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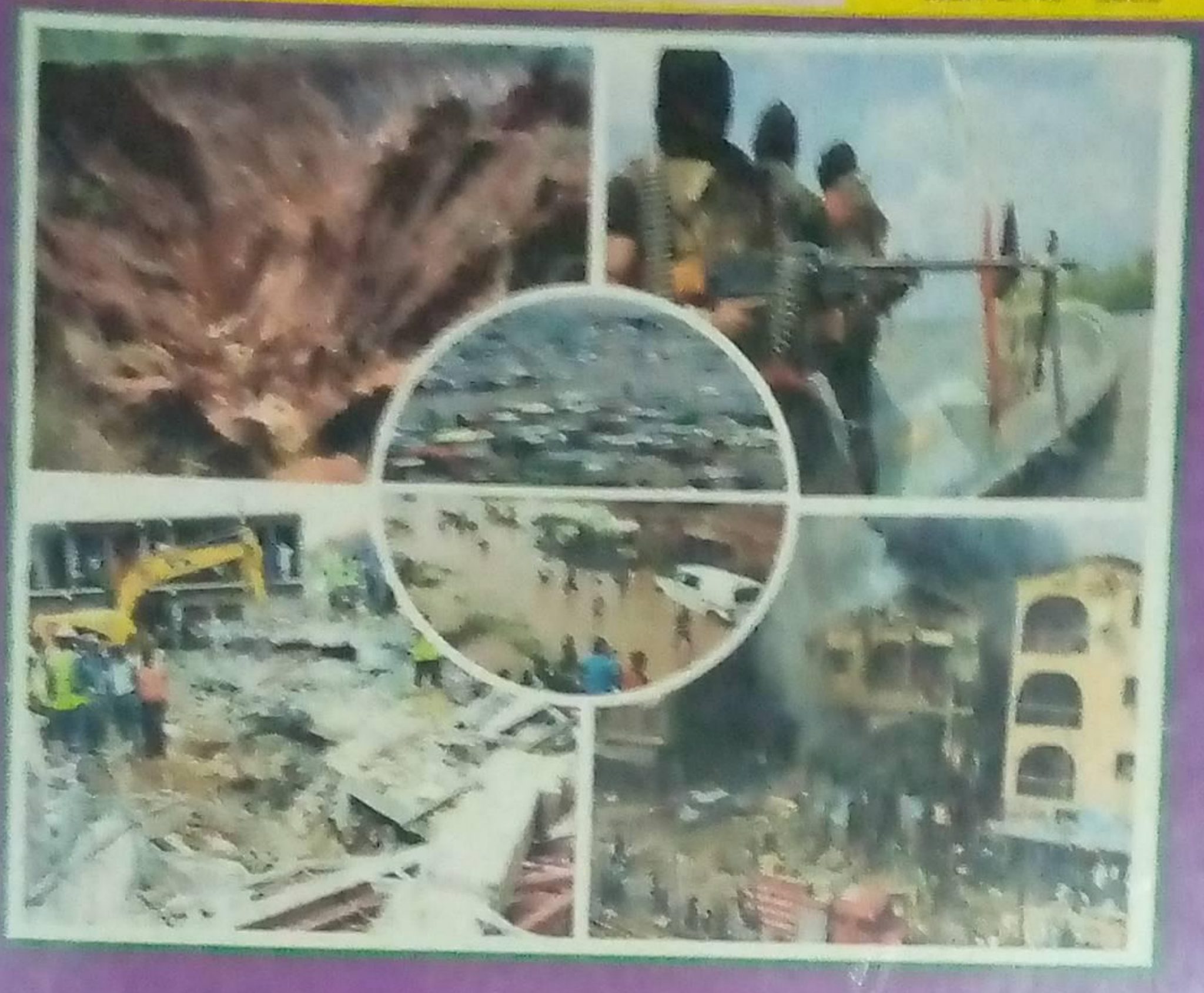

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Risk Factors and the Nature of Disaster in the Physical Distribution and Utilization of Liquefied Petroleum Gas (LPG) in Port-Harcourt City of Nigeria.

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Abstract

Oil spillage and gas flaring are one of the environmental hazards facing the Niger Delta region of Nigeria. Disasters caused by the distribution of petroleum products with the attendant economic and social consequences are common features all over the country especially in the Niger Delta region where a lot of petroleum exploration and production activities take place. This research work focuses on the distribution of LPG and the nature of its corresponding disaster with the risk imposed on Port-Harcourt area. The research study included field surveys of five oil and gas companies involved in LPG distribution, Federal Road Safety Corps (FRSC), Fire Service and the Consumers (Users) of LPG located in Port-Harcourt area of the Niger Delta region. The choices of the techniques employed for the analysis of the field survey data collected were Fault Tree Analysis (FTA), Event Tree Analysis (FTA) and Risk Perception (RP). The outcome of the FTA indicates an overall risk probability of 0.44 which is considered safe in the operations of LPG Distribution in Port-Harcourt area. These quantitative analyses in addition, confirm a direct relationship between LPG incidents and the combined critical causative factors. The risk perception for LPG distribution by users in Port Harcourt area reveals a relatively low risk perception but the utilization perception is that of a relatively safe, slightly costlier, more convenient and environmentally friendlier source of energy. The study recommends management commitment (in time, money, wearing of personal protective equipment and efforts on safety routines) as means to maintaining to safety policy and safety responsibilities. It also recommends that traffic management and road maintenance on Port Harcourt roads should be improved on.

Keywords: Disaster, Distribution, LPG, Fault-tree Analysis, Risk-factors

1. Introduction

Disaster refers to an emergency caused by natural hazards or human induced actions resulting in a significant change in circumstances over a relatively short time period (Olorunfemi and Raheem, 2002) resulting into death, displacement, disease, loss, damage to physical and service infrastructure, depletion of natural and social capitals, institutional weakening and a general disruption of economic and social activity. The unscheduled, sudden character of loss from accident makes it a disaster. Olorunfemi and Raheem (2002) stated

the such events cause considerable natural damages and interrupt the normal functioning of an economy and of society in general.

Risk is defined as the combination of the probability of an event and its negative consequences (UNISDR, 2009). The term risk is multidisciplinary and is used in a variety of contexts (UNDP, 2004). Risk is usually associated with the degree to which humans cannot cope (lack of capacity) with a particular situation e.g. natural hazard (Hewitt, 1997). Disaster risk is the product of the possible damage caused by a hazard due to the vulnerability (Tobin and Montz, 1997). The effect of a hazard (of a particular magnitude) would affect communities differently (Von Kotze, 1998). Occurrences of disaster is not subjected or restricted to a particular location, be it rural or urban. Although the frequency of disaster shows a more occurrence in the urban centres than in the rural area and this is due to the nature of activities within the urban enclave. Henk (2004) stated that disasters always have very undesirable consequences, especially when they occur in urban environments.

The issue of disaster prevention and control is currently attracting increasing attention, reflected in the rising number of publications now available on this subject (Miller and Frecker, 1994; Milne, 2000). According to Henk (2004), most studies analyze the preparation for, response to, and recovery from accidents with community-wide implications, such as so-called natural disasters, like flooding and earthquakes, and man-made disasters, for instance caused by LPG gas explosion or LPG cylinder production errors.

Distribution plays a vital role in the system of global oil trade. The transportation and storage industry is a very complex system that is composed of many independent owners. Tank trucks deliver gasoline to service stations and heating oil to houses. The nature of the disasters associated with the transportation of this type of product may include truck accidents, product spill, fire explosion, terrorism and environmental factor such as pollution. The capacity of these LPG tankers is up to 110,000bm^3 and even the large vessels with the capacity of more than 200,000bm^3 are under development (Ayham, 2010), thus spells a high level of exposure of disaster by its transportation. The aim of this study was to examine the risk factors and the nature of disasters involved in transporting liquefied petroleum gas within Port-Harcourt with the view to arrive at cost – effective prevention and mitigation measures.

2. Problem Statement

Liquefied petroleum gas has been classified as one of the classes of hazardous material. LPG associated risk can be linked to the incident that occurred on April 2, 2013 at Abuja. P.M. News (2013) reported that Karu a highly populated satellite town of the Federal Capital Territory was rocked by explosion caused by industrial gas cylinder leakage. Also, another incident occurred in Lagos State on the 26th of April, 2014, the explosion, which affected four buildings including two banks, reportedly occurred at about 8:30p.m. Lagos State Fire Service posit that the incident was caused by gas explosion (www.informationng.com, 2014). Obviously, such incidents might have catastrophic consequences.

