International Journal of Safety and Security Engineering
Vol. 14, No. 3, June, 2024, pp. 893-905
Journal homepage: http://iieta.org/journals/ijsse

Analysis of Accidents in the Oil and Gas Industry in Kuwait

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https://doi.org/10.18280/ijsse.140321

Received: 22 January 2024
Revised: 27 April 2024
Accepted: 7 May 2024
Available online: 24 June 2024

Keywords:
HFACS, human error, oil and gas, accident analysis, Kuwait

ABSTRACT

Oil and Gas Industry is highly hazardous and prone to accidents due to various errors and human factors is one of the major reasons. The paper explores accidents at oil and gas exploration sites in Kuwait due to human factors. HFACS-OGI framework is deployed for the study to understand various Human factors causing the accidents. Twenty accident reports are taken up for study from the year 2012 till 2020. From the analysis, the organizational process, inadequate supervision, Industry standards, and routine violations emerge as major causes based on frequency tables. The research suggests precautions and safety steps that need to be taken to prevent future accidents in Kuwait.

1. INTRODUCTION

Accident analysis plays a vital role in the oil and gas industry, as it helps identify the underlying causes of incidents and provides valuable insights for improving safety and preventing future accidents. One effective method of accident analysis in the oil and gas industry is the use of the Human Factors Analysis and Classification System - Oil and Gas Industry. The Human Factors Analysis and Classification System for the oil and gas industry is a widely used analytical framework that allows for a comprehensive examination and classification of causal factors contributing to accidents and incidents in the oil and gas industry [1]. This tool considers various factors such as safety culture, management commitment, safety leadership, technical failure of ageing equipment, operator competency, regulatory standards, and emerging violation issues. Accident analysis using HFACS-OGI enables a deep understanding of the complex interactions between human error and organizational factors contributing to oil and gas incidents. Analyzing accidents in the oil and gas industry using a systematic and comprehensive approach like HFACS-OGI is essential. By utilizing HFACS-OGI, organizations can identify the immediate causes of accidents and the underlying systemic issues that may have contributed to them. This allows for targeted improvements in safety practices, employee training, equipment maintenance, and overall organizational processes. Accident analysis in the oil and gas industry using HFACS-OGI provides a structured and reliable approach to uncovering the root causes of incidents.

Moreover, the research conducted by Theophilus et al. [1] on HFACS-OGI demonstrated its effectiveness in categorizing accidents and providing valuable insights into each analyzed incident. The implementation of HFACS-OGI in accident analysis within the oil and gas industry provides a comprehensive framework for examining and classifying causal factors that contribute to accidents and incidents. This framework considers various factors such as safety culture, management commitment, safety leadership, technical failure of ageing equipment, operator competency, regulatory standards, and emerging violation issues like sabotage. Applying HFACS-OGI in accident analysis not only helps identify the immediate causes of accidents but also sheds light on the larger systemic issues that may have contributed to them, such as organizational erosive drift or failures in regulatory standards. Additionally, the research confirms that failures in industry regulatory standards can create the precondition for oil and gas accidents. By utilizing HFACS-OGI, organizations in the oil and gas industry can enhance their safety culture by addressing underlying organizational factors that may have contributed to these incidents [2]. HFACS -OGI framework applicable in the upstream oil and gas industry in Kuwait. The findings for the causes of the accidents in upstream oil and gas industry were human factors after study of scientific accident investigation theories applicable on accidents. Human involvement in all operational activities like routine and non routine activities observed in this industry. HFACS framework was developed based on human factors (level-1 to level 5) and interviews focus group to prevent accidents. Accidents 20 number were taken from IOCC Oil and gas upstream industry in Kuwait for study of human factors causing accidents and develop framework for prevention of accidents. All employees including contractors, third party service employees and specialists in the industry considered for developing frame work. The majority of accidents resulted in employee personnel injury due the human factors causing accidents.

There is a need to study oil and gas accidents at Kuwait. To address the need to study oil and gas accidents in Kuwait, conducting a thorough analysis using the HFACS-OGI framework would be beneficial. This would enable a deeper understanding of the root causes and contributing factors to these accidents and allow for targeted improvements in safety

practices and regulatory standards.

2. LITERATURE REVIEW

The section briefly discusses human factors, accidents, HFACS and other related accidents to oil and Gas Industry over the last five years. One of the early studies in oil and gas industry, the research of Sun et al. [3] was about analyzing the role of human factors in the safety of oil drilling work systems and providing recommendations for improving safety. In terms of methodology, a hybrid method of Analytic Network Process (ANP) and Structural Equation Modeling (SEM) was used. The authors utilized questionnaires to gather empirical data, which was inputted into the SEM method. SEM was applied to construct the ANP model, reducing biases in expert opinions during ANP evaluation. The structure of SEM and ANP was centred on the Human Factors Analysis and Classification System (HFACS) framework, while the weight of each human factor was extracted from the ANP results. The outcomes were then compared to frequency-based methodologies to affirm the validity of the SEM-ANP method. The role of emotional intelligence was explored by Ifelebuegu et al. [4] for petroleum Industry worker's occupational safety performance and health. The results suggest that some emotional intelligence success factors were crucial for enhancing workers' health and safety performance. The professional development of said workers could be improved by developing these competencies. The aim of the study [5] was to propose an expanded version of the Human Factors Analysis and Classification System (HFACS) to cover confined space accidents in oil and gas industry. The research sought to understand the causal factors of such accidents, emphasizing the importance of organizational- and supervisory-level interventions to prevent further incidents. The study also proposed modification to the HFACS framework to incorporate 'External Influences' as a fifth level and additional categories within 'Organizational Influences'. The revised framework is intended to provide a basis for confined space accident analysis and risk management. The paper of Selvik and Bellamy [6] uses the term 'human error' in the ISO 14224 standard. It studied the discrepancies and the under-specification of various error types, mainly focusing on human errors. Comparisons were made between the 2006 and 2016 editions, noting that the term 'human error' was used more frequently in the 2016 version. A noteworthy point was the use of 'mistake' to elaborate on 'operating error' and 'maintenance error', although the term was not defined explicitly. The definition of 'human error' in ISO 14224 left several ambiguities. The lack of specified subcategories for 'human error' or 'unsafe acts' like 'lapses', 'slips', and 'violations' raised questions about the accuracy and comprehensiveness of the classification. It also sparked curiosity about why the use of 'human error' surged in the 2016 edition compared to 2006, and whether other potential subcategories or error types were overlooked or undervalued due to the overemphasis on 'human error'. The ambiguity of the term 'mistake' further complicated these questions. The research of Ye et al. [7] focuses on applying the Human Factors Analysis and Classification System (HFACS) in various domains such as aviation, mining, shipping, railway, oil and gas industry, construction, and healthcare. The HFACS was used as a tool to analyze and prevent potential accidents. In the paper, researchers confirmed human errors in shipping accidents using the HFACS and a fuzzy analytical hierarchy process. They also developed an HFACS-based data mining model to understand the emergence of human factors in marine accidents. Additionally, researchers adapted the traditional HFACS for the oil and gas industry considering regulatory shortcomings and emerging violation issues. The outcome classifications from HFACS were bolstered by multi-criteria decision-making (MCDM) to prioritize error factors. However, the study observed a lack of research using HFACS for prevention, control, response, or analysis specifically related to oil spills. The main focus of the study of Wang et al. [8] is to improve the accident prevention of SMEs (Small and Medium Enterprises) in the chemical industry. This was accomplished by revising the HFACS (Human Factors Analysis and Classification System) model, which has been ineffectively used for analyzing chemical accidents. The researchers developed a new model called HFACS-CSMEs, which includes 15 cause factors and 56 manifestations to better reflect the characteristics of chemical accidents specific to SMEs. The paper also highlights the need to customize these models for different industries due to the unique characteristics of each. A hybrid technique using HFACS, fuzzy sets theory, and Bayesian network was deployed to analyze toxic gas leakage accident [9]. The results showed that using substandard equipment, poor safety culture, and inadequate inspection of newly purchased equipment were some of the essential elements causing the accident. A new integrated HFACS framework is proposed for oil, Gas, and chemical plants [10]. The developed framework was expected through routine examination, be able to efficiently pinpoint and address the sources of human error.

