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An Investigation and Analysis of Accidents Involving Contract Workers in Europe's Oil and Gas Industry (2000 – 2014)

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ABSTRACT

This investigation aims to analyse accidents involving at least one fatality of contract workers in European countries within the oil and gas industry, and to identify and relate the possible causes of the accidents. A total of 79 significant accidents (2000-2014) were analysed within 10 European countries: Austria, Belgium, Denmark, Germany, Ireland, Italy, Netherlands, Norway, Romania and the United Kingdom. More than 90% of the contractor workers that diedduring work activities are from the upstream and midstream of the oil and gas industry in the analysedcases.

For the credibility of the analyses of the causes that lead to the accidents, a very well recognised method was used:Human Factors Analysis and Classification System (HFACS).

At least 70 out of the 123 total fatalities had inadequate supervision as one of the causes of fatality. In addition to having a significant number of fatalities associated to theinadequate supervision also had the highest frequency amongst the other subcategories is (helicopter accidents), which accountedfor a large proportion of the total accidents, while inappropriate working gear also is one vital cause of accident.

I. INTRODUCTION

Accidents involving contract workers in the oil and gas industry is a major concern globally, ever since the piper Alpha accidents which resulted in the death of 167 workers and resulted in large scale social and economic impact,continuous efforts are being made to minimize the magnitude of such future occurrence. According to the United Kingdom Government (2015), a contract worker is an individual that has a contract or other type of arrangement to do work or services personally for a reward: money or a benefit of any kind.

The study of accident causations can prevent similar events to that of 6th July (Macalister, 2013). The lessons learned from this accident revolutionized the offshore safety management and legislation in the North Sea (Offshore Technology, 2015).

The remoteness of the oil and gas facilities where the accident occur can significantly contribute to the degree of damage while investigation is measured in several ways to avert future occurrences.

The level of destruction and financial losses caused by the accident such as onshore/offshore platform fire, blowout during drilling operation, helicopter crash during transportation from flow stations are remediated. Depending on the affected companies, the rate of the physical damage and the legal regulatory requirements of the country where the accident takes placecan play a significant role to the outcome of investigation (Lordan et al, 2015).

Most European countries impose tougher regulatory sanctions on operating companies in the oil and gas industry to ensure greater Health, Safety and Environmental (HSE) standards in the oil and gas industry, and internalisation of accident preventative mechanism which has reduced accident fatality rate in those countries as reported in the International Association of Oil and Gas producersRisk Assessment Data Directory (OGP March, 2010). Intended forillustration, the accident fatality rate in the United Kingdom has reduced from 0.63 in 2000/2001 per 100,000 works to 0.46 deaths per 100,000 workers in 2014/2015 (Great Britain: Health and Safety Executive march, 2015).

However, this rate is still considered very high for a developed country as the United Kingdom, and it only shows reported cases in the industry compared to unreported cases which could even be higher than the reported cases.

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Accident contingency plans have been mapped out by regulatory organisation/authorities based on the risk assessment done to identify various hazards involved in the oil and gas industry. But the application of such plans is mostly depended on operating companies who most of the time, tend to cut corners in their implementations.

Major oil companies sometimes conduct two to three days' health and safety induction training for their contract workers before mobilization. However, most of them are usually substandard when compared to the high risk of accident involved in the operations of the oil and gas industry. When comparing the accident ratio involving contract workers to their counterpart permanent workers working in the same project, the rate of accident is very high. This is due to key indicators such as their inability to identify hazard, lack of quality training, understanding the level of risk involved in the operation, non-compliance with the permit to work system, and failure to abide with the laydown procedures among others, in carrying out task.

It is glaring that in all three key factors that contribute to fatal accident involving contract works in the oil and gas industry, the human error factor is regarded as the major element in the chain of event that usually precedes an accident (Rebeccaet al, 2015). For that reason, this article will focus on the Human Factors Analysis and Classification System (HFACS) model, that consists of a general human error framework.

