Human Factors Contributing to Accidents and Disasters in Road Transport of Petroleum Products in Kenya

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ABSTRACT

Over the past few decades, Africa has witnessed enormous increase in the number of accidents take occur during road transport of petroleum products. Some of these accidents escalated into disasters because of release of products, with subsequent explosion and fire, resulting in several injuries and fatalities. With the Sendai Framework for Disaster Risk Reduction (DRR), the focus is on disaster risk reduction, rather than disaster response. This paper identifies human factors as a major cause of road transport accidents that lead to disasters when petroleum products are released. The study area was Kenya, but the findings are applicable across the continent. The Tripod Beta methodology, an incident investigation tool, was applied to analyse some of the disasters that had occurred in the downstream petroleum sub-sector in Kenya. The analysis identified root causes of accidents and highlighted the need to focus on tanker drivers as the key stakeholders for risk reduction. The root causes were applied in the development of the questionnaire that was used in a survey. The survey was carried out using random sampling, with a sample size of 391 tanker drivers. The study concluded that tanker drivers in the age group of 30-40 years, with 6-10 years' driving experience and minimum educational level of secondary school, displayed the best performance in prevention of accidents and spills that could lead to disasters. Tanker drivers who meet these criteria should be the target of recruitment by transporters, followed by structured safety training, to achieve Goal Zero: no accident, no spill, and no disaster in the industry.

Keywords: Disaster Risk Reduction, Human Factors, Petroleum Products, Road Tanker Transportation, Tanker Drivers

I. INTRODUCTION

In 2009, a road tanker, loaded with petroleum motor spirit (PMS), or petrol, as it is commonly called, was on its way to deliver product when it rolled over at Sachangwan village, in Kenya. A petrol leak subsequently occurred and, as members of the community gathered around the tanker, with some participating in pilferage of the product, there was a large explosion and fire, which resulted in the death of over 120 persons. Ten years later, August 10, 2019, a tanker on its way to deliver petrol was involved in an accident at Morogoro-Tanzania, resulting in fire and explosion, with over 60 deaths (Deutsche Welle [DW] Global Media Forum, 2019).

On 23rd September 2020, a petroleum tanker accident occurred at Lokoja-Nigeria, followed by fire and explosion, resulting in over 25 fatalities (BBC News, 23rd September 2020). On 13th February 2022, an explosion occurred near Mutarakwa Shopping Centre on the Mai Mahiu – Nairobi highway, when an LPG tanker was involved in a road accident, subsequently leading to release of petroleum gas and explosions (Kenyan News, 13th February 2022). Fortunately, there was no fatality from this disaster, though several vehicles were destroyed, and the environment severely impacted. Every year, there are reports of accidents involving petroleum road tankers across Africa, with disastrous consequences. The root causes of some of these disasters have not been fully identified, with the likelihood of their recurrence (Shileche, 2012). It is therefore considered timely to investigate factors that contribute to these disasters, with the aim of identifying controls to prevent them and mitigating measures.

Road accidents have become a global public health concern, with a big percentage of the accidents coming from low and middle-income countries. Despite the fact that Africa is the least motorized region (2%) of the world, it accounts for 16% of the globally recorded deaths from road accidents (Uzondu et al., 2018). Over the years, road accident data has been used to evaluate improvement in road safety and the effectiveness of initiatives deployed to reduce deaths, injuries, spills, fire and explosion. However, understanding the underlying factors that lead to the accidents would enable risk reduction techniques to be explored. Abbasi et al. (2017) identified vehicle accident initiating events as human factors, vehicle defects, and road defects. Olemo (2016) found out that human factors in road accident causation in Nairobi could be as high as 94%.

The challenges of reckless driving by tanker drivers in the Kenya petroleum industry have been identified by Omuterema et al. (2012). Reckless driving could lead to accidents, which may eventually result in disasters when petroleum products are released. Eboli et al. (2019) demonstrated that age of drivers is a significant factor in road accidents. Road tanker drivers are considered a critical stakeholder in the prevention of accidents that arise from road transport of petroleum products. This study investigated the involvement of tanker drivers in accidents, and opportunities for prevention of disasters.

1.1 Objective

To identify factors contributing to disaster risks during transportation of petroleum products in Kenya

II. LITERATURE REVIEW

The increase in the frequency and severity of disasters during the past few decades are evidence of lack of resilience and sustainability of the current human environmental and industrial adaptations. Disasters occur at the interface of Society, Technology and Environment, and are basically the outcome of the interactions of these features (Oliver-Smith, 1996). Technology plays an important role in the prevention of disasters, and early-warning devices contribute to minimization of their impact. The environment is always impacted when disasters occur, with enormous societal consequences. This research was initiated based on the frequency of disasters on the African continent, and the fact that root causes of some of the disasters that occurred in Kenya may not have been properly understood, as few empirical studies had been carried out on petroleum-based disasters (Mutugi & Maingi, 2011). This highlights the need for research into past disasters by academia, and effective collaboration with the industry to develop robust DRR initiatives that will prevent future disasters and make society more resilient.