The organizational factors and influences were found to be crucial for various accidents. For maritime accidents investigations, human and organization factors framework was cultivated by Chen et al. [11]. The framework Human factors analysis and classification systems for maritime accidents HFACS-MA was developed based on Hawkin's SHEL model and Reason's Swiss cheese model. The proposed framework was found to be advantages for analyzing causality among the factors in maritime accidents. Due to the defects at higher levels, the susceptible lower levels are well identified through this framework. The proposed method addresses the issue of lacking causality details among the human organizational factors. A simple HFACS model was also used in shipping industry to improve safety level by improving safety measures [12]. Decision errors were found to be major reason behind most collisions. Conditions of operators, environmental factors, and personnel factors were found to be significant in the study.

For marine accidents, apart from HFACS-MA, HFACS-Coll (for collisions) HFACS-PV (for passenger vessels) HFACS-SIBCI (for ship collisions between assisted and shipbreaking ships in ice covered water) was deployed by Kaptan et al. [13]. The differences from the methods used for analysis were the level of external factors due to differences in national and international rules causing accidents, which was also found for operational conditions. Similarly, for railway accidents, a hybrid and organizational analysis method for HFACS-railway accidents is proposed [14]. The existing safety flaws in accidents are identified from huge data collected in the study by railway managers, manufacturers, and safety experts from workshop. Analytical Network process was used to find the prime casual factors of accident and DEMATEL method was deployed to find the influential

relationships of human organizational factors after the demonstration of reliability. A systems-theoretical accident modelling and processes called STAMP-HFACS model, a hybrid human and organizational analysis methods proposed for railway accidents [15]. To execute control actions due to casual analysis of human errors, this method is proposed for Railways accidents. Notable accident causes of human factors were uncovered and essential countermeasures were suggested to prevent further accidents. Unsafe behavior and risk assessment was done for university laboratories using HFACS-UL using fuzzy Bayesian network approach in the study of Li et al. [16]. Based on analysis from chemical laboratories at universities, 86% was the probability of unacceptable unsafe behaviour. Therefore, cooperation and commitment from different agents like lab centre director and secondary faculty leadership was desired. From 24 risk factors derived, bad organizational climate towards unsafe behaviour with a 24.1% sensitivity value was found to be crucial.

The contractor environment was analyzed in a couple of studies as detailed. A hybrid Bayesian network HFACS model was developed to predict safety performance at construction projects [17]. The framework brings forth 18 factors and systematically identifies the risk factors most sensitive in nature for the construction industry. Internal organization factors mainly due to contractors were identified in the study. Collapse of risk management systems, bad occupational safety training and absence of reporting unsafe conditions mainly due to contractors was found by study of Zarei et al. [18]. The research used a hybrid model combined with HFACS, fuzzy set theory and Bayesian network to investigate independence between the failures.

Errors in the medical profession were identified using the Software, Hardware, Environment and Liveware- SHEL model in the study of Molloy and O'Boyle [19]. Human errors in medical health care, especially in emergency rooms and operation theatres, were identified using the method, thereby identifying the training needs for medical professionals to reduce errors. The HFACS model was also deployed for incidence prevention during public health response for Covid-19 pandemic as detailed in the study of Bickley and Torgler [20]. Through the approach, targeted and appropriate measures were established to reduce possible errors in the public health system.

In Chemical process industries, explosive chemicals and flammable substances make the industry highly unsafe and hazardous. To understand the human and organizational factors, a novel Bayesian network combined with fuzzy best worst method and HFACS is proposed by Rostamabadi et al. [21]. The results from the study were found to be highly reliable. The same model was deployed for the chemical process industry by the same authors [21]. The study helped in constructing efficacious intervention strategies to prevent future accidents. HFACS-CM – coal miners is proposed to investigate unsafe acts of miners [22]. Various types of factors affecting miners' unsafe acts were probed in the study. Based on results, external environment was found be to be major factor impacting the unsafe acts. Similarly, unsafe acts of air traffic controllers were also probed using grounded theory and HFACS analysis [23]. Organizational influences, environmental factors, unsafe supervision were found to be major factors behind violations and errors. Insufficient situational awareness, poor work order and wrong order found to be common unsafe acts. The combined HFACS and SEM models were used to study how unsafe behaviours are affected by safety culture at nuclear power plants in China [24]. Inadequate supervision, organizational processes, skill-based errors, and physical environment were found to be most influential factors on latent variables.

Research gap: To better understand human factors for theil and gas industry, HFACS-OGI framework has been proposed in the study of Theophilus et al. [1]. Using the same framework, analysis of human factors for all accidents worldwide was attempted in the study of Nwankwo et al. [2]. Similarly, Safety assessment for oil drilling work system was analyzed empirically using Analytic Network process by Sun et al. [3]. However, there is a need to analyze in depth is regard to human factors towards accidents in Kuwait as discussed earlier in the introduction section.

3. RESEARCH METHODOLOGY

3.1 Data and framework

The HFACS framework uses the process of coding the incident and accident reports that have been collected from the study online [25]. The coding process and the framework used to understand and analyze these reports. The framework and the method of applying the codes to the reports and their terminology have been explained in detail in the following sections.