As stated by (Heinrich, 1931), cited in OHS body of knowledge: models of causative safety (April, 2012), an accident investigation should be done to create active safety interest and fact finding, which should lead to corrective, and proactive action centred on the facts and not to create a blame culture in an organization or work place. As also observed by (Hallnagel, 2010), accidents should be envisioned as a resultant effect from a collaboration of mutually relating variables that happen in workplace. Having clear knowledge of these collaborating and interacting sequence of events that the main causes of accident can be understood and their occurrence anticipated.

Therefore, this research investigates and analyses accident involving contract workers in the European oil and gas industry between 2000 and 2014 that resultedin at least, one fatality. The causative factors of these accidents where statistically analysed to identify the main causes of these accidents. Results of this investigation are related with the relevant HSE standards in the oil and gas industry.

Based on the findings, various recommendations that monitor standards and minimise future reoccurrence were made, and suitable health and safety education and training program for contract works in the oil and gas industry are suggested to management and operators of the oil and gas industry.

II. MATERIALS AND METHODOLOGY

For the analysis of the major accidents involving contract workers with at least one fatality in the oil and gas industry within European countries, between 2000 and 2014, the collection of data was made using two main resources: the International Association of Oil and Gas Producers (IOGP) (Safetyzone.iogp.org, 2015) and the Health and Safety Executive (HSE) (Hse.gov.uk, 2015) from the United Kingdom. All of the accident data was collected online, resulting in a selection for a total of seventy-nine (79) accidents according to the type of information provided (for example, accidents which causes could not be brainstormed because of lack of information on the incident were discarded).

Within the European region, ten (10)countries were part ofthe selection and had its accidents analysed. The countries are: Austria, Belgium, Denmark, Germany, Ireland, Italy, Netherlands, Norway, Romania, and the United Kingdom. The earliest years' of(2000 – 2004), did not have enough information on its accident causes. To reverse this inconvenience,brainstorming techniques were used to come up with suitable causes for each accident.

Brainstorming is a technique used by research authors to attempt to come up with solutions to solve a specific scientific problem by collecting spontaneous ideas from renowned industry players active in the petroleum industry (Brainstorming.co.uk 2015, Mindtools.com 2015). The research gathered a total of (79) accidents involving at least one contractor worker fatality between 2000 and 2014, with an average of approximately 10 fatalities per year.

2.1 Methodological Consideration

The main consideration in the selection of the accidents was if the accident involved at least one fatal injury of contractor workers. According to Eurostat (2015) and Brenner (2006), a fatal accident is "an accident which leads to the death of a victim within one year of the accident".Some of the cases studied in this research showed immediate death, death on the way to the Hospital, and at the Hospital.

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The accidents collected where then collated into a data base that separated them according to the year of the occurrence, how many fatal injuries where involved, the description of the accident, the type of accident and the level of failure under each one of them fell (See Table 2) below. To decide whichlevel of failureto use, the researcher referenced the Human Factors Analysis and Classification System (HFACS) method, which is a tool that provides assistance in investigation process, target training and prevention efforts (Skybrary.aero, 2015).

A scale from (0 – 2) was used to show the type of influence of the level of failure in the cause of the accident; where: 0 represents no influence from that level, 1 represents partial influence, and 2 full influences on the accident. For instance, if the accident was caused mainly because of an inadequate supervision, it will be categorised as "2" under "inadequate supervision".

2.2 Analysis Technique

To analyse the gathered data, statistical methods were used. This includes, the bivariate correlation analysis and Chi-square analysis. The first one consists of testing if the relationship between two variables is linear; as one increases or decreases, the other has the same comportment (Sphweb.bumc.bu.edu, 2015).

Also, Correlation analysiswere used to quantify the association between an independent and a dependent variable or between two independent variables (Sphweb.bumc.bu.edu, 2015). These correlations can be strong/weak and positive/negative. If the value of Pearson's (r) is close to 1, it means that there is a strong relationship between the two variables; and if it is positive, it shows that one variable increases/decreases with the other linearly. The Sig (2-tailed) tells if the correlation between the variables is statistically significant or not; if it is equal or lower than 0.005, it means that the correlation is statistically significant; and the lower this value is, the stronger is the relationship between the variables.