Instead of accident and disaster prevention programmes, the industry has been groping with “accident correction”, by focusing largely on the correction of the immediate causes of the accident. The future trend is to use incident investigation tools to identify weaknesses in the safety culture of the organisation and vulnerability of the community, and use these to prevent future occurrence of disasters (De Landre et al., 2006). This is coherent with the DRR framework, whose goal is to prevent disasters. There are several incident investigation tools are available to root causes and weaknesses within organisations. Some of these tools were reviewed before adopting the Tripod Beta Incident Investigation tool (Energy Institute, 2015). The Tripod Methodology (TM) uses the “Swiss-Cheese” model of accident causation to analyse reasons for failure of a barrier or control that could have prevented the accident or disaster. This model of accident causation describes how various “holes” (in other words, failures) can line up and eventually cause an accident or disaster (Ren et al., 2008). This implies that various types of failures in controls may have existed a long time in the organisation prior to the disaster itself, but it finally occurred when all the “holes” lined up. The focus of TM is to prevent the holes (failures) from existing, by identifying and addressing the root causes.

III. METHODS

The study reviewed disasters that have occurred in the Kenyan downstream sub-sector of the petroleum industry between 2009 and 2022, with focus on road transport of petroleum products. Over 5,000 road tanker trucks were registered in Kenya (Energy and Petroleum Regulatory Agency, Kenya [EPRA], 2020). However, other East African countries that are land-locked rely heavily on Kenya for supply of products. These countries include South Sudan, Uganda, Burundi, Rwanda and Democratic Republic of Congo (DRC), and they have road tankers that received supply of petroleum products from Kenya. It was assumed that about 5,000 road tankers from these countries were involved in fuel haulage from Kenya. It was therefore estimated that over 10,000 road tankers operate at different times across the country. According to Mugenda and Mugenda (1999), when a study population is 10,000 and above, a sample size of 384 is adequate.

The survey involved over 400 tanker drivers who were randomly selected, and 391 responses were received. The study reviewed past petroleum industry disasters in the study areas, using the Tripod Beta investigation tool

(Energy Institute, 2015). It facilitated an in-depth study of the research problem. The research designs adopted included descriptive survey, which was found appropriate for comparative analysis of accidents, injuries and spills. The demographic characteristics of respondents were as summarized in Table 1.

Table 1
Demographic Characteristics of Respondents

Category	Classification	Frequency	Percentage
Gender	Male	391	100
	Female	0	0
Age Category (Years)	24 - 29 years	28	7
	30 - 40 years	160	41
	41 - 55 years	171	44
	56 - 69 years	30	8
	70 years +	1	0.3
Driving Experience (Years)	Less than 1yr	20	5
	1- 5 years	110	29
	6 - 10 years	143	37
	11 - 15 years	68	18
	15 years +	44	11
Educational Level	No Formal Schooling	11	3
	Primary School	80	21
	Secondary School	259	67
	Tertiary Education	38	10
Driver Monthly Salary (in Kenyan Shillings)	Less than 30,000/-	181	47
	31,000 - 45,000/-	147	38
	46,000 - 75,000/-	48	12
	76,000 - 100,000/-	9	2
	Above 100,000/-	2	1

IV. RESULTS & DISCUSSIONS

The study investigated the performance of tanker drivers with respect to their age, driving experience and educational level. Performance indicators considered included number of accidents, injuries and petroleum product spill during transportation.

4.1 Drivers' Ages and Tanker Accidents

The analysis of drivers' age against accidents incurred was carried out to investigate relationship between age and the drivers' performance. Whilst the questionnaire was distributed to about 450 tanker drivers, 391 returned the completed forms. However, it was observed that 4 of the respondents did not provide their accident data.

Of the 387 respondents, 312 tanker drivers reported no involvement in accident, i.e., zero accident. Out of the drivers who had no accidents, 8% (n=26) of them were in the age group of 24 – 29 years, 43% (n=133) were in the age group of 30 – 40 years, 43% (n=135) were between 41 – 55 years, 5% (n=17) were between 56 – 69years. There was only one tanker driver in the 70-year plus group, and he had had no accident. Figure-1 presents the accident performance of the tanker drivers, based on age.