The framework selected is from the study of Theophilus et al. [1] which has created a specific Human Factors and Classification System framework specifically for the oil and gas industry. The term used for this system is called the HFACS-OGI. The paper analyses 20 reports of accidents and incidents in Kuwait from 2012 to 2020 to understand the root causes of these incidents. This framework has been used to understand the complex interaction between the human and the oil and gas industry system as set up in Kuwait. Criteria selected accidents from IOGP (International Association of Oil and Gas Producers) upstream Oil and Gas Industries -Kuwait and human injuries related accidents such as fatality and high potential Near Miss Incidents in upstream oil and gas industrial related field (Drilling, production, exploration & construction). All related accidents caused loss of human life, loss of production, financial loss to the industry

3.2 HFACS OGI framework

The HFACS framework for the oil and gas industry has five levels in which accidents and incidents have been categorized. These levels are further divided into subcategories, which help in thoroughly understanding the root causes of the accidents or incidents that occur in the oil and gas industry. The levels and the subcategories are shown in Figure 1. Based on these levels and the subcategories, the reports of the incidents have been studied and analyzed to understand the root causes of the incidents that have occurred. This allows safer processes to occur in the oil and gas industry. The analysis of the reports understands the frequency of the subcategories or the levels at which the incidents and accidents that have been reported can be studied. It gives an understanding of the major causes of incidents in the oil and gas industry, and how it varies in the environment and external factors present in a country like Kuwait.

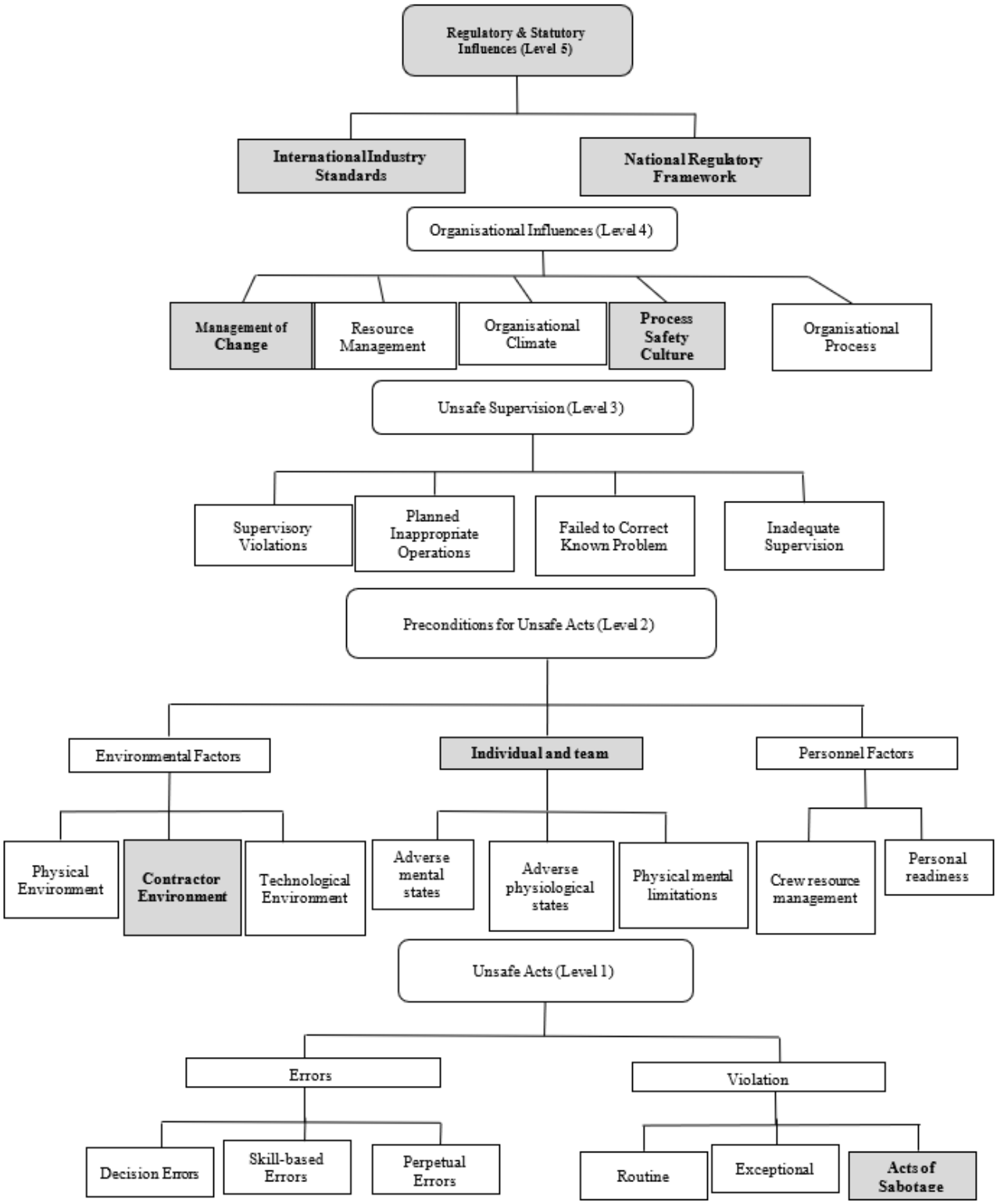

Figure 1. Flowchart of HFACS-OGI for oil and gas industry

3.3 Coding process

The coding process of the reports taken for the study and analysis has been based on the 26 categories that have been covered in the HFACS-OGI framework, as discussed before. This process helped identify the causal factors in each level and subcategory. This was done by measuring the frequencies of the codes used to assign the levels and subcategories, which helped find the root cause of incidents occurring in the oil and gas industry drilling tasks. To measure the presence of a category or subcategory, the categories were coded as 1 and for the absence of their cause, they were coded as 0. It may be seen that an incident and accident can have multiple causes present simultaneously. However, each of these categories has been coded distinctly. This has ensured the measurement of the presence of all the factors and, in turn, investigated the frequency of the categories to analyze the root causes of incidents and accidents. The correlation and interconnectedness between the levels and subcategories were measured using a chi-square test using the SPSS version 22 for Windows and Fisher's exact test to give statistical association between the higher and lower levels of categories present in

the analysis of the reports being studied. Further, the reports were analyzed using Spearman's correlation to measure the strength of the connections that were studied using the chi-square and Fisher's exact tests.

The reports found to not have any of the levels and subcategories present in the cause of the accidents or incidents being studied were removed. This was done to allow the paper to focus on the complex relationship between human factors and accidents/ incidents being studied in the oil and gas industry.

4. Analysis, Results and Discussion

Using the framework of HFACS-OGI the subcategory and level with high frequency of presence in the root cause of the accidents was found to be Level 4 which comprises of Organizational Influences. From the level 4, the subcategory that seemed to have shown a high level of presence was the organizational process, as seen from Table 1. Therefore, this shows that the processes that have been set in the oil industry seem to a lack being fixed or considering the accidents and incidents that could be conducive due to human factors.

Another subcategory which was found to have higher frequency after the organizational process was inadequate supervision from the level 3 of Unsafe supervision. This was followed by the subcategory of Industry standards from Level 5 of Regulatory and Statutory Influences. Based on the frequency distribution of the categories present in the cause of accidents and incidents, there is a strong relation between the accident/ incident and the standardizing processes of the oil and gas industry In Kuwait.

