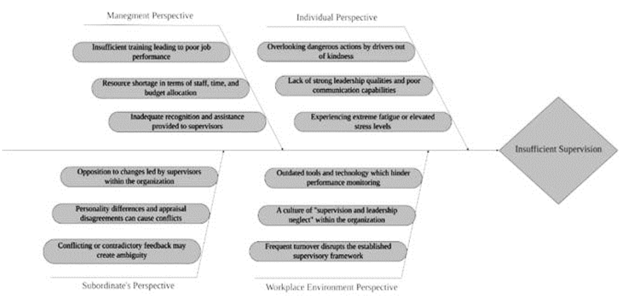


Figure 8. Fishbone analysis of insufficient supervision cause
cause

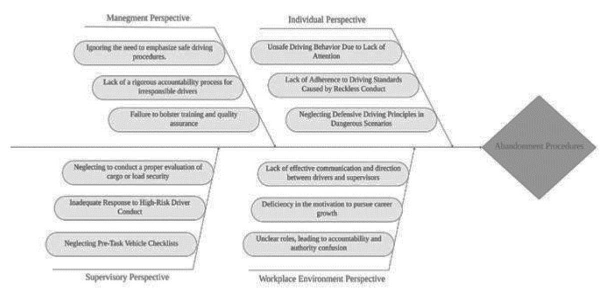


Figure 9. Fishbone analysis of abandonment procedures

Step 4: While trying to mitigate hazardous accidents, there is a need for the automobile company to improve the vehicle operating system with the help of Real-time Operating Systems. One of the major challenges in the modern automotive sector is stated to be dealing with the concept of the advanced driver-assistance system (ADAS), which has posed a significant challenge in maintaining consistency with having less reuse across the vehicle lines. There is less possibility of reuse in modern times and because of this, making software updates for future people has become more challenging (Imran & Kosar, 2020). Hence, to mitigate the concern, the company needs to make use of an open-source software system that helps ensure strong and effective benefits for work. Open-source software is something where the code can be traced by the users without any need for authentic access.

Open-source software is used to develop around 23% of commercial automobile applications where the development of sensors is done through open-source systems. The development of sensors would help to reduce hazards during transportation by giving alerts in advance regarding safety. Making it open-source helps the automobile sector make swift modifications as per the transporting environment. The pre-task automobile checklist is also something that is mitigated completely.

Table 1. FMEA on Sub-factors of Main Causes in Measure Phase

Process Step	**tial Failure Mode**	**tial Failure Effect**	**SEV**	**otential Causes**	**OCC**	**rent Process Controls**	**DET**	**RPN**	**Action Recommended**
What's the step?	In what way could the step go wrong?	What's the impact on the customer if the failure mode is not prevented or corrected?	How severe is the effect on the customer?	What causes the step to go wrong?	How frequently is the cause likely to occur?	What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?	How probable is the detection of the failure mode or its cause	The risk priority number SEV×OCC×DET	What are the actions for reducing the occurrence of the cause or for improving its detection
Use of drugs or alcohol	Lack of proper judgments	Injured customer Very dissatisfied customer	10	The absence of a supportive environment (personal/work)	1	Background checks	4	40	Regular unscheduled blood tests, and provide the needed support
No provision for mental health support	Violent acts	Serious injuries Stressed dissatisfied customer	7	The feeling of frustration, anger, and stress	8	Understanding management and supervision	5	280	Department in the company that follows the mental status of employee and provide mental support
Personal protective equipment not used or used improperly	Harm to personnel and damage to property	Injuries Annoyed dissatisfied customer	6	The absence of supervision, and smugness among individuals	5	Established policies concerning equipment's essential and proper use	6	180	Constant supervision with heavy courses to safety programs and equipment at the beginning of the employment course
Environment focuses more on the accomplishment of work ignoring safety violations attempts by employee	Personnel ignore safety policies and the importance of protective equipment	Injured and dissatisfied customer	5	Management and supervision failure	2	Safety and equipment handouts	3	30	Successful management covering all aspects of work, measuring the quality of work with the safety of employees
Ignore training for unusual situations	Extreme weather conditions surprised the employee	Injury/ death Confused dissatisfied customer	9	Employees trained in usual situations only	7	Adjust work timing according to the unusual event	8	504	Train employee on several weather conditions and scenarios aligned with testing their call of judgment
Inadequate supervision on the employee's training progress	Employees with inadequate training level	Injury/ death Very dissatisfied customer	4	Supervisors ignoring the importance of training courses	4	Mandatory passing of specific training courses	2	32	Periodic training exams with evaluation of different training-related criteria, to be carried out by the supervisors