Consequently, processing, storing and transportation of this gas must be handled with extreme care and attention by the authorities so that the risk imposed to the society and environment is minimized as much as possible. Port – Harcourt is an urban city, characterized by the use of cooking gas which is a by-product of LP gas due to the presence of bottling plants and retailing outlets that sell these products. In this study, the focus was on the transportation of LP gases and the corresponding risk imposed on the study area. The objectives are to identify the risks associated with transporting liquefied petroleum gas (LPG); examine the risk perception of employees involved in transporting liquefied petroleum gas; and examine the effectiveness of the existing risk management framework in abating LPG disaster.

3. Research Methodology

For this study, both longitudinal and cross-sectional procedures were adopted to study the risk involved in distributing LPG in Port-Harcourt. Primary and secondary sources of data were used for the purpose of gathering information for this research. The secondary data sources included books, journals etc. The data on LPG road accident was collected from federal road safety commission, River State, also data on LPG were collected from Nigeria Liquefied Natural Gas Companies, and other relevant agencies in River State, the base map and other GIS data were collected from department of geography, University of Ibadan.

Primary data were collected by means of four set of questionnaires while in-depth interviews and personal observation were also being adopted. The first set of questionnaire were administered to the operation department of LPG companies while the second set were administered to the consumers of LPG product and the third of questionnaires were administered to Federal Road Safety Commission and Fires Service department in Port-Harcourt while the fourth set was administered to LPG tanker truck drivers.

The total household population for Port-Harcourt city as at 2006 is 538,559 (NPC, 2010) while the projected growth rate of 3.2% in 2014 gives 692,899 (NPC, 2010). The official government statistics for domestic utilization of LPG in Nigeria is at 1.7% (www.punchng.com) therefore, from the projected population of Port Harcourt in 2014, the total household population framework for consumers of LPG product in Port Harcourt used for the study is (0.017) (692, 899)=11799 A factor of 0.02% (240 households) is used to calculate the sample population for the purpose of this study. Another set of 20 questionnaires were administered to the management staff of LPG companies in Port-Harcourt. That is 4 questionnaires were administered each to NNPCGAS, FORTEOILGAS, OANDOGAS, ADROSEGAS and TOTALGAS. Another set of 20 questionnaires were administered to LPG truck haulage drivers of the above mentioned companies and finally, 6 questionnaire were administered each to the Federal Road Safety Commission and the Fire Service department also in Port Harcourt.

Systematic random sampling technique was adopted for the consumer questionnaire. The data and interviews generated was processed, tabulated and analyzed to generate descriptive and inferential deductions, charts and graphs. The GIS data generated was analyzed

using geospatial tools including Google Earth and Arc Map 9.3 software. Fault Tree Analysis (probability/ Frequency estimates), Event Tree Analysis (descriptive operational procedures), Risk Perception and Regression Analysis were the techniques used for assessing the Risks inherent.

4. Literature Review

The word 'risk' derives from the early Italian *risicare*, which means 'to dare'. In this sense, according to the Britton (1998:5), risk implies a choice rather than a fate, as "*activities undertaken by individuals, organizations, or governments all involve some degree of risk through choice. All activities expose people to a potential loss or gain of something they value; their health, money, career, social position, the environment, and so on*". The term disaster risk is a multidisciplinary concept and may be used in a variety of contexts (UNDP, 2004), the same way disciplines define risk in different ways, depending on the observer (Kelman, 2003). In the case of disaster risk reduction and disaster risk management, disaster risk has a specific focus (UNDP, 2004). Studies (Helm, 1996; Sayers 2002) define risk as the probability of an event occurring linked to its possible consequences. Blaikie (1994) indicates that risk is a complex combination of vulnerability and hazard.

Studies (such as Lewis, 1999, Granger, 1999; UNISDR 2002) all come into agreement that disaster risk can be defined as the probability of harmful consequences, or expected losses (lives lost, persons injured, damage to property and/or the environment, livelihood lost, and the disruption of economic activities or social systems) due to the interaction between humans, hazards, and vulnerable conditions, with a particular source. The conventional view of disaster management draws the method of this social organization as a set of cyclic activities with reference to the periodical occurrence of disasters (Balamir, 2004). According to this view, disaster management requires a continuous chain of activities that includes 'mitigation, preparation, emergency, and recovery' (See Figure 1). All these describe a disaster management cycle that consists of connected activities and phases, which occur sequentially (Alexander, 2000).

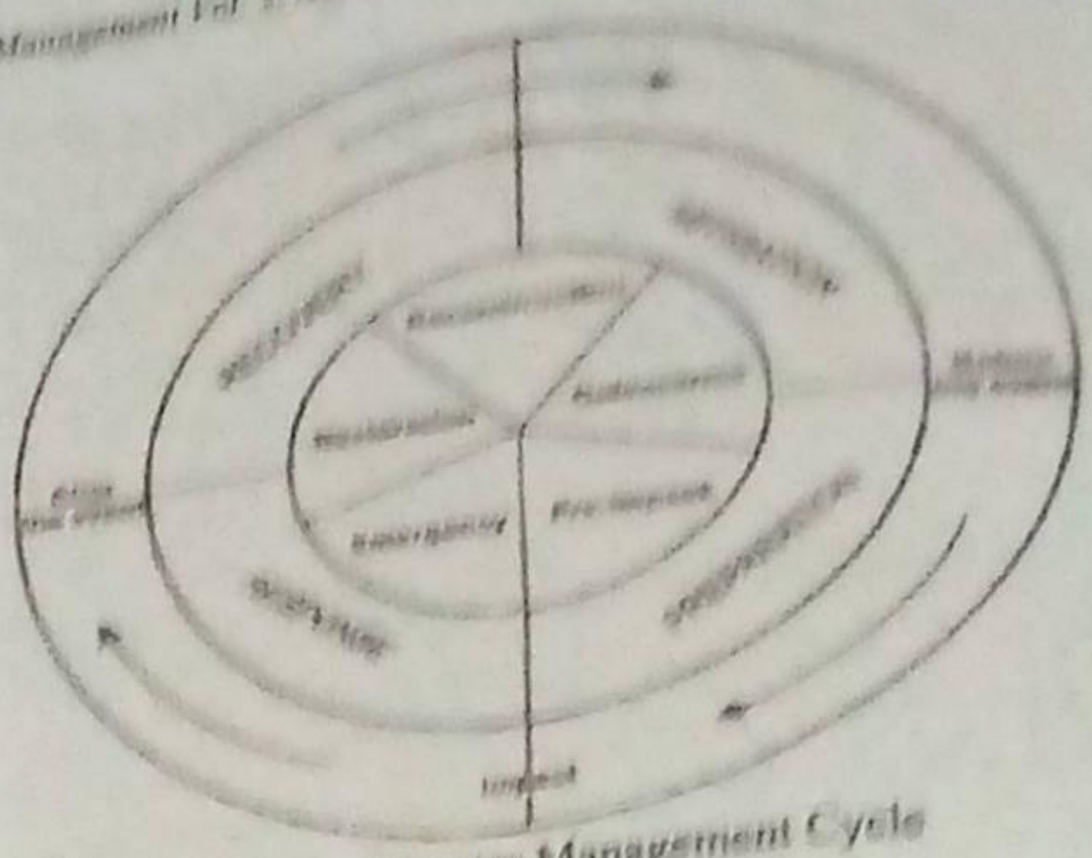

Figure 1: Disaster Management Cycle
Source: Alexander (2000)

LPG, like all fossil fuels, is a non-renewable source of energy. The development of LPG begins in the crude oil field and it ends with the storage of liquid gas. The main compositions of LPG are hydrocarbons containing three or four carbon atoms. The normal components of LPG thus, are propane (C_3H_8) and butane (C_4H_{10}). Small concentration of other hydrocarbons may also be present. Depending on the source of the LPG and how it has been produced, components other than hydrocarbons may also be present (Nonekuone, 2009). It is stored in liquid form under pressure in a steel container, cylinder or tank (of 2.5kg, 12kg, and 16kg, up to 50kg in size) in which the pressure inside ill depend on the type of LPG (commercial butane or propane) (Nonekuone, 2009).

Out of the global 249 million tonnes of LPG consumption in 2010, Asia Pacific ranked highest in consumption, while the North African countries is ranked the largest consumer in Africa with around 85% of Africa's total consumption. Although Nigeria is the largest LPG producer in Sub-Saharan Africa with a total of 47% of global demand for LPG is covered by the domestic sector in which households use LPG for cooking, water and room heating, in Africa the domestic sector accounts for more than 88 % of demand. The increasing rate of consumption throughout the world started in 2000 can be traced back to population growth as well as a growing demand for auto-gas and LPG in the petrochemical industry (PMECD, 2014).

