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Root Cause Analysis of a Jet Fuel Tanker Accident

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Abstract

Over the last two decades, economic growth in Nigeria led to a sporadic increase in air transportation, both local and international, and this, in turn, brought about a huge demand for jet fuel to satisfy the aviation needs. In Nigeria, Jet fuel is transported via Bridger Receipt Vehicles (BRV) from shore to airport depots. The presence of the BRVs has increased road activity and this has been associated with a number of accidents. This study is focussed on identifying the root cause of a BRV related accident which happened along the airport road, close to jet fuel storage depots, creating a potential for huge fire disaster. Using the fishbone diagram and a detailed root cause analysis, the study revealed that driving under the influence of alcohol and the prevailing operational challenges played a major role in the series of events that led to the accident. The paper also highlights measures for preventing a recurrence.

Keywords: Alcohol and drug abuse, Bridger Receipt Vehicles (BRV), tanker truck accidents, fuel transportation, Jet A-1 aviation fuel, risk assessment, process safety management

INTRODUCTION

Annually, road accidents accounts for 1.3 million fatalities and about 50 million severe injuries, with a global cost implication of 518 billion dollars [1]. The primary cause of accidents are most times a function of many multifaceted, and related social, technical and environmental causal factors [2, 3]. These intricacies must be effectively handled during incident investigation, to ensure that the underlying causal factors are accurately identified, and to maximize learning towards preventing a recurrence.

There are inherent risks in virtually every system, and if these risks are not well managed, the associated hazards may manifest resulting in undesirable incidents. Accidents can be prevented through risk assessment, and currently there are over seventy risk assessment methods [4] which are generally grouped into qualitative and quantitative methods. Risk assessment, and the implementation of any resulting recommendations are meant to prevent accidents, but unfortunately accidents still do occur. An accident, though undesirable, it is an opportunity to review existing process during accident investigation, in order to identify the causal factor and other gaps that can be corrected, so as to prevent a recurrence. Root cause analysis of incidents requires an in-depth understanding of operations, processes and practices associated with the incident. This is a major factor that determines whether the right questions are asked towards eliminating intangible and irrelevant factors, and isolating the root cause during investigations. The ultimate goal of any incident investigation is to prevent a repeat and ensure safety, but none the less, it is vital that appropriate knowledge is acquired from risk assessment [5] and incident case investigation, by setting relevant learning criteria that will enhance multilevel learning process as emphasized by [6].

This study, seeks to identify the root cause and highlight related operational threats accountable for a jet fuel tanker accident along the airport road in Lagos by applying the Ishikawa (Fishbone) diagram and developing the fault tree for the chain of events that culminated in the accident

A BRIEF ON LAGOS JET FUEL OPERATIONS

Lagos is a major city in Nigeria, and it is the centre of excellence and the economic nerve centre of the nation. Murtala Muhammed International Airport in Lagos is the busiest airport in the country, and it serves as a connection point for many international flights. Jet fuel is a major resource for air transportation, and some airline operators spends over 40% of their total expenditure on fuel alone, making jet fuel the single largest cost [7]. The jet fuel market globally has inherent cost fluctuations which makes it difficult for airline operators to maximize profit and also plan accurately. To mitigate this challenge, and reduce their exposure to the market volatility, different fuel hedging arrangements have been developed to minimize losses. This problem is further aggravated in Nigeria that currently does not have a local jet fuel refining capacity, and as such, jet fuel is imported from foreign refineries. The price of jet fuel fluctuates significantly in the country due to supply shortages and foreign exchange market instability, resulting in rising prices.

The aviation fuel sector in Nigeria is affected by a number of challenging factors: economic, technical, environmental, government policy, multiple levies coupled with internal

organizational issues etc. The need to thrive amidst all these elements creates a pressure on jet fuel handling operation.

Jet fuel is shipped from foreign refineries to Apapa Jetty in Lagos, where it is discharged into storage tanks at the Intermediate Shore Depot and transported to Airport Depots via tanker trucks referred to as Bridger Receipt Vehicle (BRV) in the aviation fuel industry. The movement of fuel laden trucks in a traffic congested Apapa Port area, coupled with the poor condition of the road, creates a lot of potential hazards. As a result of the traffic gridlock, and the loading challenges at the Shore Depots, it sometimes takes a full day or more for a BRV to make a single trip to the Airfield Depot, and considering the distance, this should ideally take two to four hours. The pressure on the driver is further aggravated by a "pay per load" payment method applied by some marketers, which implies that the number of trips determines the driver's pay. This may increase the tendency for over speeding once on a traffic free road, in a bid to get to the Airfield Depot on time and return quickly to the jetty for another jet fuel loading.