Process Step	**Potential Failure Mode**	**Potential Failure Effect**	**SEV**	**Potential Causes**	**OCC**	**rent Process Controls**	**DET**	**RPN**	**Action Recommended**
What's the step?	In what way could the step go wrong?	What's the impact on the customer if the failure mode is not prevented or corrected?	How severe is the effect on the customer?	What causes the step to go wrong?	How frequently is the cause likely to occur?	What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?	How probable is the detection of the failure mode or its cause	The risk priority number SEV×OCC×DET	What are the actions for reducing the occurrence of the cause or for improving its detection?
Failure to prioritize investment in leadership development and drivers training	Deficiency in management decisions and drivers' performance	Injury/ death Confused dissatisfied customer.	10	The absence of effective control and monitoring system	4	Tracking managerial decision and conducted mandatory training sessions	5	200	Regularly organize training sessions coupled with performance assessments and institute policies to improve the decision-making capabilities of management
Absence of transparent and candid communication	Inadequate decision-making leading to a rise in incidents	Injured and dissatisfied customer	8	Poor leadership and lack of clear policies and procedures	3	Established clear communication polices	6	96	Organize team-building activities to enhance relationships and communication. Also, encourage feedback process
Experience extreme fatigue coupled with elevated stress levels.	Arbitrary decision-making and inadequate performance	Injury/ death Confused dissatisfied customer	7	Inefficient allocation of tasks within the organization	5	Implemented scheduled breaks and designated rest intervals	8	280	Offer flexible work hours or remote work options to accommodate individual preferences, and ensure that workloads are reasonable and manageable
Shortage in resources in terms of time and staff allocation	Assigning excessive tasks to employees results in heightened stress levels and burnout	Injuries Annoyed dissatisfied customer	6	Poor management and underperforming human resources systems	1	Implemented a training program to ensure optimal and efficient performance	3	18	Regularly evaluate and analyse individual and team workloads
Lack of adherence to driving standards	Engaging in careless behaviour and irresponsible actions during task execution	Serious injuries Stressed dissatisfied customer	8	Ineffective monitoring and inefficient training processes	6	Enforced accountability protocols and monitored performance	8	384	Provide comprehensive training on policies during onboarding, and regularly review and update policies to reflect changes in the organizational environment.
Neglecting pre-task vehicle checklist	Ineffective vehicle operating system that may lead to hazardous situations	Injured and dissatisfied customer	7	Ignoring safety vehicle assessment procedures	3	Embed the pre-task checklist into the regular workflow	7	343	Implement regular supervision to ensure that employees are consistently using pre-task checklists

Table 2. FMEA on Sub-factors of Main Causes in Analysis Phase

Process Step	**tial Failure Mode**	**tial Failure Effect**	**SEV**	**Potential Causes**	**OCC**	**rent Process Controls**	**DET**	**RPN**	**Action Recommended**	**Actions Results**			
What's the step?	In what way could the step go wrong?	What's the impact on the customer if the failure mode is not prevented or corrected?	How severe is the effect on the customer?	What causes the step to go wrong?	How frequently is the cause likely to occur?	What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?	How probable is the detection of the failure mode or its cause	The risk priority number SEV×OCC×DET	What are the actions for reducing the occurrence of the cause or for improving its detection?	**New SEV**	**New OCC**	**New DET**	**New PRN**
Use of drugs or alcohol	Lack of proper judgments	Injured customer Very dissatisfied customer	10	The absence of a supportive environment (personal/work)	1	Background checks	4	40	Regular unscheduled blood tests, and provide the needed support	10	1	1	10
No provision for mental health support	Violent acts	Serious injuries Stressed dissatisfied customer	7	The feeling of frustration, anger, and stress	8	Understanding management and supervision	5	280	Department in the company that follows the mental status of employee and provide mental support	7	3	2	42
Personal protective equipment not used or used improperly	Harm to personnel and damage to property	Injuries Annoyed dissatisfied customer	6	The absence of supervision, and smugness among individuals	5	Established policies concerning equipment's essential and proper use	6	180	Constant supervision with heavy courses to safety programs and equipment at the beginning of the employment course	4	2	3	24
Environment focuses more on the accomplishment of work ignoring safety violations attempts by employee	Personnel ignore safety policies and the importance of protective equipment	Injured and dissatisfied customer	5	Management and supervision failure	2	Safety and equipment handouts	3	30	Successful management covering all aspects of work, measuring the quality of work with the safety of employees	4	1	1	4
Ignore training for unusual situations	Extreme weather conditions surprised the employee	Injury/ death Confused dissatisfied customer	9	Employees trained in usual situations only	7	Adjust work timing according to the unusual event	8	504	Train employee on several weather conditions and scenarios aligned with testing their call of judgment	9	4	6	216
Inadequate supervision of the employee's training progress	Employees with inadequate training level	Injury/ death Very dissatisfied customer	4	Supervisors ignoring the importance of training courses	4	Mandatory passing of specific training courses	2	32	Periodic training exams with evaluation of different training-related criteria, to be carried out by the supervisors	4	2	1	8