Gas distribution by gas majors (Total, Oando, Mobil, Forte Oil, and NNPC) and independent marketers established gas filling centers were customers and retailers can refill their gas cylinders. These facilities are limited to only large metropolitan areas. At the end of 2004 there was 203 filling plants in the country (Nigeria LPG sector improvement study, 2004), 26 of which are in Port-Harcourt. Millo, *et al.* (2009) stated some major causes of LPG accident. They posit that, Liquefied petroleum gas is a flammable gas, which has the potential to create blast accidents. Therefore, it is important that the properties and safe handling of LPG are understood and applied in the domestic and commercial/industrial situations.

3.1 Urban Planning and Disaster management

The role of planners in the management of 21st century settlement and its functionality is all inclusive. Urban managers are subjected with the role of bringing about harmony, safety and functionality in human settlement. In bringing about settlement safety, reduction in disaster is an integral factor. Planning, conceptualized as the art and science of allocating spatially, activities, structures, routes, uses and features as well as the accentuation and maximization of land as a resource towards realization of maximum realistic levels of economy, convenience, beauty, health and safety (Keeble, 1976) is done through the application of scientific methods to decision-making (Faludi, 1973). The processes of harmony and safety in the environment has brought into lime light two tool used by planners has a means to bringing about safety and reducing hazards and disasters. These are; *developmental control and land use planning*.

Development Control is the process of implementing planning standards; that is, the process of ensuring that developments are carried out in accordance with approved planning standards thereby serving as tool for promoting orderliness and safety through managing of changes so as to prevent hazard. In the case of the fire outbreak in Jakara Market in Lagos State, Adelaja (2013) stated that the "Jakara market" fire outbreak was as a result of improper strict development control of a building meant for residential purpose converted into commercial purpose and thus such building was stockpiled with explosive and fireworks" which now resulted into incidence of market fire. Also, the lack of strict compliance to planning standards such as setbacks and airspaces prevented the fire rescue officers from getting to the site of the disaster easily.

Burby *et al.* (2000) stated that policy makers are now coming to realize that a different approach is needed if natural disaster risks are to be reduced. Mileti (1999) quoted the Second National Assessment on Natural and Related Technological Hazards concluded that, *"no single approach to bringing sustainable hazard mitigation into existence shows more promise at this time than increased use of sound and equitable land-use management"*. Land-use planning is the means for gathering and analyzing information about the suitability for development of land exposed to natural hazards, so that the limitations of hazard-prone areas are understood by citizens, potential investors, and government officials (Burby *et al.*, 2000). Proper land-use planning provides an in-depth look at the process of preparing land-use plans (Kaiser *et al.*, 1995), and can be a powerful tool for reducing risks from natural disasters (Burby, 1999).

Planning programs reduce losses by affecting both the location and the design of urban development (Godschalk *et al.*, 1998). Ulutürk (2006) stated that studies recognize urban disasters, pointing out that existing risk is magnified by the failure of adequate planning, and tend to focus on the interplay between urban disasters and planning.

According to Wamsler (2004), the aspects influencing the interplay between urban disasters and planning are; *social aspects, environmental aspects, demographic aspects, economic aspects institutional aspects.*

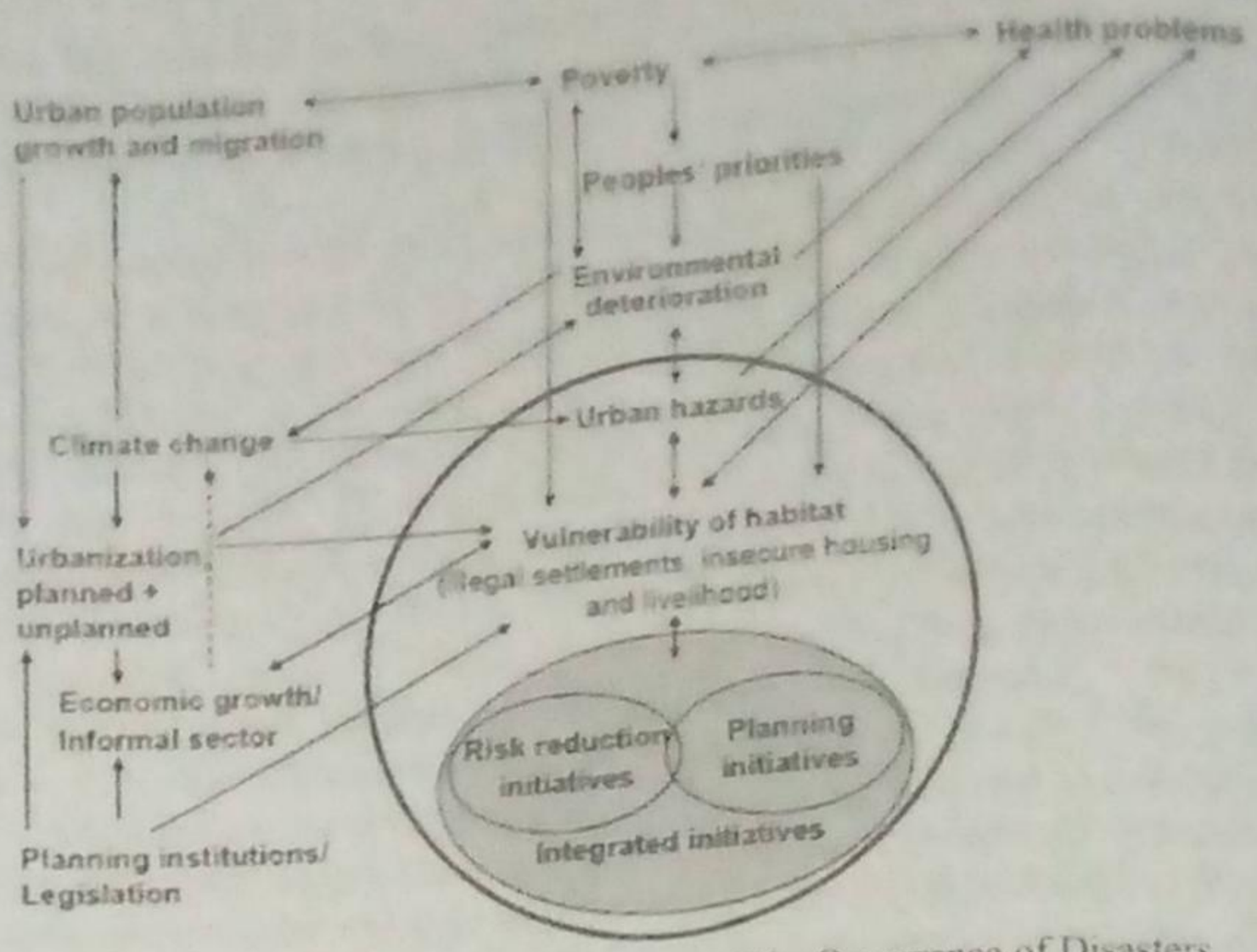

Figure 2: Interplay between Planning and the Occurrence of Disasters
Source: Wamsler (2004)

4. The Study Area

Port Harcourt is the capital of Rivers State, Nigeria. Port Harcourt is located within the humid tropics of the southern part of Nigeria and sited on a relatively firm land about 66km from the Atlantic Ocean (Ukpere, 2005). The geographical coordinates of the city limit lie approximately within latitude $4^{0}40'$ and 5^{0} 01' North and longitude 6^{0} 50^{1} and 7^{0} 01^{0} East (Figure 1). It lies along the Bonny River and is located in the Niger Delta. Port Harcourt has a population of 1,382,592 (NPC, 2006) with an estimated area of 360 km² (Bekwe 2003, Elechi and Yellowe, 2014). Commercial quantities of crude oil was discovered in Oloibiri in 1956, the first in the country and Port Harcourt's economy turned to petroleum when the first shipment of Nigerian crude oil was exported through the city in 1958.