Trucks and tankers are major cause of accidents and concerns globally, majorly because of their size and unique attributes [8, 9], coupled with the cost implication of such accidents [10, 11] and litigation issues [12]. According to [13], from 2007 to 2010 about 4,076 fuel tanker truck related fatalities were recorded in Nigeria, with 1,221 deaths in 2008 alone. This is alarming, and a drastic and sustainable effort at curbing the menace starts with a risk assessment of all causal operational factors [14], and a review of previous accidents.

THE TANKER ROLLOVER INCIDENT

On the 26th of July, 2015 a BRV was scheduled for jet fuel loading at the Apapa Jetty area. The associated traffic en-route to Apapa coupled with loading queue at the jetty area delayed the return of the BRV until very late in the evening. On arrival at Ikeja Airport area, the BRV driver parked for the night, and stayed at the park till morning when the product would be discharged from the tank. Around 10.00 a.m. in the morning on the 27th of July, the driver returned to the tanker and drove from the park towards the airport jet fuel depot. He approached the entrance gate of the facility with quite an unreasonable speed, and suddenly at about 30m away from the gate, he drove over a ramp as shown in figure 1, and the weight of the cargo loaded tanker forced the BRV to rollover, turning completely backwards with the driver trapped in the truck. It took the effort of the emergency response team to rescue the driver from the truck head before a potential explosion. Jet fuel spilled on the road and the fire fighting team had to spray foam extinguisher over the spilled jet fuel to prevent ignition. The driver was immediately rushed to the hospital for treatment.

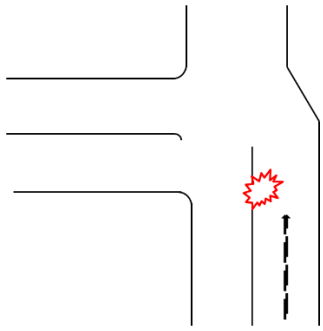


Figure 1: An area view of the incident zone and the actual accident

THE FIELD STUDY AND INVESTIGATION

A fact finding study, investigation, and analysis were carried out on the operational activities of the downstream fuel industry; with a focus on fuel tanker drivers and fuel transportation management. A major challenge with incident investigation, is the common issue of mistrust of any one deemed to be trying to find out a trade secret, and this created an initial obstacle as regards the purpose of the enquiry. Due to the low literacy level of most of the drivers, the data gathered on drivers, on the job, behavioural attributes and challenges is based on oral interview and discussion sessions with eighty four fuel tanker drivers who freely expressed their views.

The Root Cause Identification

The principle of Root Cause Analysis (RCA) is centred on the theory that the source of dangers and solutions to human, environmental and physical problems can be uniquely identified through a precise and methodical process. RCA identifies the causal chain which ultimately leads to the root cause [14, 15], it is a very effective method that applies retrospective analysis for identifying the deep causes of systemic failures and problems [14]. RCA is based on an unbiased inquiry, and criticism of all relevant elements associated with the subject of study [16], and it is suitable for envisaging likely events [17]. As described by [18], RCA is conducted in steps and these are: problem identification, a study of the incident, data collection, causal factor identification, development of a chart of findings and result

discussion. It should be noted that the accuracy of a root cause analysis can be impaired by lack of experience and expertise of the subject or issues under analysis [19], and this can be further complicated when organizational politics is introduced during RCA sessions [20].

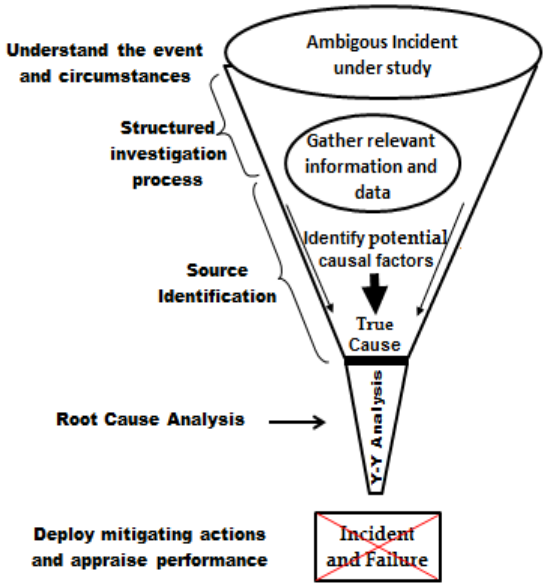


Figure 2: The Root Cause Analysis Process

According to [21], process related accidents are usually as a result of multiple causal factors, some of which are immediate cause, enabling causal factors and the actual root cause. It is vital that accident investigation correctly identifies the root cause because effort directed at correcting only the immediate causal factors may not prevent a recurrence of similar cases.