From the frequency distribution of the cause of accidents and incidents from Table 1, there is some strong interconnectedness between the levels and their immediate upper level, especially when studying from the perspective of the subcategory. As from the frequency the top four major causes were found to be:

1. Organizational process (Level 4)
2. Inadequate supervision (Level 3)
3. Industry Standards (Level 5)
4. Routine violations (Level 1)

This can be especially seen in the top three factors being responsible for the incidents that were studied. Thus, showing that there is a presence of certain amount of interconnectedness especially between the higher levels. Organizational Processes was the major contributor at the level -IV-Organizational Influences and inadequate supervision under unsafe supervision (Level-III) and routine violations under Level-I (unsafe acts) in HFACS. All these factors influenced each other, causing accidents. The aspects of the organization such as resource management, management of change, Process safety culture need improvements to prevent accidents. Resource management in financial, human and technical improvement required to prevent accidents. MOC (Management of change) requires improvement for development of MOC procedure and communication. The aspects of inadequate supervision need improvement for development of skill of supervisor through trainings to prevent accidents.

Table 1. List of subcategories that contribute to HFACS-OGI categories

HFACS-OGI	HFACS-OGI Subcategory	Frequency
Level 5 Regulatory & Statutory Influences	Industry standards	11
	National regulatory framework	0
Level 4 Organizational Influences	Process safety culture	8
	Organizational process	16
	Management of Change	2
	Resource management	1
Level 3 Unsafe Supervision	Inadequate supervision	15
Level 2 Preconditions for Unsafe Acts	Technological environment	1
	Adverse mental states	1
	Physical / mental limitations	1
	Personal readiness	1
Level 1 Unsafe Acts	Decision errors	9
	Skill-based errors	5
	Routine violations	10

Table 2. Comparison of Chi-square and fisher's test results between various levels in HFACS-OGI framework

A significant association between the upper level and adjacent downward level categories in the HFACS framework.						
		Chi-square			Fischer's test	
Factors	**Factors**	**Chi square value**	**P-Value**	**Significance**	**P-values**	**Significance**
Process safety culture	Decision errors	4.197	0.04	yes	0.074	No
Process safety culture	Routine violations	5.507	0.019	yes	0.031	Yes
Inadequate supervision	Decision errors	3.956	0.047	yes	0.074	no
P-values less than 0.05 indicate a significant relationship between categories.						

Table 3. Spearman correlation test

Factors	Factors	Spearman Correlation	P-Value	Significance	Biserial	P-Value
Process safety culture	Decision errors	-0.437	0.042	yes	-0.437	0.042
Process safety culture	Routine violations	-0.5	0.018	yes	-0.5	0.018
Inadequate supervision	Decision errors	-0.424	0.049	yes	-0.424	0.049
Correlation is significant at the 0.05 level (2-tailed).						

The interconnectedness between the levels has also been studied using the Chi-square and Fischer's tests, as seen in Table 2. These were further analyzed using Spearman's correlation test as seen in Table 3. The correlation was studied between the following factors:

1. Inadequate supervision
2. Decision error
3. Routine violations
4. Process safety
5. Number of deaths

The correlations between the first four factors were studied. The correlation of factors according to the chi-square test as seen according to Table 2 is highly significant for all the factors. However, with Fischer's test, only the relation between the Process Safety Culture and Routine violations is the only significant interconnection. According to Table 3, which covers Spearman's correlation test, all correlations are significant.

The strength of the correlation between the factors and the number of deaths has been put in a matrix as seen in Table 4. The matrix shows that the following relationships hold significance and are well interconnected. The factors are:

1. Decision error and Inadequate supervision
2. Process Safety and decision error
3. Process safety and routine violations

It can be seen that processes can impact the decision-making process and result in errors to occur and increase in the complexity of human factors' presence.

Figure 2 is the hierarchy chart, which shows the distribution of the various factors at different levels and the impact they have on the occurrence of an increased number of deaths. Therefore, showing that maximum number of accidents have occurred due to level 1 and level 4 from the framework for HFACS- OGI from Figure 1. As can be seen from Figure 2, the routine errors, skill-based errors from level 1 and issues in setting up proper organizational processes from level 4 have a major impact on the cause of accidents occurring in the oil and gas industry.

The rest of the subfactors have been found to be a cause of accidents. However, they do not have a high percentage of impact on being a cause. However, inadequate supervision, Adverse mental health conditions and personal readiness seem to have an impact. Although it may be small, it needs to be addressed due to the correlations which are found to be connected or dependent on the factors seen in Figure 2.

Table 4. Correlations

Correlations						
		Inadequate Supervision	**Decision Errors**	**Routine Violations**	**Number of Deaths**	**Process Safety**
Inadequate supervision	Pearson Correlation	1	-.424*	.232	-.085	.314
	Sig. (2-tailed)		.049	.300	.706	.155
	N	22	22	22	22	22
Decision errors	Pearson Correlation	-.424*	1	-.017	-.182	-.437*
	Sig. (2-tailed)	.049		.941	.419	.042
	N	22	22	22	22	22
Routine violations	Pearson Correlation	.232	-.017	1	-.199	-.500*
	Sig. (2-tailed)	.300	.941		.374	.018
	N	22	22	22	22	22