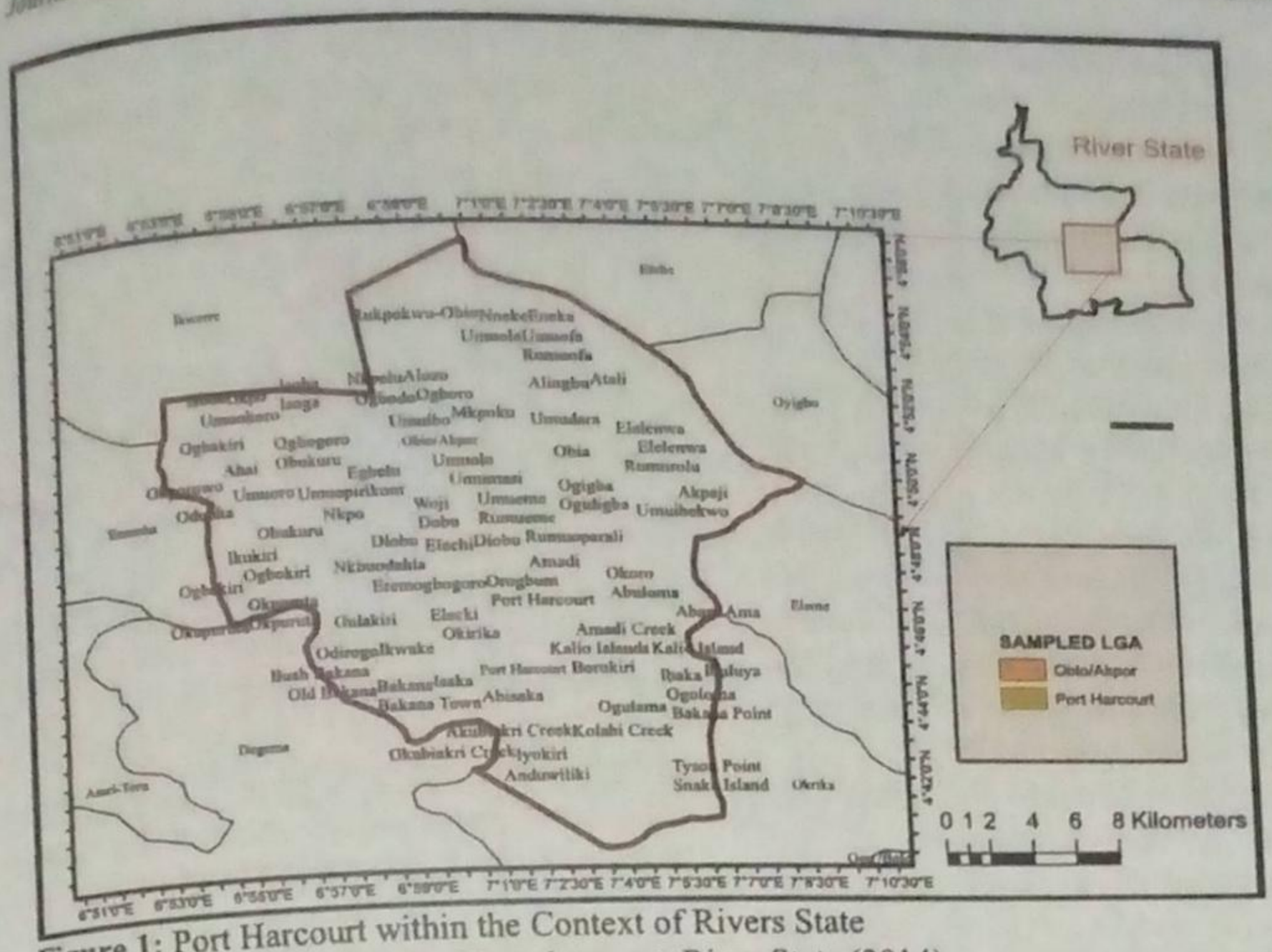

Figure 1: Port Harcourt within the Context of Rivers State
Source: Physical Planning and Development, River State (2014)

5. Risk Assessment of LPG Distribution in Port Harcourt

5.1 Definition of Terms, Symbols, Probabilities and Terminologies

The Main event is PETROLEUM FIRE EXPLOSION (Disaster) - D

Emergency Response to Fire Disaster; Fire Service Department-FS

The Intermediate events (LOA-Lines of Assurance/safeguards) is

i. Management Commitment-MC (safety sensitization, safety meetings, reports and investigations, incentives/reprimands, etc.)

ii. Traffic management- TM (control, caution, fine, arrest etc.)

The Basic and their sub-basic Events are

i. **LPG Technical Operations – TO** = (Trained Technical Personnel –TO_{PT}; Un-Trained Technical Personnel - TO_{PT}^{1}; Health Safety Environmental Practices Followed-TO_{HSE} and Health Safety Environmental Practices not Followed – TO_{HSE}^{1}).

ii. **Truck drivers- TD** = (Skills/ Training –TD_S; No Skills/ Training –TD_S^{1}; Truck Maintenance Regularly-TD_{TMR} and Truck Maintenance Rarely – TD_{TMR}^{1}).

iii. **Roads-RD = (Road** Well Maintained- RD_{RWM} ; Road Not Well Maintained – RD_{RWM}^{1} ; Adequate Traffic Signs –RD_{ATS} and Inadequate Traffic Signs – RD_{ATS}^{1})

iv. **Consumers- CS** = (Cylinder Placement Inside- CS_{CPI}; Cylinder Placement not Inside- CS_{CPI}^{1} ; Cylinder Maintenance Regularly-CS_{CMR} and Cylinder

Maintenance not Regular (Score 1)

5.2 Probabilities

1. Individual Probability (Pr) of an event is the likelihood of the event happening

If x = Number of counts of an Event A,
n = Total number of counts
Therefore, Individual Pr (A) = x / n

2. Complement Probability of Event A, Pr (A^1) = 1-Pr(A)
3. Joint Probability – Multiplication Rule, is the probability that two events will occur simultaneously. For Event A and Event B, that are independent, the joint probability is Pr (A and B) = Pr (A) Pr (B)
4. Marginal Probability – Addition Rule; is the probability of the occurrence of a single event. For Event A and Event B, the marginal probability is ; Pr (A or B) = Pr (A) + Pr (A and B).
   Likewise, Pr (B or A) = Pr (B) + Pr (B and A)
5. Independent / Dependent events
   If Pr (A / B) = Pr (B/A), the Event A and Event B are independent
   i.e. the Probability of one event is not affected by the occurrence of the other event.
   But if Pr (A/ B) is not equal to Pr (B/A) , the Event A and Event B are dependent
   i.e. the Probability of one event is affected by the occurrence of the other event
6. Union Probability of Event A and Event B is Pr (A U B_1) =Pr (A_1 and B_1)+ Pr (A_1 and B_2) + Pr (A_2 and B_1).

6. Results and Discussion

6.1 LPG Technical Operations

The analysis from Figure 2 reveals that the raw field data collated in respect of Technical Operations. The Analysis shows that 90% of the technical staff is trained while the remaining 10% are untrained staff. Also 85% of the trained staff has basic health safety environmental knowledge and remaining 15% have little or no knowledge on environmental safety of LPG product.
Total Number of data = Number of Technical staff surveyed from different Companies mentioned. Therefore, Individual Probabilities (Likelihood) of the critical sub-basic Events of Technical Personnel (TO_{PT}, TO_{PT}^1) and Incentives (TO_{HSE}, TO_{HSE}^1) identified are:

Pr (TO_{PT}) = 18/20 = 0.90
Pr (TO_{PT}^1) = 2/20 =0.10
Pr (TO_{HSE}) = 17/20 =0.85
Pr (TO_{HSE}^1) =3/20 =0.15

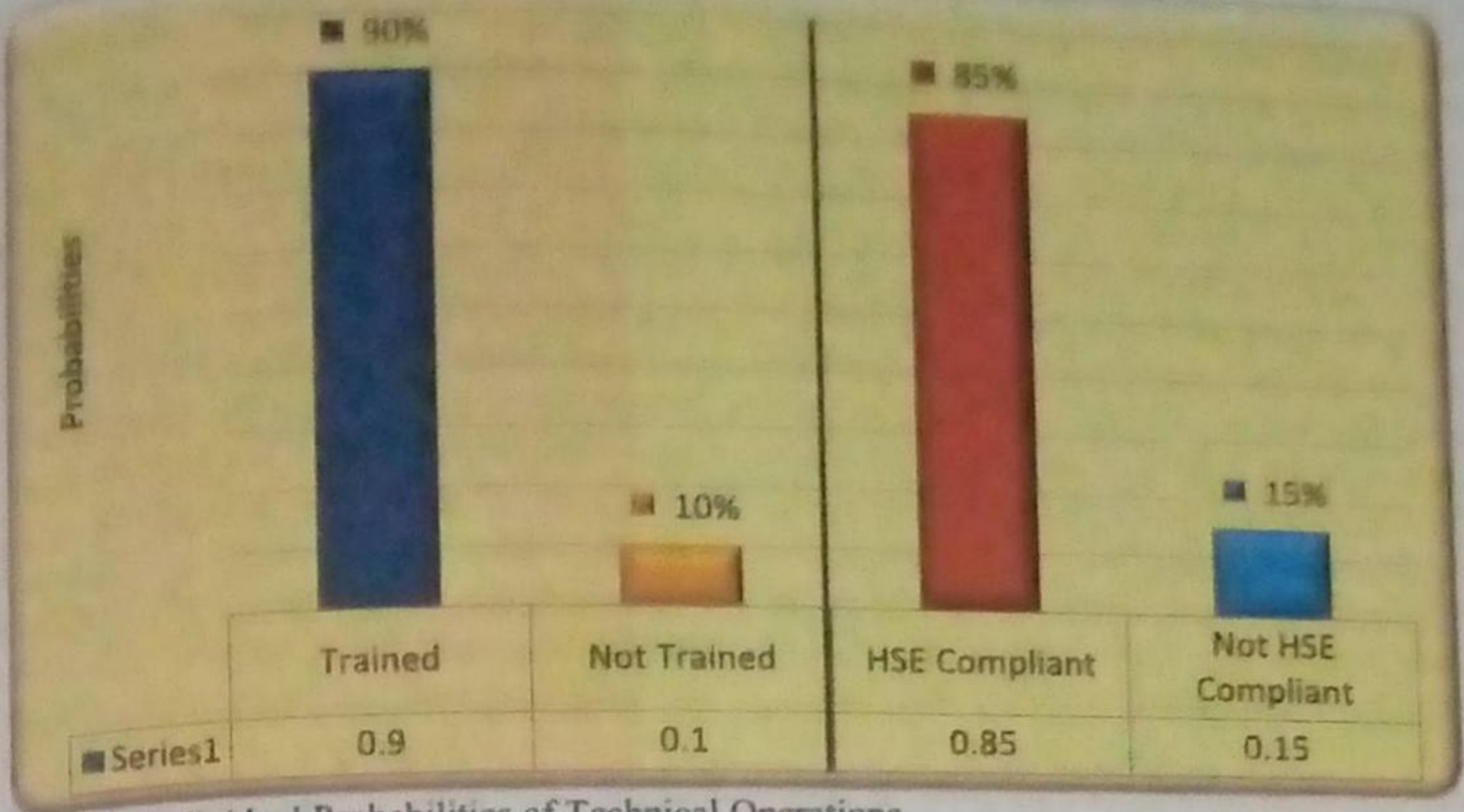

Figure 2: Individual Probabilities of Technical Operations
Source: Authors analysis 2015

The study revealed that 95% of the truck drivers are trained regularly while 5% are not trained regularly. 95% of the truck drivers are trained on the safety measures involved in transporting liquefied petroleum gas and how to avert a disaster if any accident occurs. (See Figure 3). Total data= Total number of Truck drivers surveyed. Therefore, Individual Probabilities (Likelihood) of the critical sub-basic Events of Truck Drivers' Skills/Training (TD_S, TD_S^1) and Truck Maintenance (TD_{TMR}, TD_{TMR}^1) identified are:

$Pr(TD_S) = 19/20 = 0.95$
$Pr(TD_S^1) = 1/20 = 0.05$
$Pr(TD_{TMR}) = 18/20 = 0.90$
$Pr(TD_{TMR}) = 2/20 = 0.1$

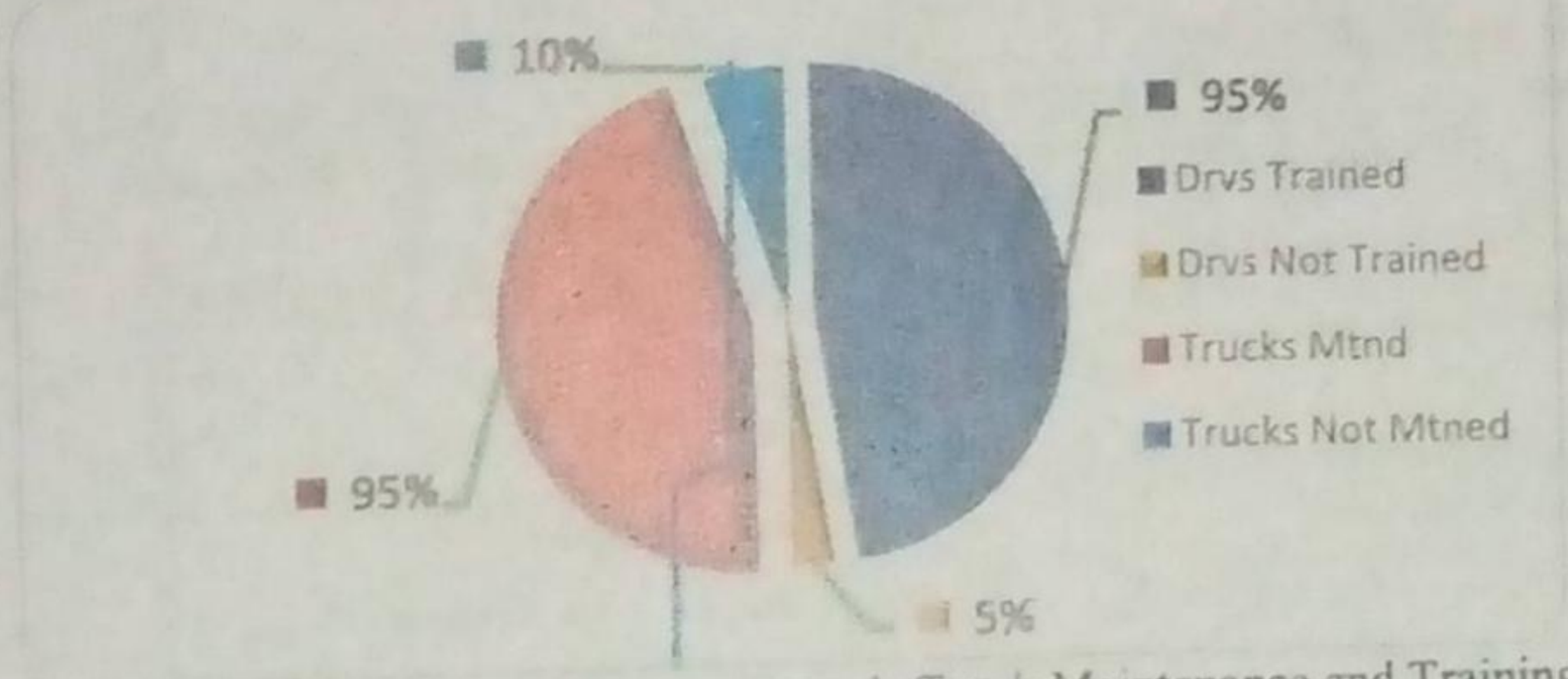

Figure 3: Truck Drivers Response towards Truck Maintenance and Training
Source: Authors analysis 2015

6.2 Road Safety and maintenance

The study analysis shown in Table 1 revealed that 81% of the roads are not maintained and 19% are regularly maintained. This result shows poor maintenance culture of the government which put the life and property of the people at risk. The table also revealed minimal safety measures on road. However, 50% of the responses accept that traffic signs are adequate while the remaining 50% object that there is non-availability of the road traffic signs which put the life of the people at a very high risk. This result implies that the roads are poorly maintained and not good for transporting dangerous goods like LPG.

Total Data for is 26= Number of the Truck drivers plus FRSC staffs surveyed Therefore, Individual Probabilities of the critical sub-basic Events of road maintenance (RM_{RWM}, RM_{RWM}^{1}) and road traffic signs (RTS_{ATS}, RTS_{ATS}^{1}) identified are:

$Pr(RM_{RWM}) = 5/26 = 0.19$
$Pr(RM_{RWM}^{1}) = 21/26 = 0.81$
$Pr(RTS_{ATS}) = 13/26 = 0.50$
$Pr(RTS_{ATS}^{1}) = 13/26 = 0.50$

6.3 LPG Users Safety Perception

The Table below shows precaution level in averting associated risk of using LPG Cylinder. The analysis revealed that, 172 (71.6%) of the respondents that uses the Cylinder inside their kitchens while the remaining 68 (28.3%) use the cylinder outside their kitchens. Also, the maintenance culture of the respondent shows that 138 (57.5%) regular spray and check if there are leakages in the cylinder while 102 (42.5%) doesn't maintain their LPG cooking cylinder. This reveals that, the level of risk is still very high and poor consumer knowledge on the risk associated with non-maintenance of the LPG Cylinder.

Total number= Number of consumers surveyed.