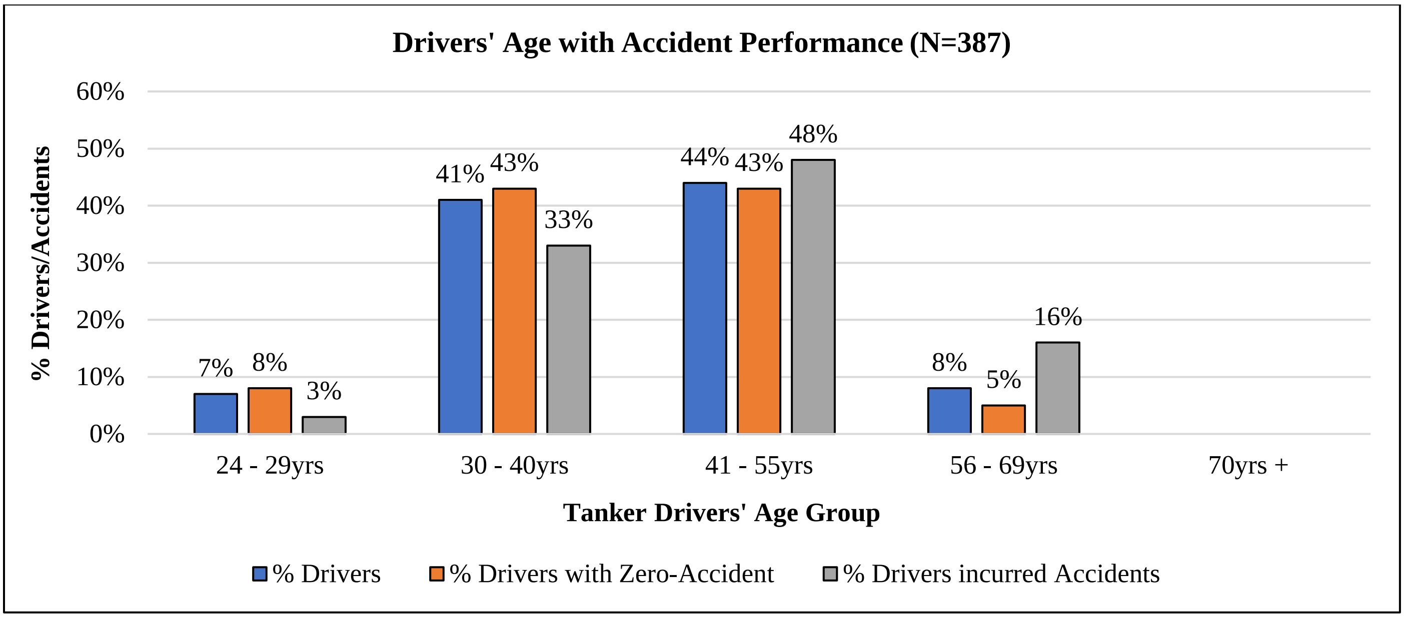

Figure 1
Accident Performance of Tanker Drivers Based on Age Groups

It was observed that only drivers in 24 – 29 years and 30 – 40 years groups achieved higher percentage of zero-accident performance compared with their group size. Drivers in 24 – 29 years group represented 7% of the overall driver population, and achieved 8% of the overall zero-accident performance. Drivers in 30 – 40 years group represented 41% of the driver population, and achieved 43% of the overall zero-accident performance. This implied drivers in both age groups, i.e., 24 – 29 years and 30 – 40 years, contributed proportionally more to prevention of accidents.

The analysis revealed that drivers in 41 – 55 years group represented 44% of the tanker driver population, but achieved 43% of the overall zero-accident performance. Drivers in 56 – 69 years group represented 8% of the driver population, but achieved 5% of the overall zero-accident performance. Therefore, these two groups, 41 – 55 years and 56-69 years, made lower contributions to zero-accident performance compared to their individual group size.

When motor vehicle accidents incurred by the tanker drivers were considered, it was observed that 3% of those who had road accidents were in the age group of 24 – 29 years, compared with the group size of 7% of overall tanker drivers' population. In effect, the contribution of drivers in this group to accidents was proportionally lower to their population size.

It was observed that 33% of drivers that incurred accidents were in the 30 – 40 years age group, which represented 41% of the overall tanker drivers' population. This group also contributed lower accidents compared with its population size.

Drivers in the age groups of 41 – 55 years, who represented 44% of the driver population, incurred 48% of the overall accidents; hence the group contributed higher percentage of accidents compared with its population size. Drivers in 56 - 69 years' group, who represented 8% of the driver population, incurred 16% of the total accidents. Both groups of drivers, 45 – 55 years and 56 – 69 years, achieved worse proportional performance of accidents compared to their group size. The findings of this study were congruent with research of Al-Masaeid (1996) in Jordan that showed the age of tanker drivers could be a contributory factor in road accidents. From foregoing analysis, drivers in the age group 30 – 40 years had the overall best performance with respect to accident performance.

4.2 Ages of Drivers and Incidences of Injuries

An analysis of driver's age and driving-related injuries sustained by tanker drivers was carried out during the study. Out of the 391 respondents, it was observed that 2 tanker drivers did not provide their injury data. Table-2 presents the breakdown of drivers' injury performance, including zero-injury.