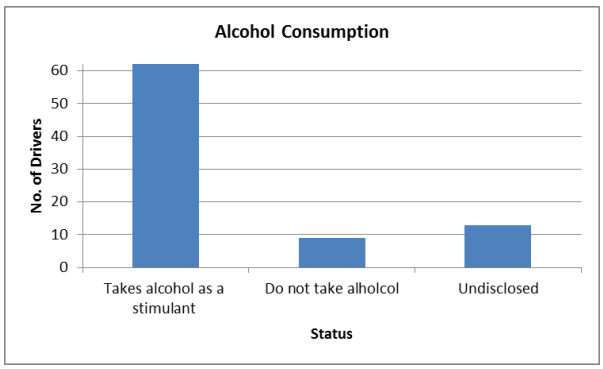
A detailed fact finding and incident review was performed to identify all factors that might have played a role in the series of events that culminated in the ultimate incident - the tank rollover and jet fuel spillage. The factors identified are presented in the Ishikawa diagram of figure 5, with the critical operations inherent causal factors starred (*).

The Investigation Findings

The root cause analysis process detailed in figure 2, identified alcohol induced loss of concentration as the root cause of the jet fuel tanker rollover, coupled with organizational failures as regards proper planning of jet fuel loading trips, non-deployment of rollover protection system on the trucks, and the use of tank and accessories that does not meet the product containment requirement on rollover. This is detailed in the fault tree diagram of figure 6. The driver was confirmed to be under the influence of alcohol. Several studies on the effects of alcohol on workers has established its work performance and concentration inhibition effects [22, 23]. This accident proves to be one of the easily preventable mishaps which still occurred due to carelessness [24], human error [3, 25-27], reckless behaviour and the lack of systems to check same, particularly since the same driver has a known history of alcohol issue.

Alcohol has many negative impacts on the brain motor control when taken excessively, and it has been associated with many road mishaps. Alcohol increases the rate of vehicle accidents [28, 29] and according to a study by [30], even the average medical cost is 1.8 times more for patients with alcohol in their blood stream than those without alcohol. The study by [31] also found that about 70% of alcohol related road fatalities occurred on a straight road, which shows the extent of the effect of alcohol on coordination and concentration.

The data collected from the sampled drivers in the fuel haulage enterprise revealed that 74% of the drivers take alcohol as a stimulant to enhance job performance, 11% of the drivers are non-drinkers, although abstinence from alcohol is mostly not for safety reasons but because of religious affiliations. The remaining 15% refused to disclose their on-the-job alcohol consumption habit as shown in figure 3a and figure 3b. Among those that take alcohol, 37% claims alcohol clears their vision while driving, and the remaining 63% claims alcohol sharpens their reflexes and helps them stay alert. About 21% of the sampled drivers have been involved in one form of accident, and 89% of this group takes alcohol and this emphasizes the connection between alcohol and road accidents. A risk concern observed from the interview, is the believe in spiritual protection that can either prevent accident or secure the life of the driver during an accident. This spiritual security is likely to promote at risk driving behaviour.



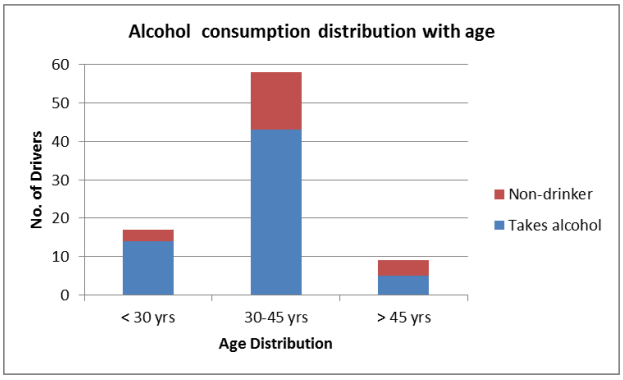


Figure 3a & 3b: Alcohol consumption pattern among truck tanker drivers

Figure 4 shows the percentage of the drivers that responded in the affirmative to the following six questions:

- Is the level of job remuneration and motivation poor?
- Are companies cutting cost on adequate maintenance? Poor maintenance is a major challenge in the transportation sector in Africa [27].
- Is traffic gridlock an operational challenge?
- Does driver use phone while driving?
- Does driver increase speed significantly on traffic free roads?
- Is on the job refresher training adequate?

Based on the views of the drivers, with 100% affirmative response, the findings show the significance of traffic gridlock as a major challenge to smooth transportation of jet fuel in Lagos, coupled with the associated increased stress level and job frustration. This has a tendency to lead to over speeding when the driver is on a free lane as a natural expression of freedom from the boredom and frustration of been held up for hours in traffic at the Shore Depot area, and also in a bit to return quickly to the Airport Depot on time for a quick discharge. This position is further supported by the 72% affirmative response of drivers who confirms that they usually maintain a high speed once on a free lane.