Therefore, Individual Probabilities (Likelihood) of the critical sub-basic Events of cylinder placement (CS_{CPI}, CS_{CPI}^{1}) and cylinder maintenance (CS_{CMR}, CS_{CMR}^{1}) identified are:

$Pr(CS_{CPI}) = 172/240 = 0.84$
$Pr(CS_{CPI}^{1}) = 68/240 = 0.16$
$Pr(CS_{CMR}) = 138/240 = 0.58$
$Pr(CS_{CMR}^{1}) = 102/240 = 0.42$

Table 1: Roads Safety and Maintenance

No of Respondents	Maintenance		Traffic Signs	
	Well Maintained	Not well Maintained	Adequate	Inadequate
26	5	21	13	13
100%	19%	81%	50%	50%

Source: Authors analysis 2015

Table 2: Consumers exposure to risk and disaster

Respondents	Cylinder Placement		Cylinder Maintenance	
	Inside CS_{CPI}	Not Inside CS_{CPI}^{1}	Regular CS_{CMR}	Not Regular CS_{CMR}^{1}
240	172	68	138	102
100	(71.6%)	28.3%	(57.5%)	(42.5%)

[1]Source: Authors analysis 2015.

6.4 Fault Tree Analysis (A Quantitative Analysis)

Table 3 shows the Joint Probability of the Most Critical Events of Untrained Technical Personnel and HSE not followed is 0.02. While the Marginal Probability for Untrained Technical Personnel is 0.10, the Marginal Probability of HSE not followed is 0.16. Therefore, the Union Probability of these two most critical events that will lead to the occurrence of Disaster is given by $Pr(A_1 \cup B_1) = Pr(A_1 \text{ and } B_1) + Pr(A_1 \text{ and } B_2) + Pr(A_2 \text{ and } B_1)$.

Note that in this case, A_1 –Untrained Technical Personnel; B_1 - HSE not followed; A_2- Trained Technical Personnel and B_2- HSE Followed

From the computed table above; therefore, $Pr(A_1 \cup B_1) = 0.02 + 0.08 + 0.14 = \mathbf{0.24}$

6.5 Truck Drivers response analysis on truck and training.

Analysis shown in Figure 4 shows the Joint Probability of the most critical events of Untrained Truck drivers and Trucks not regularly maintained is 0.01. While the Marginal Probability for Untrained Truck drivers is 0.06, the Marginal Probability of trucks not regularly maintained is 0.10. Therefore, the Union Probability of these two most critical events that will lead to the occurrence of Disaster is given by $Pr(A_1 \cup B_1) = Pr(A_1 \text{ and } B_1) + Pr(A_1 \text{ and } B_2) + Pr(A_2 \text{ and } B_1)$.

Note that in this case, A_1 –Untrained Truck Drivers; B_1 - Trucks not regularly maintained; A_2- Trained Truck Drivers and B_2- Trucks regularly maintained.

From the computed table above; therefore, $Pr(A_1 \cup B_1) = 0.01 + 0.05 + 0.09 = \mathbf{0.15}$.

Table 3: LPG Technical Operations

	TO_{PT}	$TO_{PT}{}^{1}$	TOTAL
TO_{HSE}	0.76	0.08	0.84
$TO_{HSE}{}^{1}$	0.14	0.02	0.16
TOTAL	0.90	0.10	1

Source: Authors Computed Values from Individual Probability and the Formulae for Joint Probability and Marginal Probability

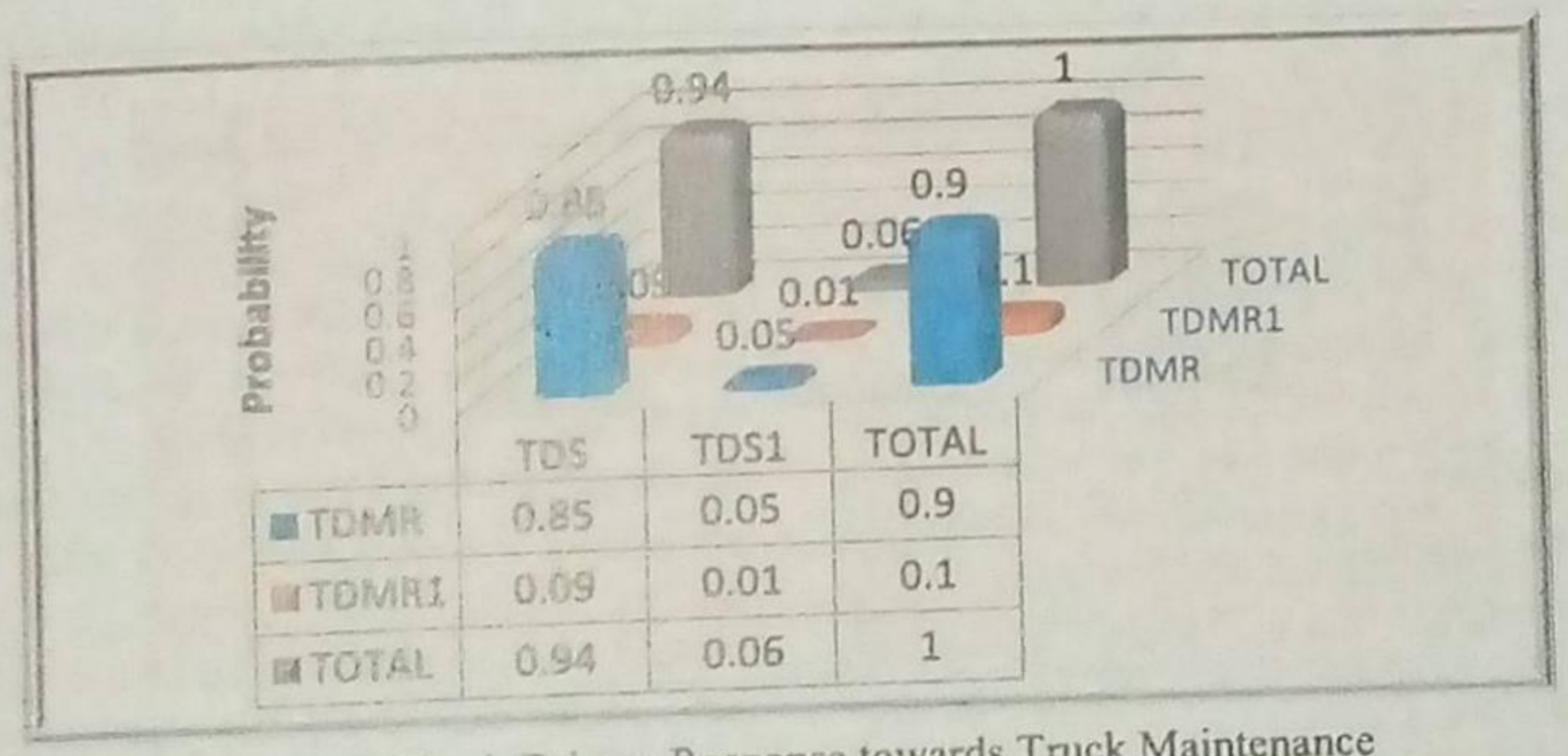

Figure 4: Truck Drivers Response towards Truck Maintenance
Source: Authors Computed Values from Counts Table and the Formula for Joint Probability and Marginal Probability

6.6 Analysis of Road plied by LPG distributors

Table 4 shows the Joint Probability of the Most Critical Events of not well maintained roads and Inadequate Traffic signs is 0.41. While the Marginal Probability for not well maintained roads is 0.82, the Marginal Probability of inadequate traffic signs is 0.50. Therefore, the Union Probability of these two most critical events that will lead to the occurrence of Disaster is given by $Pr(A_1 \cup B_1) = Pr(A_1 \text{ and } B_1) + Pr(A_1 \text{ and } B_2) + Pr(A_2 \text{ and } B_1)$

Note that in this case,

A_1 –Not well maintained roads;

A_2- Well maintained roads

B_1 - Inadequate Traffic signs; B_2- Adequate Traffic signs

From the computed table above;

Therefore, $Pr(A_1 \cup B_1) = 0.41 + 0.41 + 0.09 = \mathbf{0.91}$.