Process Step	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes	OCC	rent Process Controls	DET	RPN	Action Recommended	Actions Results			
What's the step?	In what way could the step go wrong?	What's the impact on the customer if the failure mode is not prevented or corrected?	How) severe is the effect on the customer?	What causes the step to go wrong?	How frequently is the cause likely to occur?	What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?	How probable is the detection of the failure mode or its cause	The risk priority number SEV×OCC×DET	What are the actions for reducing the occurrence of the cause or for improving its detection?	New SEV	New OCC	New DET	New PRN
Failure to prioritize investment in leadership development and drivers training	Deficiency in management decisions and drivers' performance	Injury/ death Confused dissatisfied customer.	10	The absence of effective control and monitoring system	4	Tracking managerial decision and conducted mandatory training sessions	5	200	Regularly organize training sessions coupled with performance assessments and institute policies to improve the decision-making capabilities of management	8	2	1	16
Absence of transparent and candid communication	Inadequate decision- making leading to a rise in incidents	Injured and dissatisfied customer	8	Poor leadership and lack of clear policies and procedures	3	Established clear communication polices	6	96	Organize team-building activities to enhance relationships and communication. Also, encourage feedback process	3	2	2	12
Experience extreme fatigue coupled with elevated stress levels.	Arbitrary decision-making and inadequate performance	Injury/ death Confused dissatisfied customer	7	Inefficient allocation of tasks within the organization	5	Implemented scheduled breaks and designated rest intervals	8	280	Offer flexible work hours or remote work options to accommodate individual preferences, and ensure that workloads are reasonable and manageable	7	2	3	42
Shortage in resources in terms of time and staff allocation	Assigning excessive tasks to employees results in heightened stress levels and burnout	Injuries Annoyed dissatisfied customer	6	Poor management and underperforming human resources systems	1	Implemented a training program to ensure optimal and efficient performance	3	18	Regularly evaluate and analyze individual and team workloads	5	1	1	5

Lack of adherence to driving standards	Engaging in careless behaviour and irresponsible actions during task execution	Serious injuries Stressed dissatisfied customer	8	Ineffective monitoring and inefficient training processes	6	Enforced accountability protocols and monitored performance	8	384	Provide comprehensive training on policies during onboarding, and regularly review and update policies to reflect changes in the organizational environment.	6	2	3	36
Neglecting pre-task vehicle checklist	Ineffective vehicle operating system that may lead to hazardous situations	Injured and dissatisfied customer	7	Ignoring safety vehicle assessment procedures	3	Embed the pre- task checklist into the regular workflow	7	343	Implement regular supervision to ensure that employees are consistently using pre-task checklists	7	2	3	42

Moreover, there is a need to improve the decision-making process by putting emphasis on planning and setting a deadline process. The use of the planning process is done for assessing the automotive manufacturing process and optimizing them and adopting the car manufacturing companies. In addition, planning for the marketing and communication process for the employees is required to ensure that there is sufficient benefit for the work (Riba et al. 2020.pp.3674-3683). Along with the change in the internal operational design, the automobile companies are also required to follow up with the following important aspects to reduce accidents:

1- Employees need to go through training in applying the open-source software process.
2- Improvement in the development of human resources who can develop AI-driven sensors and integrate them with open-source software to mitigate the possibility of accidents.
3- Mitigate the challenge overdoing of the work by allowing the employees to have flexible work hours and sufficient benefits. Having flexible work hours helps to maximize the staff`s work, and because of this, there is sufficient improvement in the manufacturing quality.
4- Focus on departmentalization of the tasks to reduce the possibility of excessive tasks.
5- Automotive companies emphasize marketing and development to make more people aware of the importance of safety concerns. Also, a need for the vehicles to develop a safety mechanism within the vehicle to reduce the negative impact on drivers and other passengers if the vehicle meets with an accident.
6- Lastly, there is a need for automotive companies to focus on mental health policies within the organization to ensure that they are dealing with challenging situations.