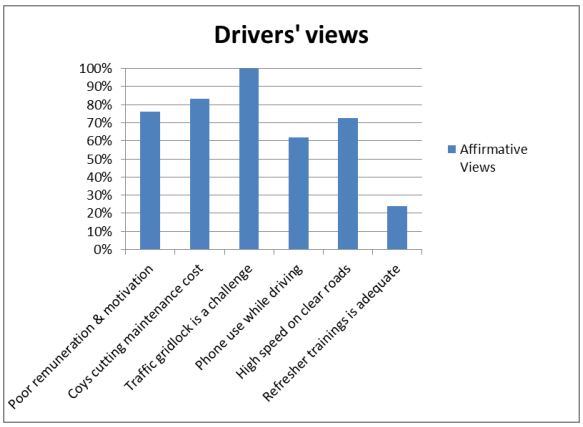


Figure 4: Drivers' response to industry related questions

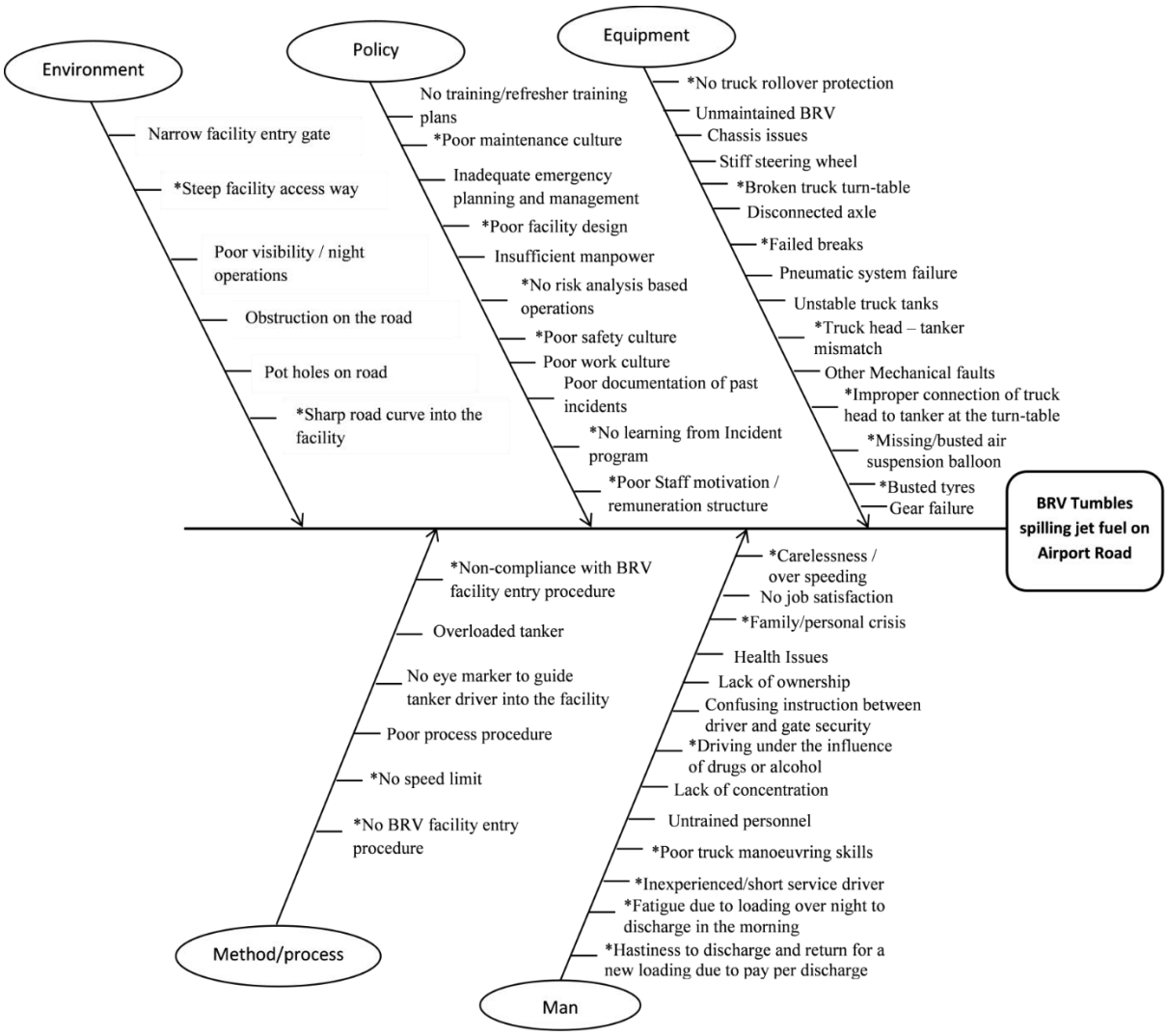


Figure 5: Ishikawa potential causal factor diagram

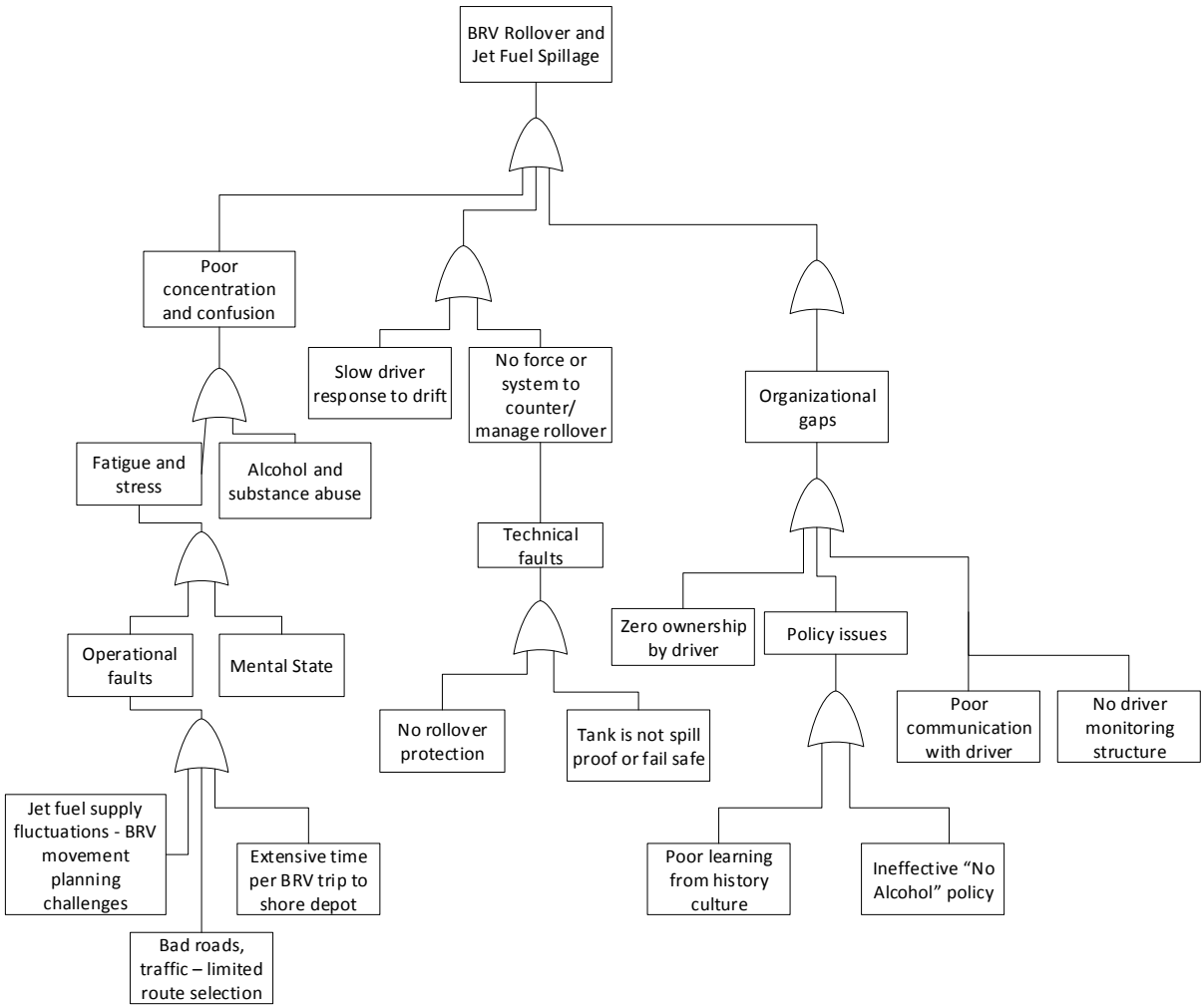


Figure 6: Tanker Rollover Fault tree

RISK IDENTIFICATION, ASSESSMENT AND RESPONSE

A statistical study reveals that more than 1,300 tanker truck accidents are recorded yearly [32]. This constitutes a major safety risk to the tanker driver, other motorist, pedestrians and others living around such incident zones.

Fuel Cargo tanker fire is a menace that seems to be on a growing trend in Lagos both in the day and night, and this calls for an urgent intervention via quality risk assessment. Ensuring a comprehensive industry safety requires not just the risk assessment, but a committed implementation of safety audit findings by all stakeholders. Therefore, it has become imperative to ensure that safety goes beyond paper work to full implementation, and post implementation reviews, and this can be achieved via appropriate rule enforcement has emphasized by [2]. Accidents are seldom accidental [33] and ultimately, achieving safety is no accident. Safety comes as a result of intentional, specific and purpose oriented efforts of management, employees and regulatory bodies; this starts with a risk assessment [34].

Risk identification, assessment and response tracking is a repetitive process and a methodical tool for risk prioritization, in terms of the potential severity and likelihood of occurrence. For an effective awareness, tracking and update of risk status, a risk register must be maintained. During the risk identification process an accurate description of the risk is vital for a successful risk management. During this study, the statement "due to a specific **cause** an uncertain **event** could occur which would lead to undesirable **consequences**" was used as a guide for differentiating between the three key assessment components. A guide risk assessment process which could be implemented by the stakeholders for a further industry wide assessment is detailed in figure 7.