The second intended to test the probability of an observed distribution being due to chance. It measures how well the observed distribution of data fits with the distribution that is expected if the variables are independent(Ling, 2008). The program used to realise this analysis was IMB's SPSS Statistics Data Editor 22, provided by Coventry University, UK.

2.3 Human Factors Analysisand Classification System (HFACS)

The HFACS is a model developed out ofan organizationally based model of human error, also called the "Swiss cheese" model, created by James Reason in (1990), to approach the origin of human error to support aviation accidents' investigations. The Swiss cheese model had a particular problem – it did not specify what the "holes in the cheese" were, because it was a simple theory with few details on how to apply it in real life situations (Shappell and Wiegmann, 2000), and (Li et al, 2008). Thus, the HFACS presents human errors and the factors that underpin them in four distinct levels as can be seen in (Figure 1) below:

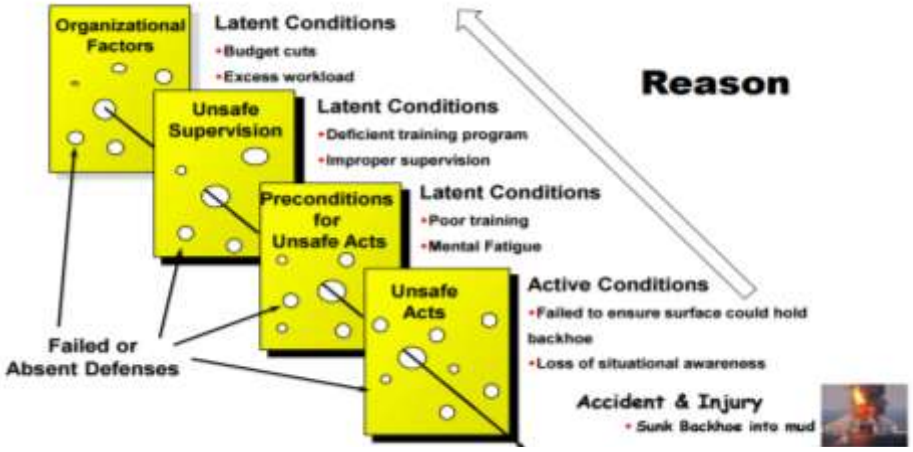

Figure 1:The various Levels of the HFACS Model (Theophilus, 2015)

The above method consists of four levels of human failure and their own subcategories. Level 1, known as unsafe acts is the first step when analysing cases. It is subdivided into two subcategories: errors and violations. Errors group situations where decisions errors, skill-based errors and perceptual errors are involved; while routine and exceptional are grouped under violations

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(Shappell and Wiegmann, 2000), and (Daramola, 2014).

The next level is the Level 2: preconditions to unsafe acts. It is impossible to focus on the error that is being done/unsafe act being undertaken without getting a perception of what caused it. It is sub-divided into environmental factors, conditions of operators, and personnel factors (Hfacs.com, 2015).

Level 3; known as unsafe supervision, shows the possibility of supervisors failing to comply with the regulations stated by the company at their level of responsibility. Its subcategories are: inadequate supervision, planned inappropriate operations, failed to correct problem and supervisory violations.

The highest level of them all is the level 4; the organisational influences. The management failure to implement the supervisory practices, and the conditions and actions of front-line operators (Daramola, 2014).

III. RESULTS AND DISCUSSION

Out of the seventy-Nine(79) accidents,there is a sum of 123 fatal injuries. The contract workers' fatalities were categorized into type of accidents. The type of accident categorization was based on IOGP's incident/event categories (see Appendix 1 below for definition ofeach category). The types of accidents with the most fatalities were:Others (n=54), Explosion (n=12), and struck by (n=18). The category of accidents with less fatalities were; Caught by and caught in with less than 1% for both. The type of accident "Other" represents all of the accidents that cannot be positioned under the other categories defined by the IOGP.Examples of this are helicopter and vehicle accidents, as shown in (Figure 2) below.