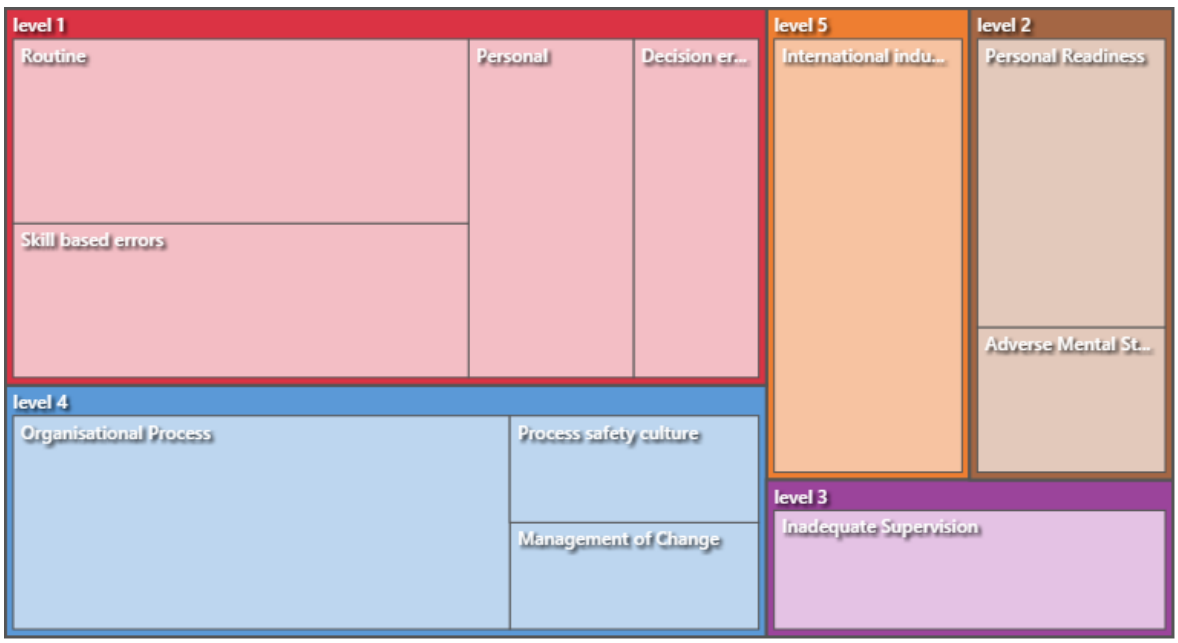

Figure 2. Hierarchy chart

Figure 3 shows a correlation between the different variables which have had a major contributing factor in deaths occurring in the oil and gas industry. The chart discusses the similar number of cases that occur based on the type of incident and the department in which it occurs. As can be seen that, getting struck by an instrument in the drilling department has seen similar cases a minimum of 6 times in the other departments. In Figure 3 the chart identifies the number of cases that have occurred in a similar fashion over the years in the oil and gas industry. From Figure 3, one of the departments with a high number of incidents may have occurred is the drilling department. Where getting struck by the equipment or caught in, between or under a certain area has been seen occurring frequently from 2010 to 2020. At the same time, there's a high frequency of accidents in both the production and construction departments after the drilling department in oil and gas. Therefore, creating a need to address the cause of accidents and procedures being followed in these departments.

Figure 4 discusses the number of deaths in the period of 2012-2020 that have occurred in the oil and gas industry in Kuwait. these number of deaths have been seen against the activities which were being performed by the deceased. From the chart, it can be seen that there is no pattern or a particular correlation in the accidents that occurred in the multiple activities. However, it definitely shows the presence of human factors as there is no consistent reduction but more of an random [24] occurrence of deaths in the past decade. Therefore, Figure 4 confirms the requirement to manage human factors to minimize the risks that each task/ activity possesses when humans interact with the activity and system of activity.