Table 2

Breakdown of Driver's Injury Performance on Basis of Age

Driver Age	NUMBER OF DRIVERS WHO SUSTAINED INJURIES					
	0 (No-Injury)	1	2	3	>4	**Total**
Above70yrs	1	0	0	0	0	1
56 - 69yrs	27	3	0	0	0	30
41 -55yrs	154	12	4	0	0	170
30 -40yrs	154	5	1	0	0	160
24 - 29yrs	27	1	0	0	0	28
TOTAL	**363**	**21**	**5**	**0**	**0**	**389**

It was observed that 363 (93%) of drivers did not incur any driving-related injury during their employment period with their employers/transporters. A Chi-Square test was carried out from Table 2 to find out if the association between age of drivers and those that sustained injuries were statistically significant. The analysis was as presented in Table-3.

Table 3

Chi-Square Test of the Association between Drivers Age and Number of Injuries Sustained

Chi-Square Tests			
	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.965[a]	8	.540
Likelihood Ratio	7.589	8	.475
Linear-by-Linear Association	3.452	1	.063
N of Valid Cases	389		

a. 9 cells (60.0%) have expected count less than 5. The minimum expected count is .01.

From the table, $\chi(1) = 6.965$, $p = 0.540$; which implies there was no statistical significance association between age groups of the drivers and those that sustained injuries; i.e., drivers equally sustain injuries irrespective of age groups. A one sample t-test was carried out to determine if there was a difference in age groups that achieved zero-injury performance. It was discovered that the age group difference among the drivers who did not sustain injuries was not significant since the significant level of 0.097 was greater than 0.05, as shown in Table 4.

Table 4

One Sample t-Test to determine if there was a Difference in Age Group of Drivers who sustained Zero Injuries

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
0 (No-Injury)	2.163	4	.097	72.6000	-20.602	165.802

The outcome of analysis of the injury performance of tanker drivers, based on their age, was as presented in Figure 2.

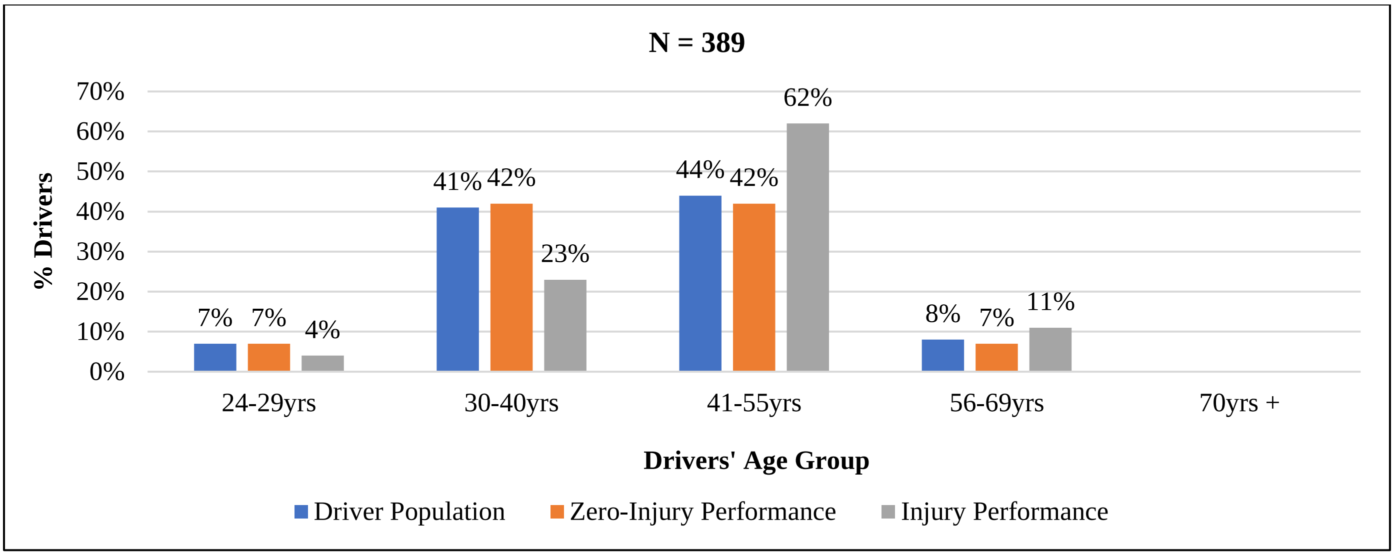

Figure 2
Injury Performance of Tanker Drivers Based on Age

It was observed that, of all the age groups, only drivers within 30 – 40 years achieved a zero-injury performance better (i.e., higher) than its proportional size. This group achieved 42% of zero-injury, whilst its group size was 41%. Simultaneously, the group contributed lower proportional injury performance of 23%, when compared with its group size. Every other group had either lower or equal proportional zero-injury performance, whilst some had higher proportional contributions to injury rates.