Figure 5 shows the Joint Probability of the Most Critical Events of Cylinder Placement Inside and cylinder not regularly maintained is 0.35. While the Marginal Probability for Cylinder Placement Inside is 0.84, the Marginal Probability of cylinder not regularly maintained is 0.42. Therefore, the Union Probability of these two most critical events that will lead to the occurrence of Disaster is given by $Pr(A_1 \cup B_1) = Pr(A_1 \text{ and } B_1) + Pr(A_1 \text{ and } B_2) + Pr(A_2 \text{ and } B_1)$

Note that in this case,

A_1 –Cylinder Placement Inside;

B_1 - Cylinder not regularly maintained

A_2- Cylinder Placement Outside;

B_2- Cylinder regularly maintained

From the computed table above;

Therefore, Union $Pr(A_1 \cup B_1) = 0.35 + 0.49 + 0.09 = \mathbf{0.93}$

Table 4: Roads Analysis

	RM_{RWM}	RM_{RWM}^1	Total
RTS_{ATS}	0.09	0.41	0.50
RTS_{ATS}^1	0.09	0.41	0.50
Total	0.18	0.82	1

Source: Authors Computed Values from Counts Table and the Formula for Joint Probability and Marginal Probability.

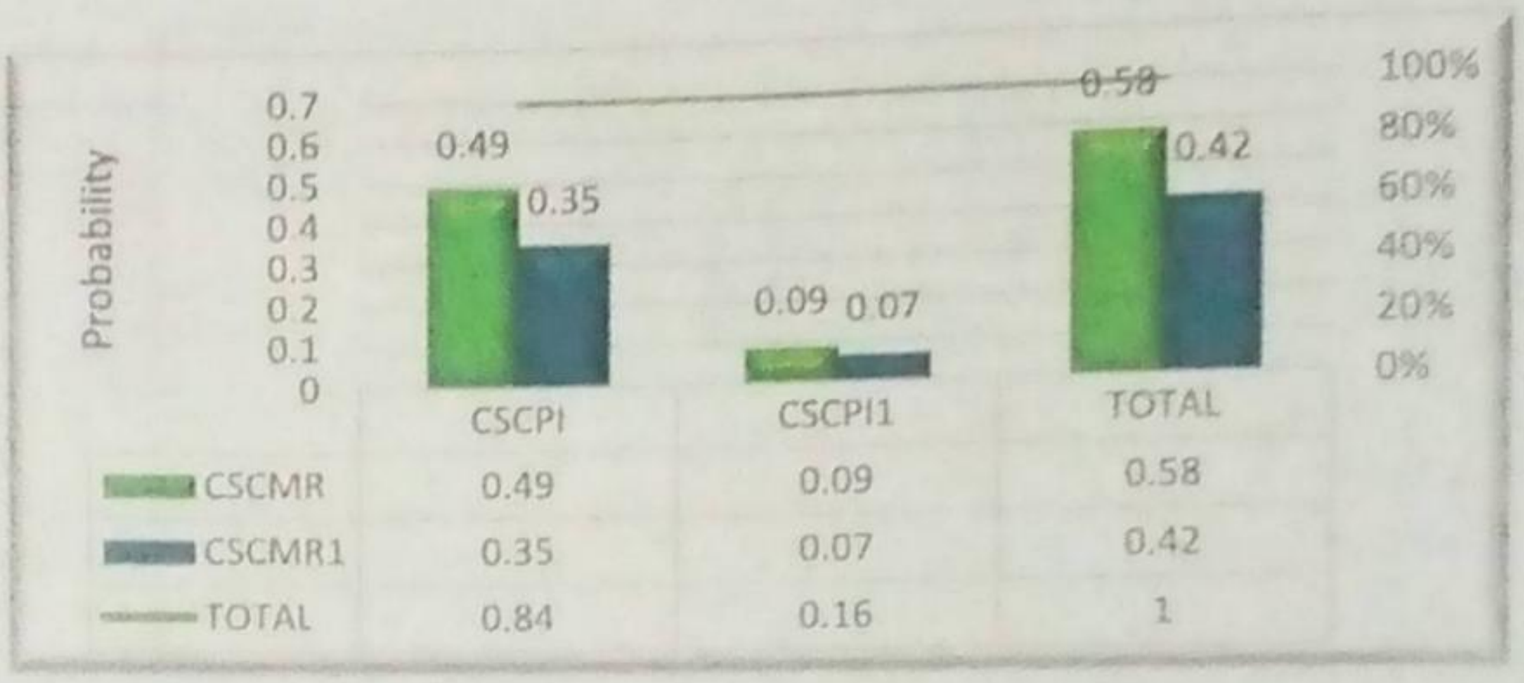

Figure 5: Consumers

Source: Authors Computed Values from Counts Table and the Formula for Joint Probability and Marginal Probability

Management Commitment (MC) and Federal Road Service Commission (FRSC) are Lines of Assurance/ Safeguards Events with Individual Probability Pr (MC) = Individual Probability Pr (FRSC) = 0.5 since the Events could only be either effective or ineffective. Since Lines of Assurance- (Management commitment and FRSC Traffic Management) are meant to be Safeguards or checks on the basic / sub-basic Events, when in place and effective then 'AND GATE' exists which in turn affects the Union Probability to make the outcome a Joint Probability. On the other hand, 'OR GATE' exists when there are no Safeguards / Checks (or ineffective safeguards) leaving the Union Probability unaffected.

Therefore, Joint Probability of (Untrained Technical Personnel and HSE not Followed) and MC = (0.24) (0.5) = 0.12 as shown in the Fault tree when effective MC is in place. The Joint Probability of TD & RD = Pr (TD, RD) = (0.15 + 0.91) / 2 (0.5) = 0.27 due to the effect of Traffic management and MC Safeguards. In situations when safeguards are not in place or found to be ineffective the Probability is 0.24 for the basic Event TD and (0.51 + 0.91) / 2 = 0.71 for the basic Events of TD and RD respectively.
For the basic Event of Consumers, the Probability (Pr = 0.93) remains the same since there is no Line of Assurance. Finally, the Risk Probability Overall for the distribution of LPG in Port Harcourt metropolis Pr (Overall) = 0.24+ (0.91+ 0.51)/2 + 0.93) /3 = 0.63 when Management Commitment and Traffic Management are not in place or safeguards are not effective while, Pr (Overall) = (0.12 + 0.27 + 0.93) / 3 = 0.44 due to the level of Management Commitment and Traffic management put in place. It can therefore be concluded from the quantitative analysis on the Fault Tree of LPG Distribution in Port Harcourt that Management Commitment and effective Traffic management put in place have a positive effect of reduction (inversely proportional to) on the Risk in LPG Distribution. It can also be stated that from this quantitative analysis that there is a significant indirect relationship between the levels of skills/trainings/experience acquired by LPG tanker drivers and the state of the tankers they drive with the level of Risk while Distributing LPG.

From the field survey, 90% of the drivers surveyed are well-trained and drive trucks that are regularly maintained but only about 20% were involved in minor road accidents/offences while daily plying on poorly maintained roads with inadequate traffic signs. The present condition of the roads themselves actually have a relationship with the risks recorded and could further increase the risks in LPG distribution. This establishes a significant relationship between the skills of the drivers, condition of the trucks and the condition of roads with Disaster in LPG Distribution.

Taking into consideration the consumers, this study shows a Risk level of 36/240 = 0.15 which is significantly low. This indicates that the utilization of LPG by consumers is of low Risk hence significant low level of Disaster in Port Harcourt due to the awareness of proper placement and proper maintenance (condition) of LPG cylinders. Thus the finding from this study like the third hypothesis shows a significant relationship between the placement and

the condition of cylinders with the level of risk.

6.7 Supervisory Measures

Personnel engaged in LP Gas operations receive formal trainings by competent persons for their normal activities and for emergencies. LP Gas facilities have emergency planning and response programmes appropriate to the hazards and risks which they represent. These include correct handling procedures to avoid injury.

6.8 Risk Perception for LPG compared with other sources of fuel

A comparative counts study of users' perception of LPG distribution and utilization compared with other sources of fuel such as kerosene, firewood, coal etc. was conducted among 240 respondents who are users of LPG. Interviews were conducted and comparative questions asked on important attributes of convenience, length of timing for cooking, environmental sustainability, safety and cost that lead to the respondents' perception forming.

Table 5 more of the respondents (96%) of the comparative counts study believe that LPG utilization is more convenient than the other sources of fuel, while the remaining 4% of the respondents believe LPG is less convenient. The study further revealed that 97% of the respondents in the comparative counts study have the perception from personal utilization of LPG that it is faster in cooking than other sources of fuel. Only 3% of the respondents have an opposite perception. Although, (99%) of the users of LPG who were respondents in the comparative counts study say that LPG utilization is environmentally friendlier (less pollution) with less carbon footprints than other sources of fuel Only 1% of the respondents believe in the contrary. A comparative counts study with other sources of fuel shows more of the users' (83%) of LPG have a perception of safety for LPG utilization. Only 17% of the users feel LPG utilization is unsafe. In which 23% of the respondents in the field comparative counts of this study think that LPG utilization is not expensive while 77% of the respondents think otherwise.