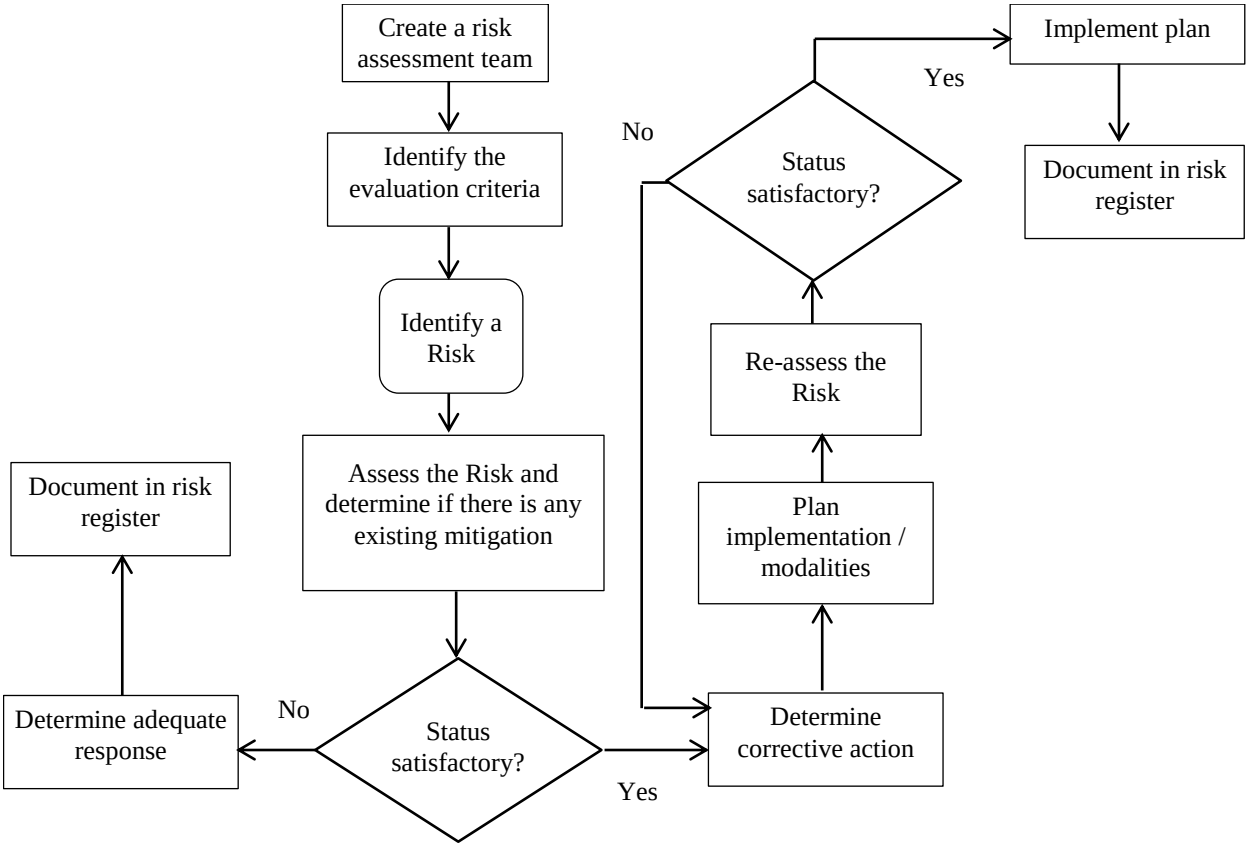


Figure 7: Risk assessment process flow

RISK OF FIRE AT THE PARK

The Ikeja BRV Park shown in figure 8 is located off the airfield jet fuel depot area, and it is basically and open land area with no major structural features of a standard park. The BRVs associated with the park and Apapa Shore Depots handles a major portion of the national jet fuel distribution. The confined nature of the park with limited space for the number of trucks, results in BRVs parking outside the park, along the road creating a risk for other road users. The parking arrangement, abandonment of faulty or decommissioned BRVs in the park which blocks easy access and free movement, limited access way in case of emergency, indiscriminate smoking in, and around the park, waste and tire burning close to the park, fuel leaks and engine oil spills on the floor of the park, coupled with multiple alcoholic drink sales outlet and vendors in and around the park which promotes intoxication; all creates a major hazard risk as detailed in the hazard bowtie of figure 9. The statuesque demands further risk reviews and multiagency collaboration towards deploying safety restorative actions.