The analysis of injuries from accidents revealed two groups of drivers, 41 – 55 years and 56 – 69 years, contributed proportionally more to occurrence of injuries among the tanker driver population. Whilst the population size of drivers in the 41 – 55 years group was 44%, they contributed 62% of the overall injuries. Drivers in the 56- 69 years group represented 8% of the driver population, but contributed 11% of the injuries. Injuries incurred by tanker drivers resulted in lower productivity due to associated absences from work on health grounds. Each day's absence from work resulted in losses to employers in terms of salaries for work not done, medical treatment expenses and sometimes legal costs, where third parties are involved. These factors affect both the productivity and profitability of the companies the tanker drivers work for. Therefore, the study revealed drivers in the 41 – 55 years and 56 – 69 years contributed towards lower productivity, and erosion in profitability of the companies.

Besides injuries and loss of life, traffic accidents result in medical costs, physical pain, permanent disability and travel anxiety, as well as effect on household income and national economy. They also reduce the quality of life. Therefore, road traffic crashes affect not only the health of individuals, but also their family members, as the impact can drive households into poverty when they struggle to cope with long-term consequences of the events, including the costs of medical care, rehabilitation and loss of family members (Hordofa et al., 2018).

Research has established that road traffic accidents claim the largest toll of human life and tend to be the most serious problem, not only in Kenya, but also around the world. Globally, millions of people are coping with the death or disability of family members from road traffic injury (Ahmed et al., 2023). Therefore, the focus should be on reduction of accident rate within the petroleum industry to improve the economy and GDP, as well as reduction in human suffering and loss. The study showed that drivers in the 30 – 40 years' group contributed the least injury rate out of the population of tanker drivers that participated in the survey.

4.3 Drivers' Ages and Product Spill Incidences

An analysis of oil spills performance of the drivers based on age was carried out, with drivers indicating number of spills they had incurred. It was observed that 3 respondents did not provide spill performance data. Out of the 388 tanker drivers that provided spill performance data, 341 (88 %) tanker drivers indicated they had not been involved in any product spill. The graphical representation of the spills performance of tanker drivers based on their age groups is shown in Figure 3.

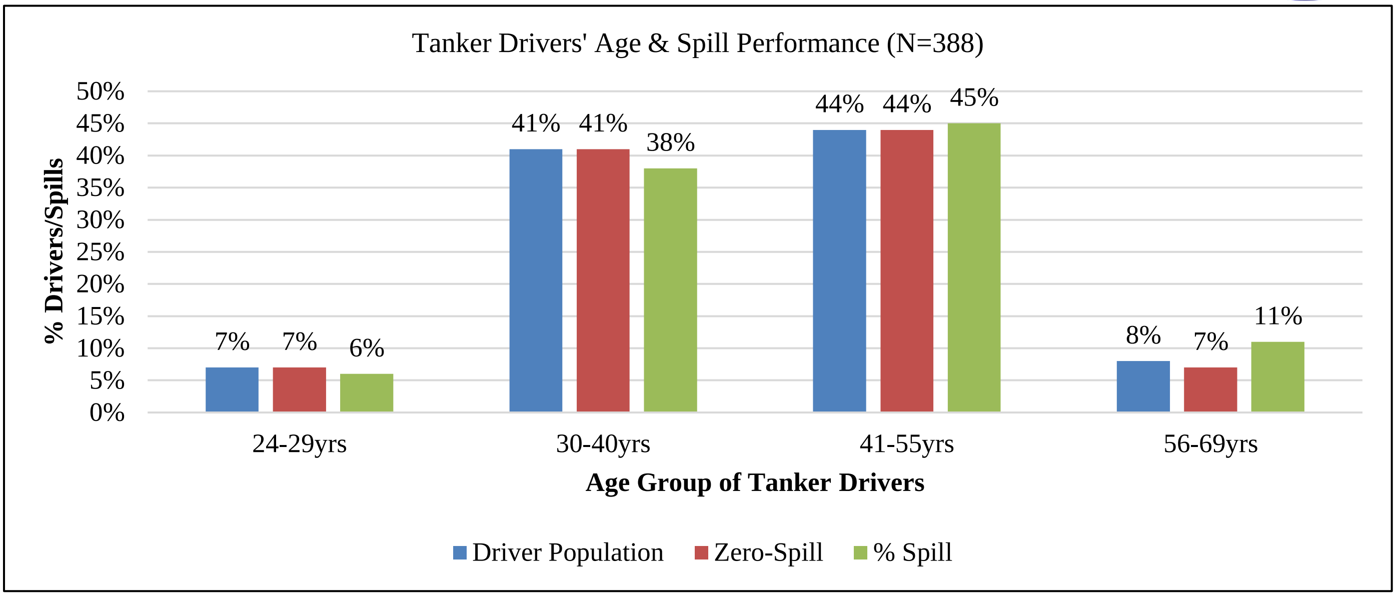

Figure 3
Tanker Drivers' Age Groups and Spill Performance

It was observed that drivers in the 24 – 29 years' group represented 7% of the population, and achieved 7% of zero-spill performance, whilst contributing 6% of spills incurred by the total driver population.

Drivers in the 30 – 40 years' group, who represented 41% of the driver population, achieved 41% zero-spill, whilst contributing 38% of the overall spills.