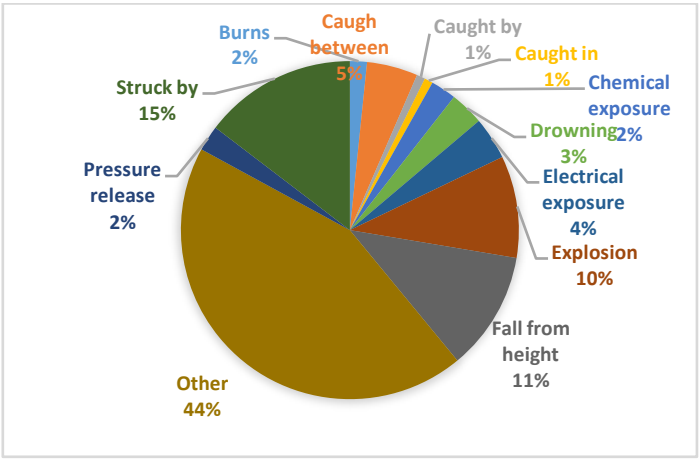

Figure 2: Percentages representation of all types of accidents under investigation

The distribution of accidents involving fatalities from 2000 to 2014 according to the country of origin is shown in (Figure3) below. The United Kingdom (UK) represents the country with the highest number of fatalities in this research. According to the Health and Safety Executive (HSE, 2015), in the period between 2000 and 2012, UK had lower rates of accidents with fatalities at work (general industries), than the rest of the European Union, which means that UK has a significant part of its fatalities at work in the oil and gas industry within the period under investigation.

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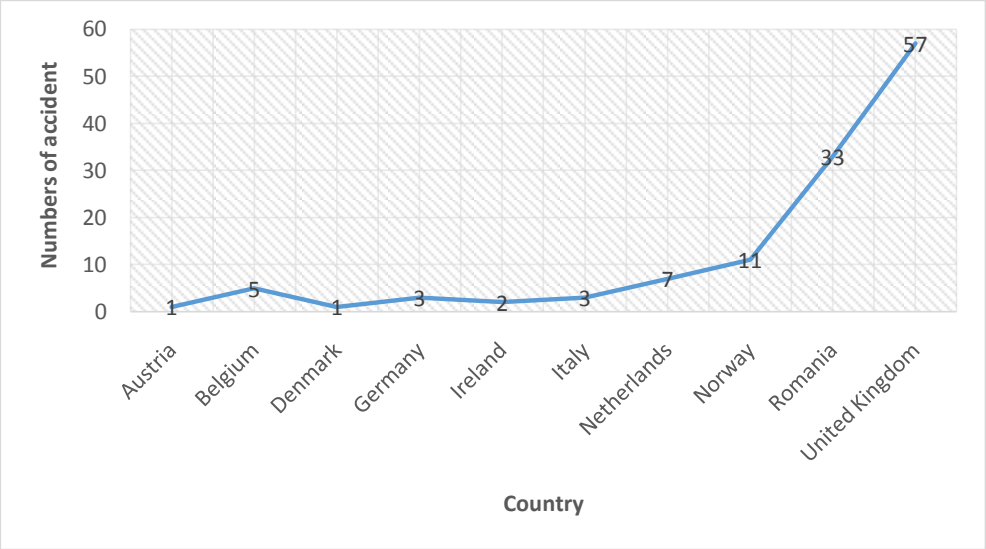

Figure 3: Number of fatalities according to country of origin (2000 – 2014)

The upstreamoil and gas industries is characterized as the search, recovery and production of crude oil and natural gas, usually referred to as the exploration and production sector. The midstream is mainly the sector that has the gathering system (oil and gas storage) and transportation, and sometimes is considered to have elements both from the up and downstream sectors. Downstream consists of the refining and distribution of the oil/natural gas, and the products derived from it (Psgdover.com, 2015).