Figure 8: The BRV Park

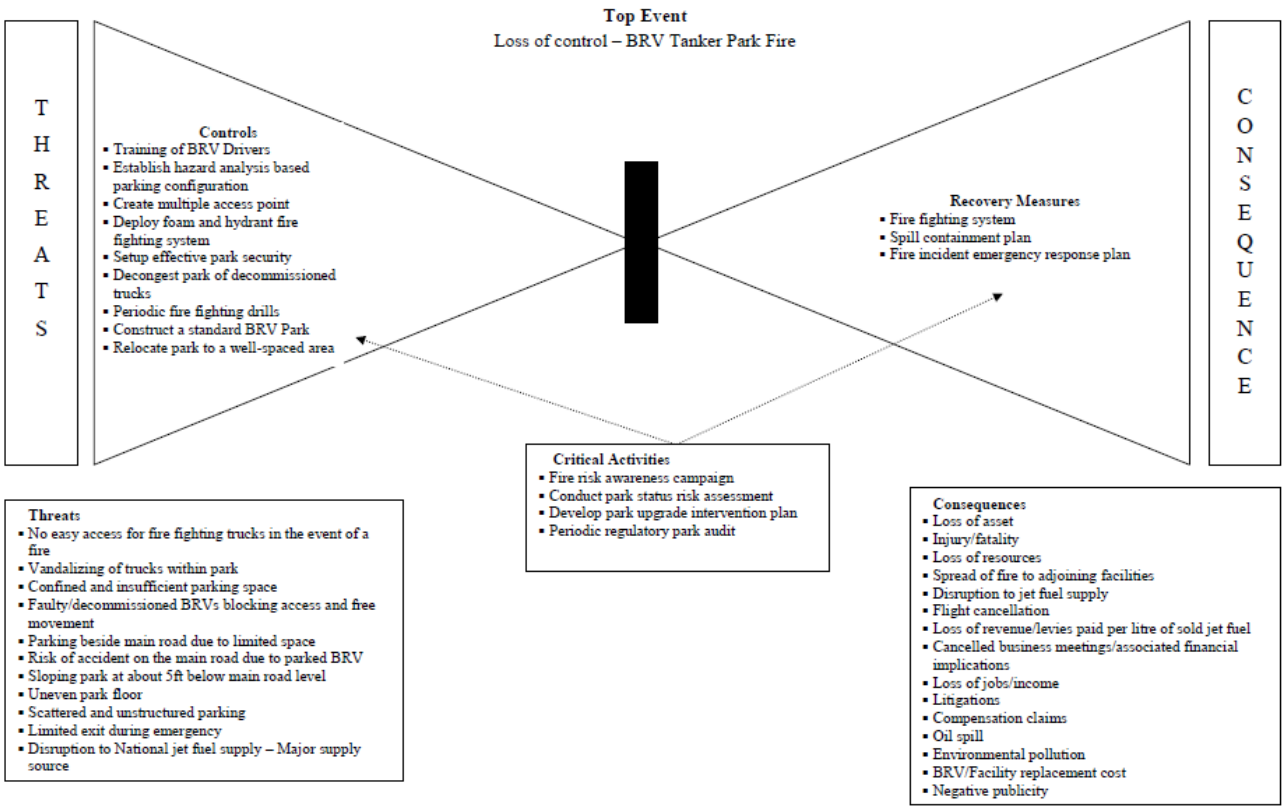


Figure 9: The Hazard Bowtie

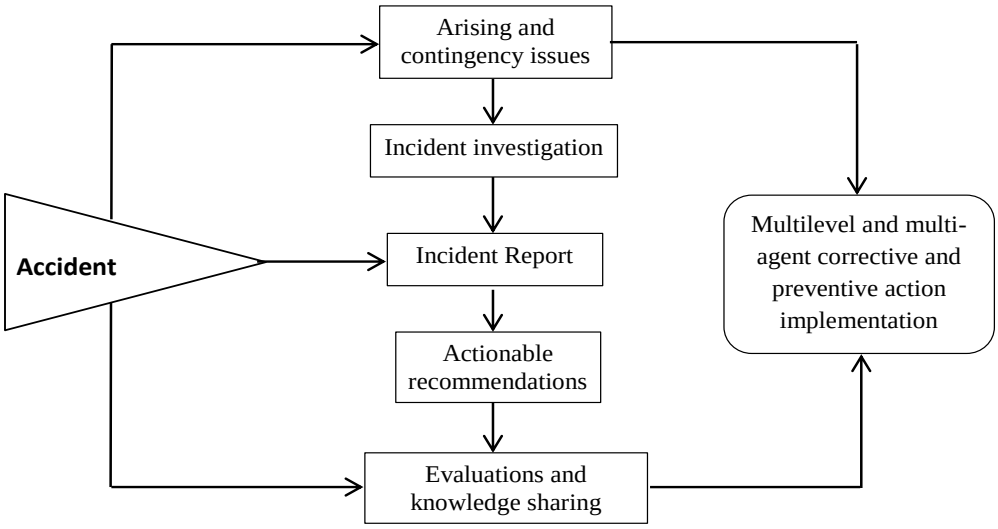


Figure 10: 360° Accident investigation and action implementation loop

ACCIDENT PREVENTION AND ACTION PLAN IMPLEMENTATION

An accident investigation is not fully successful until relevant corrective measures can be developed from the study and applied in mitigating recurrences. Achieving a holistic accident review success requires and all involving multi-agent participation and action execution as expressed in figure 10.