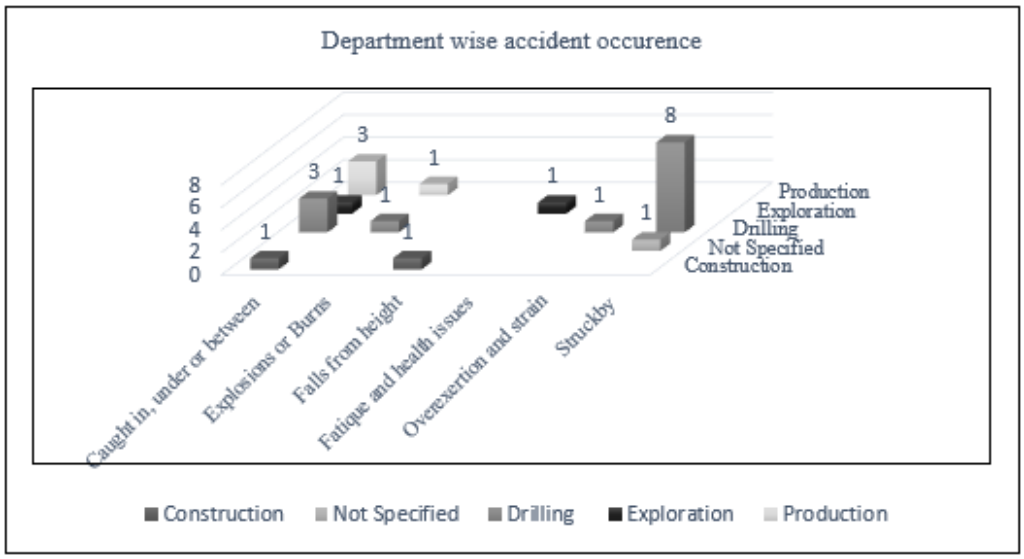

Figure 3. Department wise incident occurrence

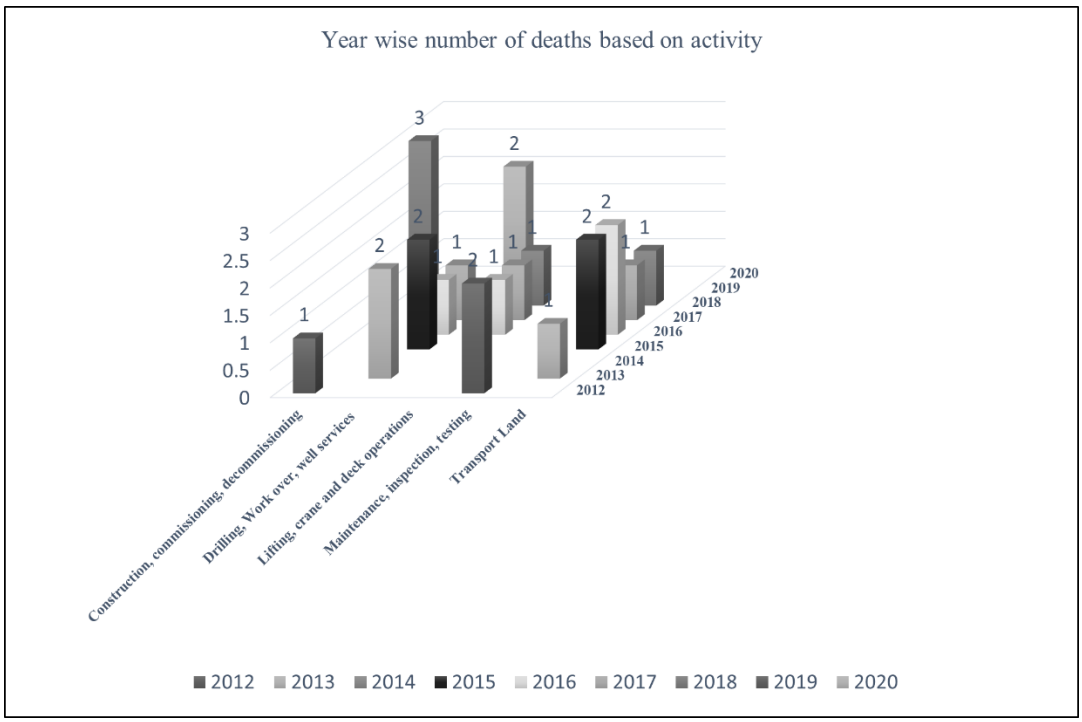

Figure 4. Year wise number of deaths based on activities

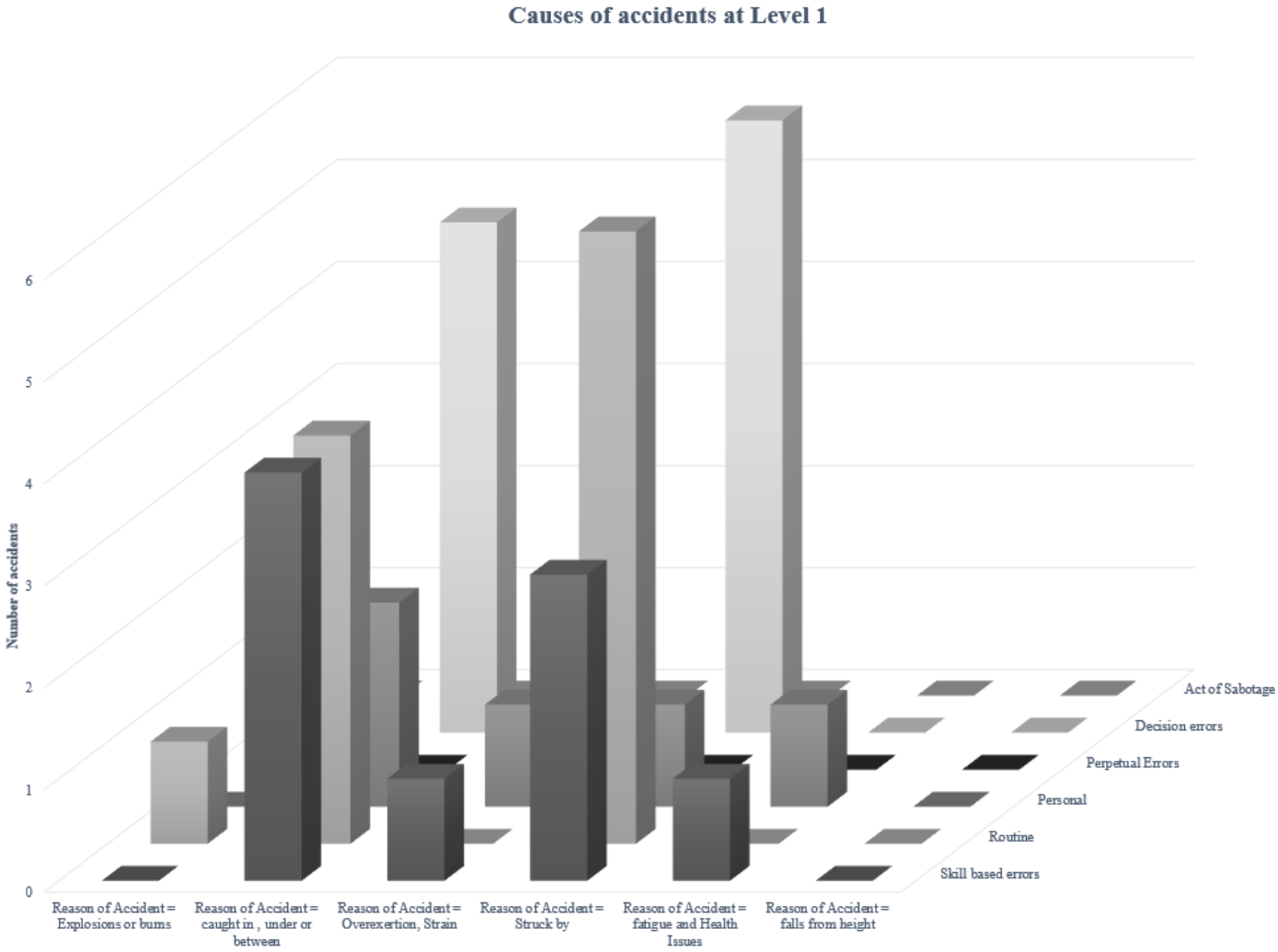

Figure 5. Causes of accidents at level 1

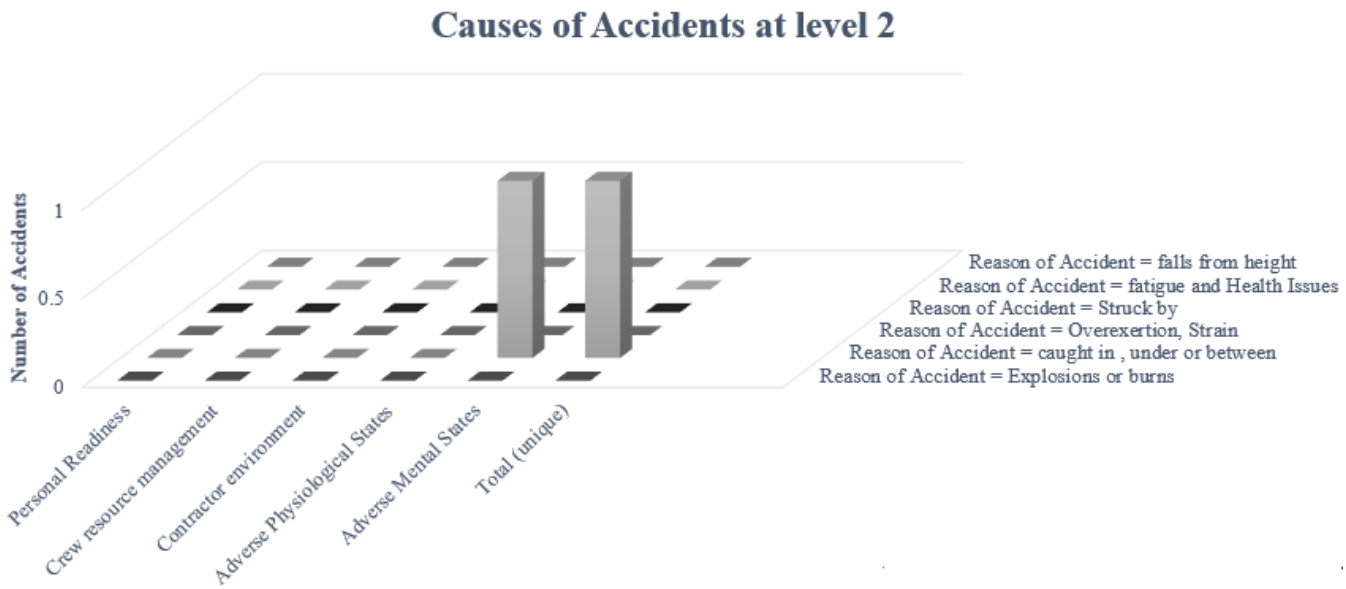

Figure 6. Causes of accidents at level 2

Table 5. Pearson correlation-coding similarity

Code A	Code B	Pearson Correlation Coefficient
Nodes\\level 1\Routine	Nodes\\level 3\Inadequate Supervision	0.46225
Nodes\\level 1\Skill based errors	Nodes\\level 1\Personal	0.431187
Nodes\\level 4\Organisational Process	Nodes\\level 2\Adverse Mental States	-0.690066