Drivers in the 41 – 55 years' group represented 44% of the driver population, achieved 44% zero-spill performance, but contributed 45% of the overall spills. Hence, its spill performance was worse than its population size. It was observed that drivers in the age group of 56 – 69 years represented 8% of the driver population, but contributed 11% of spills incurred.

After review of the foregoing analysis of drivers' age and their performance, it was observed that drivers in the 30 – 40 age group had consistently good performance with respect to all the 3 dependent variables, i.e., motor vehicle accidents, injuries and spills. This group of drivers made higher contributions to zero-accident, zero-injury and zero-spill performance compared with their proportional size, and lower rates of accidents, injuries and spills.

Therefore, drivers in the 30 and 40 years' age group made the most effective contributions towards sustainability of the business through prevention and reduction of accidents, injuries and spills, The study revealed performances of drivers in this age group were consistently good, for zero-accident, zero-injury and zero-spill, as well as lower rates of accidents, injuries and spills. Hordofa et al. (2018) had highlighted that age of drivers could be a predictor of road accidents. The research, which was carried out in Ethiopia, showed that about 75% of fatalities arising from road traffic accidents were caused by young drivers in the age group of 18 – 30 years.

Al-Masaeid (1996) also recommended that employment of tanker drivers above 30 years old would result in a successful measure of reducing road tanker accidents. This is congruent with research that identified severity of non-fatal road accidents was associated with the age of drivers (Eboli et al., 2019). Findings from this study are in agreement with other research work that have identified age as a factor in road transport safety. This study identified tanker drivers in the age group of 30 and 40 years as being most effective in reduction of accidents, injuries and spills in the petroleum industry.

4.4 Driving Experience and Performance of Tanker Drivers

The study investigated driving experience of tanker drivers as a contributory factor in the reduction of accidents. It was however observed that 2 respondents did not provide data about their driving experience, including 4 drivers that did not provide their accident data. Therefore, the analysis covered 385 tanker drivers, out of the 391 respondents. Following the analysis of responses, the graphical representation of driving experience and accident statistics of the tanker drivers are presented in Figure-4.

From the analysis, it was observed that tanker drivers with less than one-year driving experience represented 5% of the driver population, achieved 5% of zero-accident performance, and were responsible for 3% of the motor vehicle accidents. This group of drivers achieved lower proportionate accident percentage compared to their size.

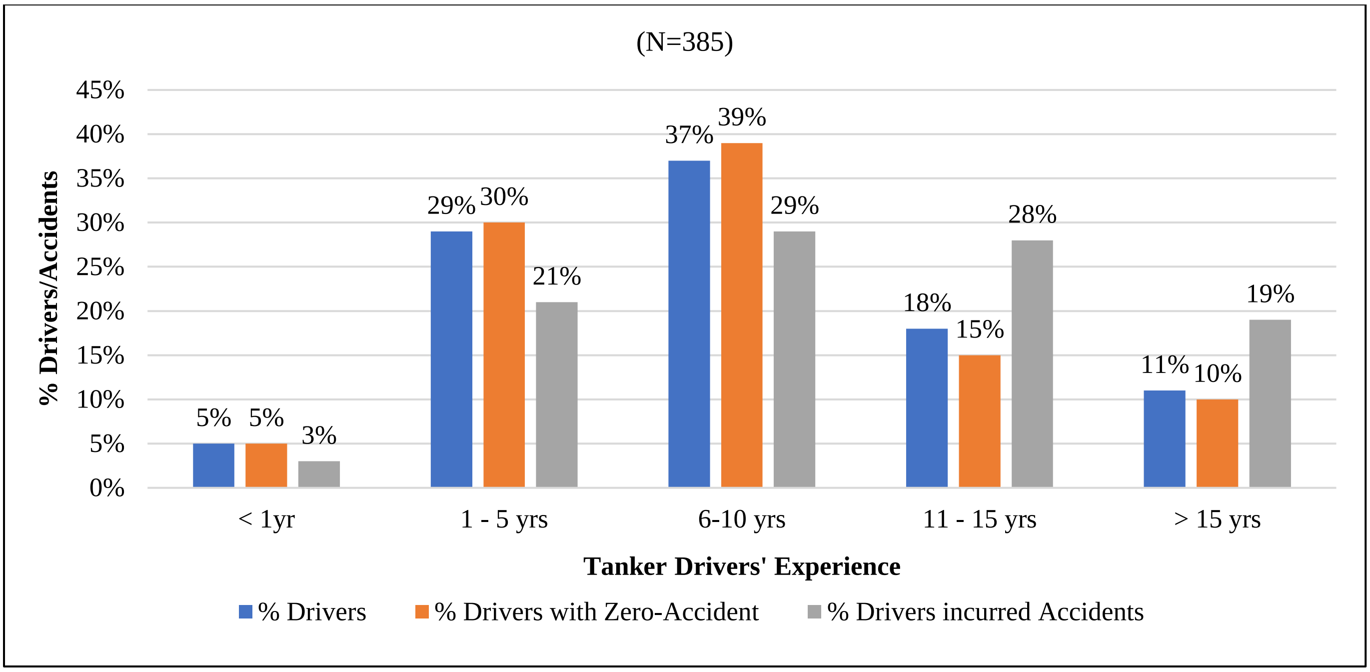

Figure 4
Graph Showing Distribution of Tanker Drivers' Experiences and Performance