Nevertheless, investigating options like the use of pipelines is essential to improve safety while transporting oil and gas. Along with the benefit of having less maintenance cost, there are also fewer barriers to the use of pipelines compared to land transport. Other than that, there is also a need for the drivers to be trained with ultra-large crude carrier trucks to ensure that there are fewer accidents and hazards while delivering oil. Step 5: The use of the control strategy is done to make sure that there is enough maintenance of the safety program to control the number of bad incidents. To control the possibility of accidents, there is a need to implement management and supervision-related training for the workers. The main intention of the review is to assess the adjustments made to the safety programs and make as much improvement as possible. To ensure proper control of the work, there is a need to ensure proper control in the decision-making process related to the training of the employees. The training needs to be done to ensure that there is control in communication and testing. The use of communication helps to address errors in transportation and ensure that there is sufficient benefit for work. The extent to which the possibility of an accident is reduced, and the future possibility of adjustment are some of the major factors that need to be reviewed. The criteria of the open-source software and neglecting the pre-task vehicle is something that needs to be controlled to optimize the control of the vehicle operating system (Pamucar *et al.,* 2021). The possible self-driving capacity and the possible advancement of the safety program are also something that is discussed. The strength of the sensors in mitigating the work is discussed across the world (Angelevska *et al.,* 2021). The use of an oscilloscope is done to assess the electrical signal that comes out of the sensors to assess the basic criteria for the work. Making practical use of the sensors is one of the most important aspects that helps to control the rate of accidents across the world. Its important to make use of proper testing of the efficiency of autonomous vehicles to deliver oil and gas in land transportation, and deal with the shortage of resources to reduce the possibility of hazards. Along with the assessment of the technology, there is a need to ensure a continuous review of the technology. The utilization of various control strategies is prevalent in most safety systems, significantly impacting land transportation safety within the oil and gas sector. Firstly, engineering devices, such as AI-driven automation, present an opportunity to enhance safety controls within companies. Incorporating technologies like the antilock brake system can advance brake systems further. Secondly, administrative controls focus on areas like emergency preparedness and maintenance contract signage, alongside the establishment of policies concerning speed limits and safe driving practices. Providing comprehensive training to drivers and conducting regular assessment checks are also integral aspects. Lastly, Personal Protective Equipment (PPE) control emphasizes the importance of drivers wearing appropriate gear, like gloves and hats, during shipment handling to minimize risks and reduce shipment loads. Additionally, highlighting the necessity of proper footwear for driving in extreme weather conditions ensures driver safety.

5.2 Validation

The statistical validation analysis of the data yields the following results:

1. Paired T-Test for SEV Ratings:

- T-Statistic: 5.95
- P-Value: 1.57e-05 (significantly less than 0.05)
- Interpretation: The paired T-test shows a statistically significant difference between the initial and new SEV (Severity) ratings. This indicates that the recommended actions in the FMEA have significantly reduced the severity ratings of the potential failure modes.

2. Descriptive Statistics for SEV Ratings:

- Initial SEV Mean: 7.39
- New SEV Mean: 6.11
- Initial SEV Standard Deviation: 1.69
- New SEV Standard Deviation: 2.03
- The reduction in the mean SEV rating and the corresponding P-value from the paired T-test suggest that the actions effectively reduced the issues' severity.

3. Descriptive Statistics for OCC Ratings:

- Initial OCC Mean: 3.94
- Initial OCC Standard Deviation: 2.04
- New OCC Mean: 1.94
- New OCC Standard Deviation: 0.73

4. Descriptive Statistics for RPN (Risk Priority Number) Ratings:

- Initial PRN Mean: 206.00
- Initial PRN Standard Deviation: 151.58
- New PRN Mean: 33.89
- New PRN Standard Deviation: 47.90

The statistical validation strongly suggests that the actions recommended in the FMEA effectively reduced the severity, occurrence, and risk priority number of potential failure modes.

5.3 Challenges

The implementation of such innovative technologies such as ADAS requires a heavy investment of money from car manufacturers. Nonetheless, any error in the testing phase would require an update on the whole software (Kaur, P., & Sobti, R, 2017). So, the main challenging issue for ADAS would be in terms of cost; softwares in industry face challenges in adoption, in comparison to the current implementation (Wiese et al., 2018). AI-driven sensors are usually within all autonomous vehicles. Such vehicles reduce risks and any damage related to human factors; however, it does need the process of huge data of different parameters, such as different types of vehicles, weather conditions, other road users, etc. (El Makhloufi, 2023). From the human-related aspect, adjusting flexible working hours for employees would positively affect their mental health; however, addressing employees' mental health requires more than that; it requires solid programs for all individuals in the company, and the barrier here would be the low level of awareness, as some people tend to underestimate the importance of good mental health. Lastly, the use of pipelines in the oil and gas industry as a replacement for land transport is not 100% applicable depending on the material being transported, and it requires several approvals for pipeline construction, in addition to operation costs and maintenance (Wang et al., 2022).

6. Conclusion

In summary, this study used the Six Sigma methodology to identify human factors as the main contributors to safety issues in the UAE's oil and gas land transportation sector. Achieving objectives through a systematic Lean Six Sigma approach, the research highlighted trends in work-related fatalities based on data from the International Association of Oil and Gas Producers. Proposed control strategies include training, communication protocols, and technological advancements. The study offers valuable insights for stakeholders working towards accident prevention and environmental protection in oil and gas transportation.

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