From the worldperspective of accidents, 54.4% of the total accident occurs at the upstream sector, 39,4% occurs at the midstream, and 6.3% downstream. This means that, the corrective actions need to focus on reducing accident rate at the upstream and midstream sectors in the oil and gas industry.

1.1. HFACS Analysis

The distribution of the HFACS levels and subcategories used in this research can be seen in (Table 1) below. Level 1 (Unsafe acts), had decision errors as its most frequent subcategory representing (37.4% of all accidents). This is followed by skill-based errors, representing (20.3% of all accidents).

Decision errors can involve situations such as: improper procedure, misdiagnosed emergency, wrong response to emergency, exceeded ability, inappropriate manoeuvre, poor decisions, and others, according to (Shappell and Wiegmann 2000) and(Li et al, 2008). Take for instance, a contract worker decided on his own to enter a high voltage cell and tried to handle some contacts, without follow the company's procedures thereby, making a decision error. Skill-based errors can involve breakdown in visual scan, fail to prioritise attention, inadvertent use of flight controls, omit steps in procedures, among others. An example, of this situation isaccident concerninga welder who failed to recognise (distraction) that the inner part of a mast he was disassembling could strike him, and his death was as a result of this minor error.

Table 1: Frequency and percentage of HFACS levels and subcategories for all accidents.

Level	Subcategory	Frequency	Percentage of all accidents
Unsafe acts	Skill-based errors	25	20.3
	Decision errors	41	37.4
	Perceptual errors	4	10.6
	Routine violations	4	4.1
	Exceptional violations	9	7.3
Precondition to unsafe acts	Physical environment	9	13.0
	Technological environment	2	2.4

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	Adverse physiological	4	5.7
	Physical/mental limitations	15	21.1
	Crew resource management	19	18.7
	Personal readiness	5	6.5
Unsafe supervision	Inadequate supervision	58	56.9
	Planned inappropriate operations	37	31.7
Organisational influences	Resource management	39	54.5
	Organisational process	37	32.5

In Level 2 which is (Precondition to unsafe acts), the two most frequent subcategories are: crew resource management and physical/mental limitations. Crew resource management can involve failure to conduct adequate brief, lack of teamwork and poor communication/coordination, failure of leadership, etc. Example of this type of accident, is a situation where the communication procedures were improper during a drilling operation. One of the crew members tried to jump inside a bulldozer while another member drove it, ending up caught between the tracker and the cradle. The victim died 13 days after the accident. Another accident example, is a reflection on a typical physical/mental limitation case, as the contractor driver was involved in an accident because he failed to take any significant action to avoid colliding with a 5-tonne truck traveling in the opposite direction.

Level 3 (Unsafe supervision), had high frequencies both for inadequate supervision and for planned inappropriate operations. Inadequate supervision involves errors such as failure to provide proper training, guidance, adequate technical data and/or procedures and adequate rest period before carrying out the job. A clear example for such accident is of the human error category, and it happened to a crew member that died by been stricken by an anchor chain.He did not have the adequate training for the job he was doing as later investigation revealed.

Level 4 (Organisational influences) had resource management as the most frequent subcategory. This subcategory is influenced by errors such as purchase of unsuitable equipment, poor maintenance in equipment, amongst others. A case of note is an accident that occurred in one of the countries (name withheld) under investigation.The deceased fell from height whilst replacing stairs treads that were missing in the platform. The management responsibility is to ensure that all resources are provided. However, in this case, for an unknown reason, the stairs tread was removed (change in permitted work method) which was not properly communicated to the staff involved.

Although, this analysis was able to find the causal factors for each accident individually, it was insufficient to inform if the errors detected are, in any way, related. For this to be possible to analyse, two statistical methods were adopted; which is correlation, and chi-square analysis methods, as their results are analysed below.