Tanker drivers with 1 and 5 years' experience represented 29% of the driver population, achieved 30% of zero-accident, and incurred 21% of the vehicle accidents. Therefore, this group contributed proportionally higher to zero-accident performance than its size, whilst contributing proportionally lower to vehicle accidents.

Tanker drivers with 6 and 10 years' experience represented 37% of the driver population, achieved 39% of the overall zero-accident performance, and incurred 29% of the accidents. It was observed the two group of drivers, i.e., those with 1 and 5 years' experience and 6 and 10 years' experience, achieved better zero-accident performance than their population size, and proportionally lower accident rate. However, when the differential between the population size and percentage zero-accident performance on one hand, and the population size against accident rates on the other hand, were analyzed, it was observed that tanker drivers with 6 and 10 years driving experience had marginally better performance than those with 1 and 5 years' experience.

Tanker drivers with between 11 and 15 years driving experience represented 18% of the driver population, contributed 15% of zero-accident performance, and incurred 28% of the vehicle accidents. Therefore, these drivers contributed less to zero-accident performance, and incurred proportionally higher percentage of accidents.

Tanker drivers with over 15 years' driving experience represented 11% of the population, but incurred 19% of the accidents.

The foregoing analysis revealed drivers with 6 and 10 years' driving experience had lowest contributions to accidents. For sustainable management of petroleum products transport by road, one of the key objectives is for tanker drivers to achieve zero-accident performance, thereby maximizing profitability. Though the research by Hordofa et al (2018) suggested driving experience of drivers was not a determinant factor for fatal accidents, this study revealed that tanker drivers with driving experience of 6 and 10 years made the most contributions to safe driving without accidents (zero-accident), and had the least accident rate.

4.5 Tanker Drivers' Educational Levels and Performance

The high mortality rate of illiterate and low-literate in various age groups indicate that educational level plays a crucial role as a factor in road accidents, requiring related organizations to take necessary measures and policies (Lofti et al., 2019). Education is important for drivers to understand traffic signs, transport policies, guidelines and rules, and provides knowledge for encouraging compliance. The study classified educational levels of tanker drivers into four: No formal schooling, Primary, Secondary, and Tertiary levels. Out of the 391 respondents, one tanker driver did not specify his educational level. It was observed that 313 (80%) of the tanker drivers had not been involved in any accident. Figure-5 presents performance of the tanker drivers based on their educational levels.