From comparative study and interviews, the tabulation of field comparative counts and derived percentages of perception for LPG with other sources of fuel like firewood, coal, kerosene etc. for domestic use revealed that:

1. Risk Perception for LPG Distribution in Port Harcourt is relatively low.

The Risk perception of LPG Distribution and Utilization in Port Harcourt is Low. This is confirmed by the quantitative analysis of this study where the Risk Probability (overall) of all the operations involved in LPG distribution in Port Harcourt is found to be 0.44. This suggests that a Risk Pr (Overall) of 0.44 could be considered as the threshold probability for LPG Distribution in Port-Harcourt. For a higher Risk Pr (Overall) □ 0.44, risk management measures should be put in place for the operations in such a system to function safely without the associated Disaster happening. A limiting Risk Probability of 0.44 is therefore suggested for LPG Distribution because of the nature of the associated Disaster of petroleum fire explosion.

Table 5: Comparative Counts of Attributes of LPG with other sources of Fuel.

Total No. of Respondents	More Convenient	Faster for cooking	Neater (Less Smoke)	Relatively Safe	Costlier
240	230	235	238	200	185
100%	96%	97%	99%	83%	77%

Source: Authors Field Comparative Counts / Derived % Perception for LPG

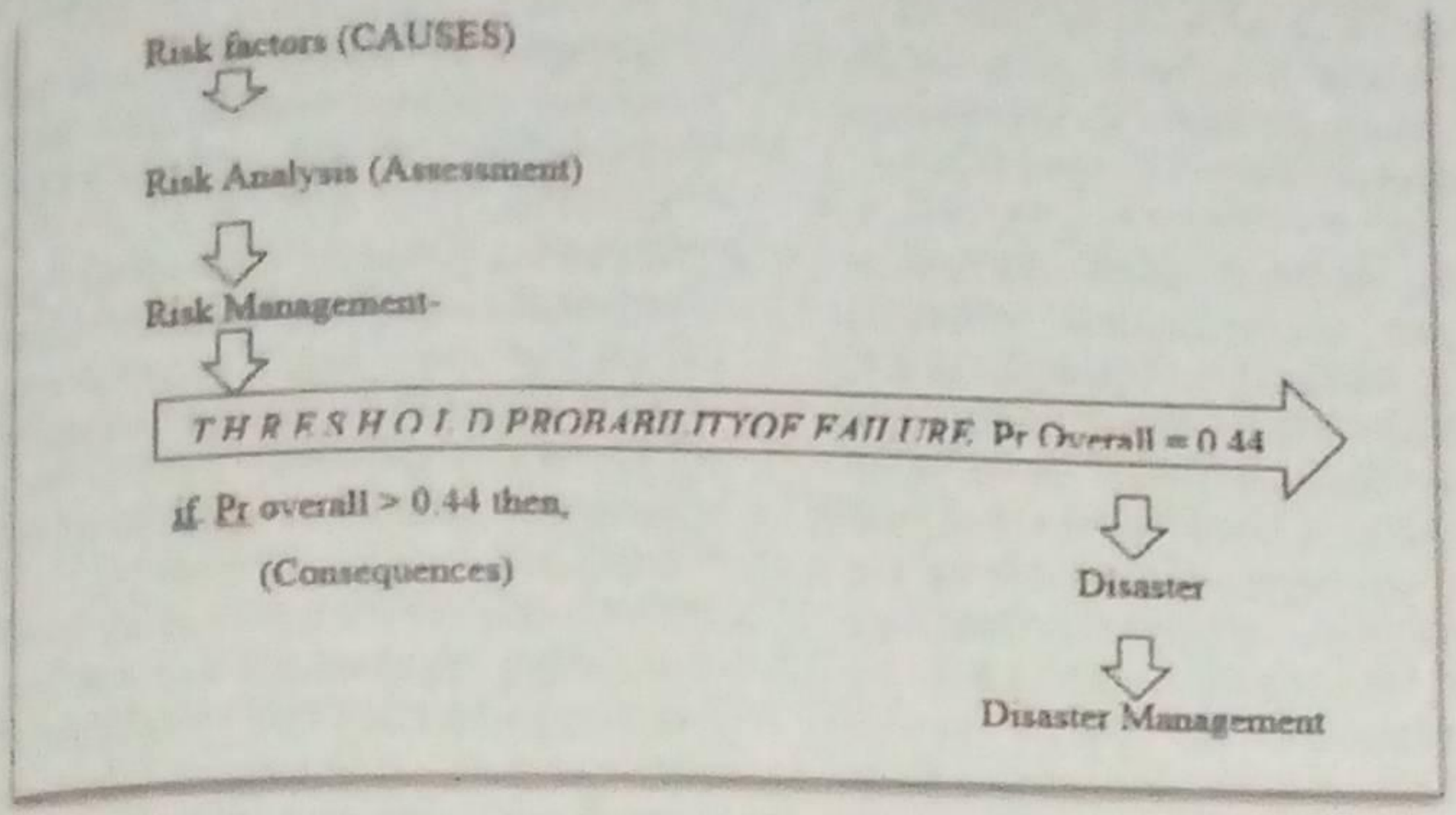

Figure 7: Graphical Modeling of Risk-Disaster Relationship of LPG Distribution in Port-Harcourt.

2. LPG Utilization Perception of users is that LPG is relatively safe, slightly costlier, more convenient and environmentally friendlier.
3. However, Consumers Perception of the nature of LPG Disaster is generally that of life and property destructive fire

7. LPG Distribution and Utilization: Challenges and Recommendations

7.1 Challenges facing LPG distribution and utilization

The challenges in LPG distribution and utilization are numerous. They are essentially safety issues which vary from the LPG refilling plants / companies, to truck drivers, to dealers and to individual consumers in the chain of LPG distribution and utilization. The recommendations are therefore to improve safety by reducing the number of unsafe acts and situations at work environment and in the homes.

A major challenge of safety in the plants is the failure to follow 'normal' procedures which is a significant factor in almost every accident whether the accident resulted in a fatality, lost time injury, equipment damage, production loss or near miss. Interview with some of the workers show that they think that by taking short cuts they are doing what the supervisor and management want: that is getting the job done faster.

Another challenge is the non - retraining opportunities for the LPG truck drivers who are always on the busy schedule of haulage activities to deliver LPG supplies without any refresher driving courses to further sharpen their skills and update their driving / traffic(highway) knowledge. Bad spots on the highways congested and filled with potholes are other challenges faced in the haulage distribution of LPG.

A growing challenge in LPG distribution in Nigeria is the current insecurity caused by the number of fatalities due to bomb blasts from IEDs (Improvised Explosive Devices) made from filled LPG cylinders illegally diverted for criminal and terrorism purposes by the Boko Haram insurgents. This challenge has led to a negative perception by foreign nationals of Nigeria as an insecure nation to live in and invest for economic activities.

For consumers, the challenge faced in Port Harcourt and environs is lack of public sensitization on the dangers of LPG fire and the methods of placement and maintenance of acquired cylinders. Finally, challenges of human error from the actions/inactions of the government, management, supervisors, technical operators, truck drivers, dealers and the consumers in the chain of LPG distribution and utilization are foreseeable among other challenges and therefore amenable to control measures.

7.2 Recommendations

Based on the study findings, the following were recommended by the study

1. Improvement in management commitment (in time, money, wearing of personal protective equipment and efforts on safety routines) to safety policy and safety responsibilities
2. Improved safety audit on safety climate with respect to efficient truck maintenance and efficient road worthiness of the haulage trucks should also be regularly done by the VIO (Vehicle Inspection Officer)
3. Management should also have a method designed to investigate and record near-misses, injuries and accidents
4. Improved workers' motivation and communication are recommended methods to obtain employees involvement in safety issues. Likewise, stringent rules and discipline should be applied when necessary.
5. The value of initial training and retraining opportunities is reinstated and recommended to be provided to all categories of employees whether managerial, technical staff, operators or truck drivers.
6. The study also suggests taking effective corrective actions, maintaining discipline by enforcing HSE procedures and a comprehensive knowledge of the ability of all the staff working under him including drawing up maintenance schedule for the plant, equipment, different instruments, trucks etc.
7. The place of community participation is seen a means to solving the problem of insecurity crisis with respect of using LPG as explosive.
8. Public awareness of the advantages (affordability) of LPG for domestic utilization to would-be users with the safety regulations in the homes should be increased by agencies of government and the marketers in the distribution of LPG

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