1.2. Correlation

In this research, the correlation was done between the HFACS levels (starting from the lowest to the highest). There were significant correlations between the levels. As shown in (Table 2) below; the total number of correlations on each level is clearly indicated. Between level 1and 2 has six (6) correlations; between levels 2 and 3 has four (4) correlations; and between level 3 and 4 there are two (2)correlations. The correlations highlighted in the (Table 2), represent the strongest relationships (Pearson's r closer to 1 and Sig.2 (tailed) closer to 0), and therefore they are the focus in this section of the article.

Table 2:Significant Correlation between levels of accident under investigation

Level 1: unsafe acts	Level 2: precondition to unsafe acts	Pearson correlation	Sig.(2-tailed)
Physical/mental limitations	Skill based errors	0.534	0.040
	Decision errors	0.667	0.007
	Perceptual errors	0.729	0.002
	Routine errors	0.518	0.048
	Exceptional violations	0.575	0.025

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Physical environment	Perceptual errors	0.845	0.000

Level 2: preconditions to unsafe acts	**Level 3: unsafe supervision**	**Pearson correlation**	**Sig.(2-tailed)**
Physical environment	Inadequate supervision	0.545	0.036
	Planned inappropriate operations	0.757	0.001
Physical/mental limitations	Inadequate supervision	0.756	0.001
	Planned inappropriate operations	0.579	0.024

Level 3: Unsafe supervision	**Level 4: Organisational influences**	**Pearson correlation**	**Sig.(2-tailed)**
Inadequate supervision	Organisational process	0.672	0.006
Planned inappropriate operations	Organisational process	0.855	0.000

The strong correlations are represented in a flowchart to analyse the path of the significant causal factors of the accidents under investigation.

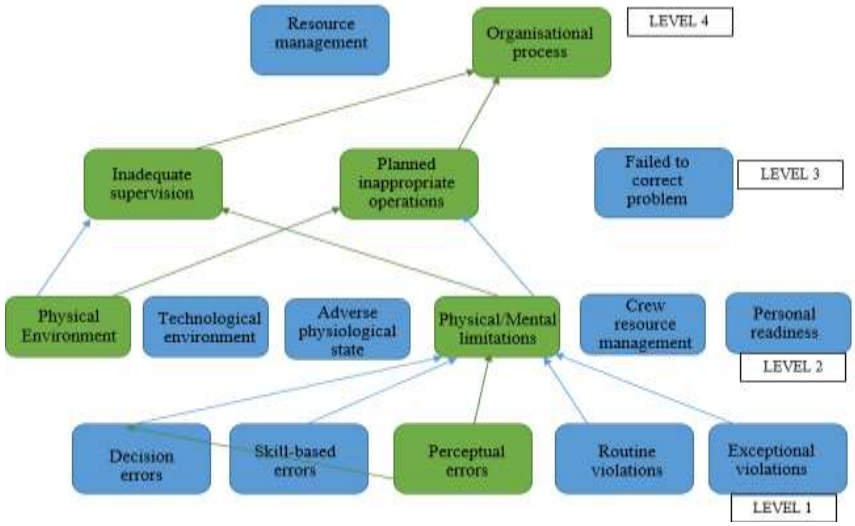

Figure 4: Flowchart of significant causal path for the level correlation

Although, all of the subcategories of level 1 have a significant correlation with the level 2, perceptual errors are going to be the base of the discussion because it leads us to two very strongly related path up to level 4, which means it is linked with the highest level of the HFACS framework.

Organisational process is a very high-level matter, as it is at level 4, which means it is of a great importance and its decisions influences the levels below. According to OHSAS 18001 (2007), the top management has the responsibility of providing a policy that offers an appropriate management system to the nature and scale of the organization's occupational health and safety (OH&S) risks, and includes commitment to prevention of injury and ill health. The organisation process can cause inadequate supervision if the OH&S risk management is not taken into consideration. Organisation process failure was found in 32.5% of the totalaccidents analysed.

As Lenné et al, (2012) implied, the efficiency of an organisation's supervisory arrangements is a key factor in system safety and performance, linking it with the responsibility of guaranteeing an adequate supervision to the company.