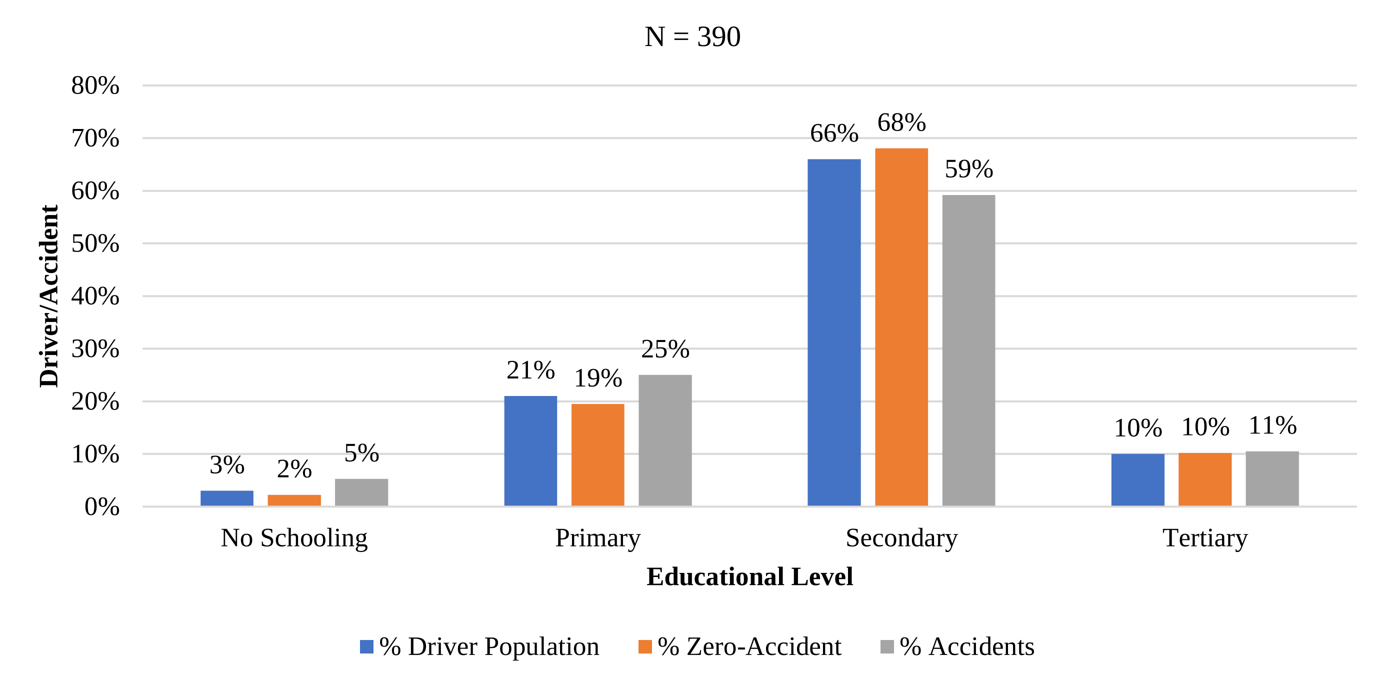

Figure 5
Tanker Drivers' Accident Performance Based on Education Levels

It was observed that drivers with no formal schooling, who represented 3% of the population, contributed 2% of zero-accident performance, but incurred 5% of the accidents. Drivers that had primary education represented 21% of the population and contributed 19% of zero-accident, but incurred 25% of accidents. Drivers that had secondary education represented 66% of the population, contributed 68% to the zero-accident performance, and incurred 59% of accidents. Drivers that had tertiary education represented 10% of the population, contributed 10% of zero-accident performance, but incurred 11% of accidents.

Foregoing analysis showed that tanker drivers with secondary school level education had the best performance, and it was the only group that had lower proportional accident rate compared with its population. On the other hand, drivers with no formal schooling had the worst performance, as they incurred accidents almost twice their proportional size of 3%.

Researchers Sami et al. (2013) have found significant relationships between educational level and mortality rate in road traffic accidents. It was shown that youths and uneducated people suffer more fatal road accidents. This finding is in agreement with this study, as drivers with no schooling and primary education level had worse motor accident performance compared with drivers that had minimum secondary school education. The study confirmed that educational level of tanker drivers can influence rate of accidents and disasters during road transportation of petroleum products. Bhattacharjee et al. (2011) demonstrated that education is vital and essential in all accident prevention activities. It is generally true that well-trained and careful people may avoid accidents and injuries when carrying out risky and dangerous activities. Another study carried out in Ethiopia (Hordofa et al., 2018) revealed that drivers who had primary level education or lower caused a large number of fatalities (56%), whilst fewer fatalities (23%) were caused by drivers that had a minimum of secondary level education.

The effect of human factors on disasters during road transportation of petroleum products is a subject that needs to be given more attention. This study demonstrated that the age of tanker drivers, their driving experience and level of education were contributory factors to accidents and spills that could lead to disasters in the industry. The study revealed that drivers within the age group of 30 – 40 years, driving experience of 6 – 10 years, and educational level of secondary school had the least accident rate and made highest contributions to safe driving performance. The study also investigated the influence of salary on performance of tanker drivers, but did not come to a definite conclusion. The study did not cover occupational or mental health issues of the drivers.

Some of the limitations of this study have been considered. There was no input from female tanker drivers, as none was encountered during the field study. It is however unlikely that input from the few female drivers would have made enormous difference to the findings. Respondents to the survey were selected randomly, and it was observed that only one driver was in the age group of 70 years and above. This may not be unconnected with the national retirement age limit of 60 years for people in public service. It was therefore expected that the number of drivers older than 70 years would be few. It is uncertain if more respondents from drivers in that age group could have influenced the findings of the study. The survey questionnaire did not include identification of nationality of tanker drivers. It has now been noted that some of the tankers could have been from any of the surrounding countries that collect products from Kenya. However, the nationality of the tanker drivers may not have had a huge influence on the findings of the study.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

This study revealed drivers in 30 – 40 years age group had the best road transport safety performance with respect to zero-accident, zero-injury and zero-spill, and minimization of accidents in the study area. With respect to driving experience, drivers who had 6 – 10 years' experience had the best performance. The study also revealed tanker drivers who had secondary school education had the least vehicle accident rate.

5.2 Recommendations

From this analysis, the study has recommended setting industry standards for tanker drivers to include minimum age of 30 years, with minimum driving experience of 6 years, and secondary school educational level. If accepted, it should be rigorously implemented by all transporters involved in haulage of petroleum products. It will contribute to reduction of accidents that could lead to disasters. In addition, consideration should be given to introduction of a structured training scheme for tanker drivers, which should include defensive driving training, to give tanker drivers skills and ability to drive safely in spite of the mistakes of other road users. By putting these measures in place, the petroleum industry can achieve enormous reduction in accidents, and prevention of disasters during road transport of products.

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