One of the major ways of preventing accidents is through the introduction of a barrier between the source of harmful energy and at-risk objects and persons as applied by [35, 36]. Figure 11 shows a barrier element structure for curtailing the consequences and minimizing the impact after a jet fuel tanker truck rollover and fuel-spill accident.

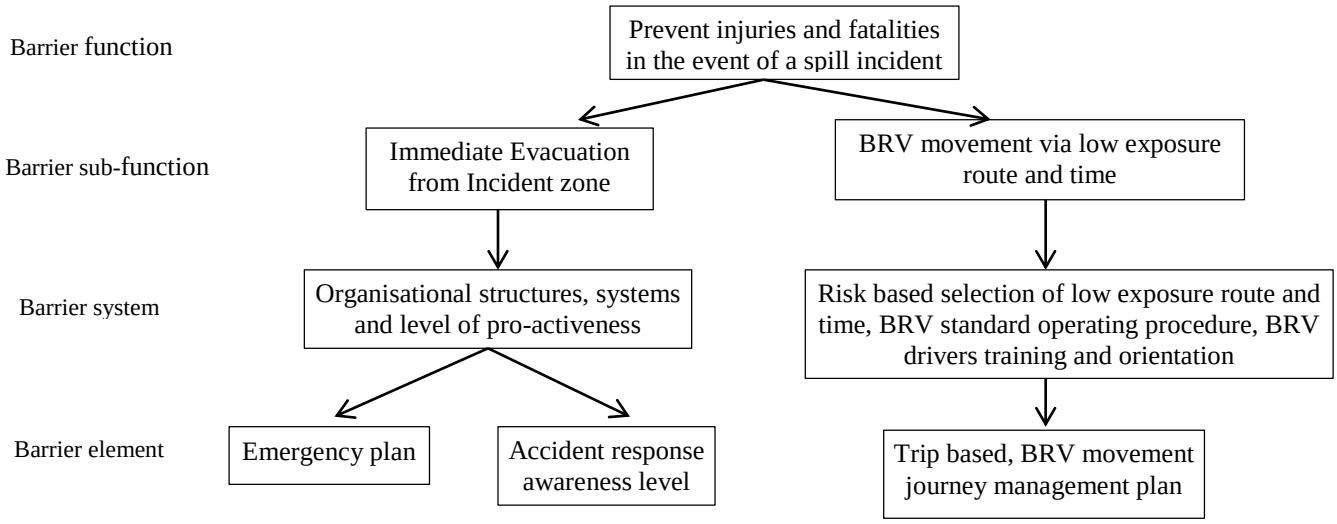


Figure 11: BRV Accident Escalation Barrier Diagram

This accident has brought to light the following operational requirements:

- The need to enforce and extend drug and alcohol policy on drivers and even to third parties (Contractors etc.)
- The need to ensure adequate driver compensation and motivation towards eliminating job frustration induced drunkenness [37]
- The need to ensure proper safety education of fuel tanker drivers as emphasized by [24]
- Legislation against setting up bars around tanker parks; easy source of alcohol around parks has been identified as a major challenge to safe transportation [38].
- As a deterrent, impromptu alcohol and drug test should be carried out on drivers to check alcohol consumption. The study by [39] revealed the effectiveness of random and unscheduled alcohol and drug test.
- Structures, procedures and policies should be deployed to ensure that avoidable accidents don't happen.

CONCLUSION

The airport BRV rollover accident is one of the few of such accidents in Nigeria with no resulting fire, property destruction and fatality. This is due to the closeness of the accident zone to the airport, and the ready availability of emergency response crew that mobilized to the site immediately. A resulting fire close to jet fuel depots with millions of litres of jet fuel in storage would have been a major national disaster. Notwithstanding the extent to which the accident was appropriately managed, it still created traffic grid lock, negative publicity, loss of product, equipment damage, injury, jet fuel spillage and the associated environmental impacts.

A repeat of such an undesirable event must be prevented at all means, particularly in the light of the information now available on the causal factors. Industry regulatory authorities need to enforce the kick-off of a rollover prevention program and device installation for fuel tanker trucks; although this does not guarantee that such a program would prevent all driver inherent errors, but it can help in identifying ways to make the road safe for all users, even with the presence of fuel loaded tanker trucks.

The root cause analysis has revealed that preventing fuel tanker accidents requires a combination of goal oriented strategies which incorporates managerial, technical, training, policy reviews, staff motivation, involvement of relevant agencies etc. as a holistic safety enriching approach.

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