The inadequate supervision and the physical/mental limitation have a positive and

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strong correlation (significant=0.756), which means that as one variable increases, the other increases with it. This is because the supervisor is responsible to identify the worker's capabilities for the tasks he is assigned. If the supervisor fails to detect the worker's limitation, it implies the worker is subject to commit perceptual errors.

Perceptual errors occur often.It happens when the worker misjudges situations, trying to find answers to the gaps of his current situation. A worker that is driving/flying at night that has his vision limited is in a situation where he needs to take a decision about how to get to a safe destination without causing an accident. The perceptual error can happen if he relies in the wrong intuition.

Perceptual error is linked both to the physical/mental limitations, and to the physical environment. The first relation is very strong at (sig.=0.729) because the decision (on how to not cause an accident, in this case) is also based on the knowledge or physical capability (e.g., inability to see well from afar), the worker has on the task he/she is performing. The physic environment relates to the perceptual errors because it provides the scenario in which the situations are happening (for instance, if there is sufficient light or not).

A very strong lesson learned (amongst many) in the Piper Alpha disaster was that, training, monitoring, and auditing had been poor and the lessons from a previous relevant accident had not been followed through. Evacuation procedures had not been practised adequately (Findingpetroleum.com,2015), amongst other factors that fall under the organisation process.

1.3. Chi-squareAnalyses

The chi-square test, was used to identify the relationship between the HFACS subcategories. With the Chi-square analysis, there were only three significant associations between adjacent categories of level 1 and level 2, as it can be seen in (Table 3) below. It is clear that all of the relationships found are very strong (sig.close to zero). The first two of the relationships found are a repetition of the results obtained with the correlation analysis: physical/mental limitation with both perceptual errors and routine violations. The third relationship, perceptual errors and adverse physiology state appears for the first time, but is equally strong.

Table 3. Chi-square Analysis between HFACS levelsand categories

Categories	Chi-square	Fisher's exact test
	Sig. (2-tailed)	
Routine violation* Physical/mental limitations	0.003	0.020
Perceptual errors* Physical/mental limitations	0.000	0.010
Perceptual errors* Adverse physiological state	0.000	0.011

The first one can be justified by the fact that the physical or mental limitations of the contract worker can make him/her fail to comply with the procedures without noticing, constantly making the same mistake. The justification to perceptual errors could be that there is information overload to the contract worker, causing visual illusion or spatial disorientation (perceptual errors). Situations such as mental fatigue, stress or loss of situations awareness are significantly related to commitment of perceptual errors, as shown in (Figure 5) below.

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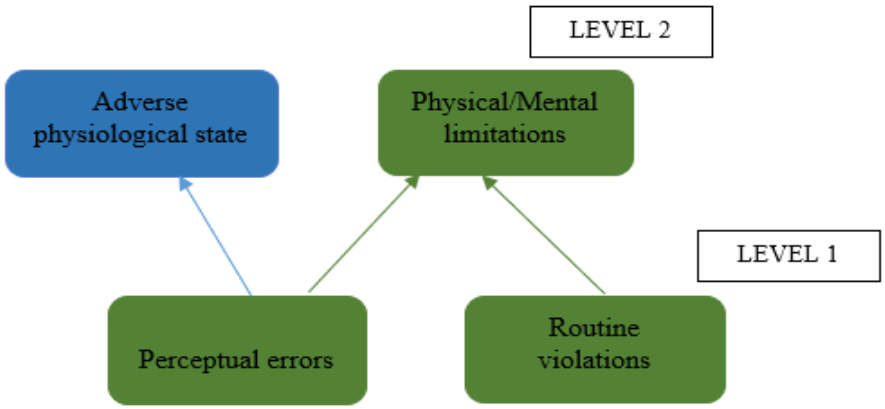

Figure 5: Flowchart of significant causal path for chi-square Analysis

IV. CONCLUSION

This research article shows the report of accident fatalities in the European oil and gas industry between (2000 – 2014), with a large proportion of occurrence in the upstream sector (54.4%), against (39.4%) for the midstream sector, and (6.33%) for downstream sector of the oil and gas industry due to various safety challengesin the sector.