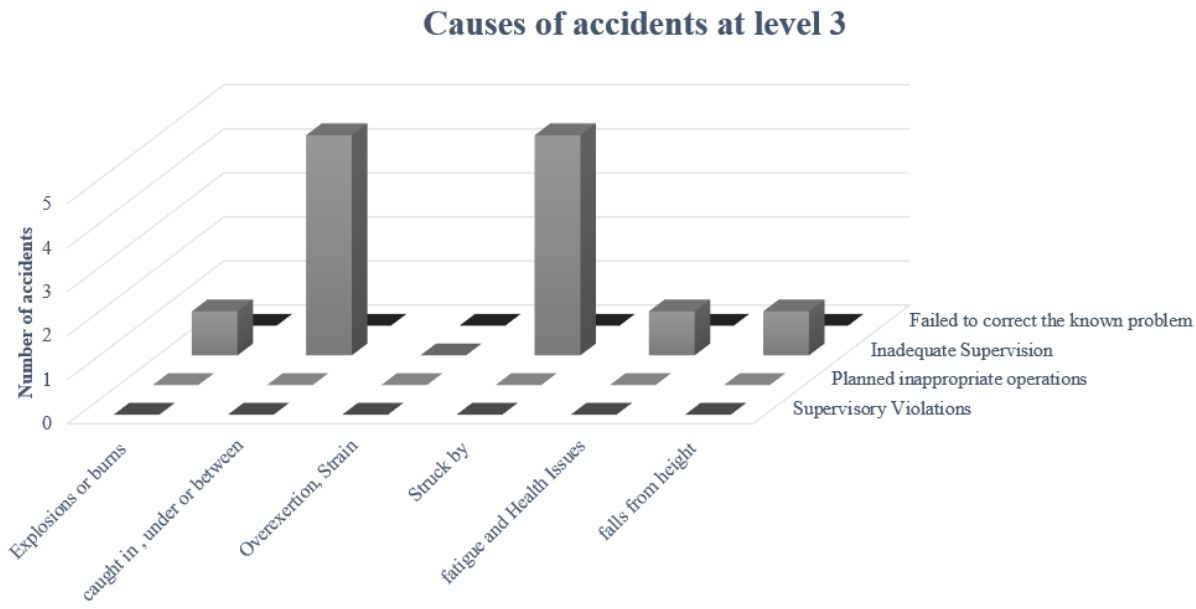

Figure 7. Causes of accidents at level 3

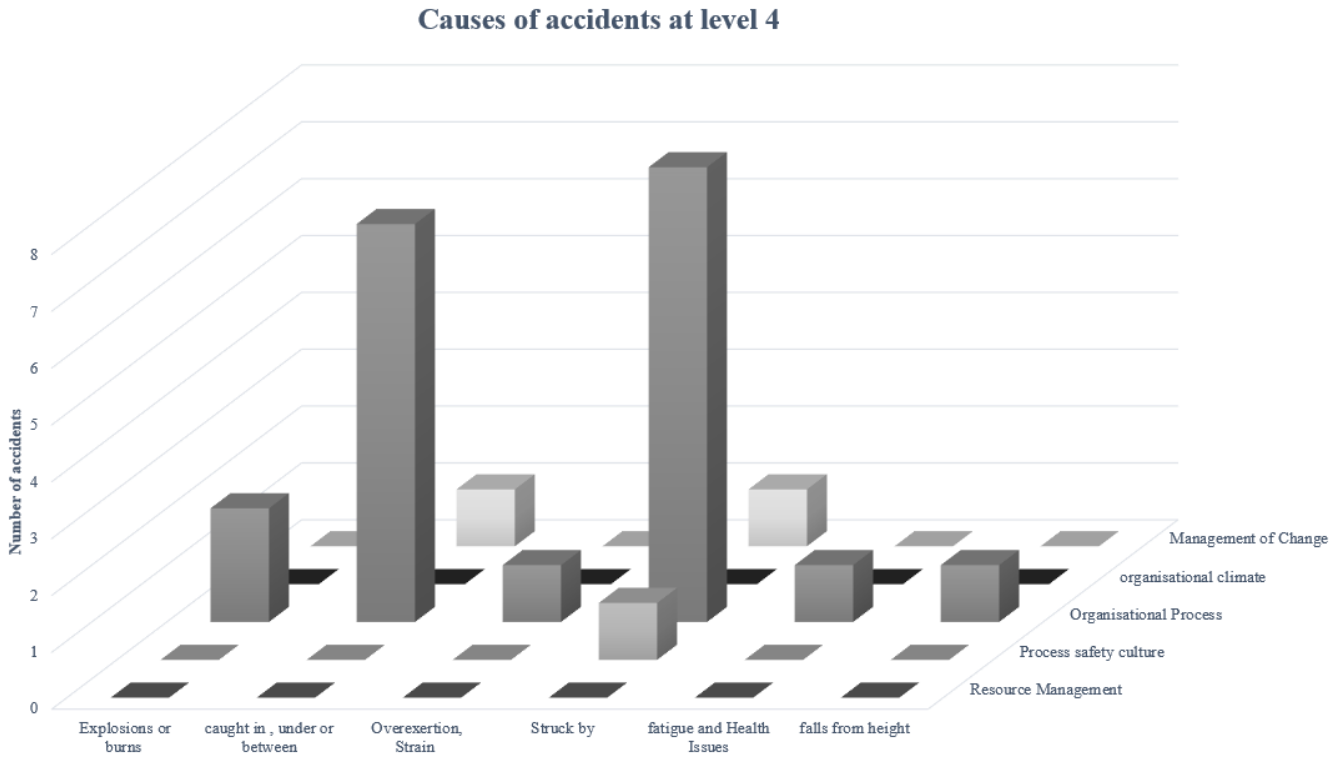

Figure 8. Causes of accidents at level 4

Table 6. Pearson Coefficient- word similarity

Code A	Code B	Pearson Correlation Coefficient
Nodes\\level 1\Skill based errors	Nodes\\level 5\International industry standards	0.759234
Nodes\\level 1\Routine	Nodes\\level 1\Personal	0.687624
Nodes\\level 4\Organisational Process	Nodes\\level 3\Inadequate Supervision	0.667486
Nodes\\level 4\Process safety culture	Nodes\\level 4\Organisational Process	0.666822
Nodes\\level 1\Skill based errors	Nodes\\level 1\Decision errors	0.593225

From Figure 5 struck by and caught in, out and between were found to be major causes of accidents at level 1. From Figure 6, adverse mental stress and total stress were the major causes of accidents at level 2. Like level 1, struck by and caught in, out and between were major causes of accidents at level 3 and 4 as shown in Figure 7 and Figure 8, respectively.

Cluster Based on similar coding and relationships between the factors at various levels in brought forward in Figure 9 and Table 5, respectively. From Table 5, there appears to be a weak correlation between organizational processes and adverse mental states.

Cluster based on word similarity and the Pearson correlation

coefficient values are brought forward in Table 6 and Figure 10 respectively. A positive correlation between Skill-based errors and International Industry standards appears to exist. Followed by routine and personal factors. Weak correlation appears between skill-based errors and decision errors.