The three subcategories of the HFACS levels with the highest percentages of occurrence of fatalities were: Inadequate supervision (56.9%), resource management (54.5%) and decision errors (36.6%). The reflection of these high repetitions can be seen in cases where: contractors do not follow the company's procedures; or wherelack of maintenance in some of the equipment leads to fatalities because of its failure.

The two statistical methods used to analyse the accident data were the bivariate correlation and the chi-square test. The first one defined the correlation between the levels 1 and 2, 2 and 3,and 3 and 4. Its results showed that there were two strong relationship paths that linked the four levels, where the first path indicates: organisational, process-planned, inappropriate operations-physicalenvironment-perception errors; meaning that there is a strong influence of the high level 4's decisions in the errors being committed by the contract workers.

The second path demonstrates: organisational, process-inadequate supervision, physical/mental limitation-perception errors. This empathises that, the operational process influences the low level 1 errors in various ways, meaning the recommendations should focus on changing the management's culture in the oil and gas industry.

The chi-square test has only three significant relationships, and its result showed similarity with the correlation results, having the same physical/mental limitations related to perceptual errors and a new relation between perceptual errors and adverse physiological state.The conclusion in this is that, the physical/mental limitations also have a strong influence in the accidents within contract workers, hence, precautionary measures need to be taken has part of the recommendation below.

V. RECOMMENDATIONS

Looking at (Figure 2) above, the highest type of accidentwas Others (such as helicopter and vehicle accidents). Helicopter crashes contributed to a large majority of fatality numbers in a single accident, and for that reason, it is recommendedthat tighter regulations and inspection, improvements in the maintenance of the helicopters, and continuous training of contract workers is necessary to avert future occurrence.

Basic Offshore Safety Induction and Emergency Training (BOSIET) is a recognised program of the (Blackpool and The Fylde College, 2015),for training workers that are new in the oil and gas industry. The researcher therefore, recommend that this training is done with determined frequency to invigorate the workers. BOSIET covers safety induction, Helicopter Underwater Escape Training (HUET), sea survival, firefighting and self-rescue.

Organisational processes are the factor that takes most responsibility for the accidents as supported by Bell and Healey (2006), and since they are controlled by the management team, it is recommended that, the trainings regarding HSE are not limited to the contract workers (our initial target of analysis). It is also, recommended that, not only the contractor workers, but the supervisors as well as the management body take the National Examination Board in Safety and Health (NEBOSH), as it covers the basics of safety process, responsibility of health and safety, environmental risk assessment, common risks and controls in the

process safety industry, hazards and controls associated with work equipment, amongst others(Nebosh.org.uk, 2015).

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Appendices

Appendix 1. IOGP's incident/event categories

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4.10 Incident/event categories

The following list should be used for Reports 1A, 2 and 3:

- *Assault or Violent Act*
- *Caught In, Under or Between* includes injuries where the injured person(s) is crushed or similarly injured in non-impact cases e.g. between machinery moving parts or other objects, caught between rolling tubulars, crushed between a ship and a dock, or similar incidents.
- *Confined Space*
- *Cut, Puncture, Scrape*
- *Explosions or Burns* are injuries caused by the effects of fire and explosion such as burns, toxic gases, asphyxiation. 'Explosion' means a rapid combustion, not an overpressure. For example, a person hit by flying debris from a vessel explosion is classed in the category 'struck by'.
- *Exposure Electrical* includes incidents other than fatalities that involve electrical shock or electrical burns etc.
- *Exposure: Noise, Chemical, Biological, Vibration*
- *Falls from height* are injuries caused by incidents where a person falls off, over or onto something.
- *Overexertion/Strain*
- *Pressure release*
- *Slips and Trips (at the same height)*
- *Struck By* describes incidents where injury results from being impacted by moving equipment and machinery, or by flying or falling objects. Water related, drowning Incidents where water played a significant role.
- *Water related, drowning*
- *Other* is the category to specify where the injury cannot be logically classed under other headings. Includes air transport incidents.