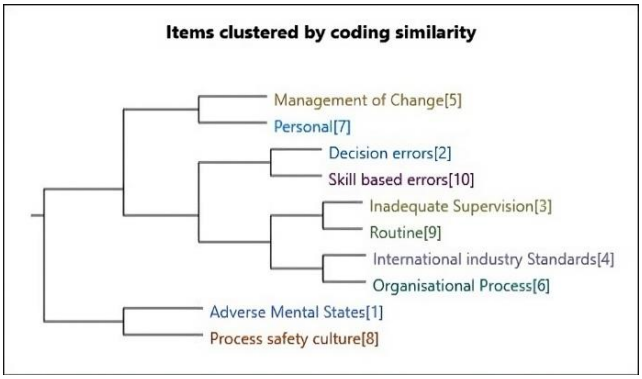

Figure 9. Cluster on similar coding

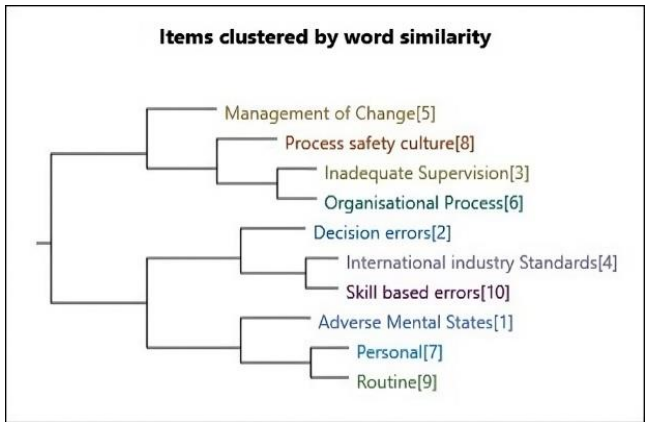

Figure 10. Cluster on similar wording

5. Conclusion and Suggestions

Drilling operations were found critical and high-risk activities which cause significant contribution of incidents such as high potential property damage incident, lost time injuries and fatalities. The different nationalities employees were engaged for the operation of drilling in remote location on shore with bad weather conditions such as high wind, high temperature, and high humid conditions. The employees were found working in drilling operation by main contractors and third-party contractors. The competency level of employees in the junior level was found low engaged in drilling critical operational activities which led to injuries to the employees. There was a major contribution of unsafe acts found in HFACS analysis led to incidents in drilling operations. There was skill gap found in employees' competence level, which needs to fill the gap through training of employees before engaging in critical operational activities. Most employees got injuries and fatalities in main contractor employees as well as third party contractor who engaged jobs such as cementing, mud logging, perforation, directional drilling, wireline logging, coil tubing, ESP run and well testing, Well Head fixing, lifting operation, rig down and rig move jobs engaged in the drilling operation.

The training of contract employees for continuous professional development to maintain skill required to work in critical operational activities to avoid incidents in drilling operation. The trainings such as mandatory job specific trainings such as rig pass safety, safety induction, rig operation, confined space safety, permit to work safety, lifting and rigging safety, defensive driving, H2S and firefighting and first aid training, well control training should be conducted by certified third party and certificates with validity as per the requirement to be issued. The training matrix of employees and percentage of completion of training for employees monthly should be monitored. The competency assessment of employee should be conducted on quarterly basis through questionnaire and interview basis and the percentage of marks for employees should be evaluated to identify the gaps in competency of employees and ensure employees trained to fill the gaps on continuous basis. There were human factors of unsafe acts (Level-1) from the contractor employees found in drilling and work over operation in onshore rig operations which cause major fatal and non-fatal incidents and loss of property and damage to the environment. The unsafe acts monitoring and actions to control it should be done on regular basis to avoid incidents in the rig sites. A behaviour-based program should be developed and appreciation of BBS (Behaviour Based System) for employees following HSE (Health, safety and environment) to motivate employees and create a good safety culture. Daily monitoring of Unsafe acts in BBS and actions to control unsafe acts and status of close out of unsafe acts and analysis of unsafe acts identified in BBS card such as STOP Card /star card required to control the incidents. Training regarding BBS awareness is required at all levels of employees, including junior and senior, as well as top management employees.

There were issues regarding contractor environment (Level-2) such as a shortage of workforce and lack of skill to perform the job, shortage of safety Personnel protective equipment and poor competency level of employees engaged in critical operation, shortage of resources, communication problems with crew due to English language barrier, poor living arrangements resulted into incidents. Contractor should ensure sufficient competent manpower, safety PPEs, resources and good living arrangement to avoid incidents at the rig sites. There were technical factors (Level-2 preconditions for unsafe acts) in drilling operation such as lack of safety interlocking system, safety function not working in rig operation software system, well control equipment not working condition etc. causing incidents to employees working in that environment. There was shortage of manpower in drilling operation found in junior as well as senior manpower such as roustabout in junior field and floorman and Assistant driller in senior field and shortage of resource in the equipment side such as well control equipment, cranes, forklifts, power tongs, elevators, and safety personnel protective equipment (Safety harness, Shoes, coverall, gloves, helmets) etc. cause incidents. There was unsafe supervision (Level-3) found in drilling and workover operation supervisors engaged in supervising the jobs which led to incidents. Supervisors play an important role in supervising the job and ensure the employee follows safety rules and standards during the job to avoid any incident. Management should arrange sufficient resources to the rig sites and deliver the resources without delay for safe drilling operation. There were supervisors' issues replated supervision of job, supervisor violations and failure to correct the job found in drilling and workover operation due to lack of knowledge of roles and responsibilities of supervisors, increase of workload, SIMOP (Simultaneous operation) job,

gaps in competency of the supervisors. The major contribution of fatality from drilling and work over operational activities was line of fire (Stuck in between drill pipes and casings, roll over pipes, electrical energy, rotating parts, high pressure, hit by vehicles, lifting operation, Drop objects etc.). Lifting operation was high risk activity during handling casing and drilling pipes from catwalk to rig floor using cranes and forklifts. Stuck up and hit by drill pipes and casings with employees working on rig floor resulted in injuries and fatality were found in the HFACS analysis in oil and gas upstream industry. Posters of LOF at designated places in the local language and Training programs to cover all employees to create awareness of line of fire should be conducted. Development of LOF procedure and standard and implement in drilling industry to control the line of fire incident.

Drop objects from crown block, monkey boards, stabbing boards, and rig floors were found in rigs used for oil and gas exploration on shore and offshore industry. Drop objects which was major serious concern for the safety of the employees working on rigs. Fall of materials from height and fall of persons from rig floor V -gate openings, rig floor missing handrails and gates led to serious injuries fatalities to employees. Rig down and rig move and rig up activities which were found high risk critical activities and chances of objects from height high led to incidents. Rig move plan as per specific rig move, lifting plan and SOP (Standard operating procedure) for critical activities to be reviewed by competent authority and approved for implementation. Drop object surveys by third parties and line of fire audits. Employee surveys on LOF on a regular basis should be conducted to control the line of fire incidents. The organizational influences (Level-4) were one factor causing incidents in the drilling industry due to lack of commitment from top management for health and safety and environment for employees working in the drilling industry. Contractor organizations deployed in rigs in drilling operations focus more time on operation to achieve targets set by client and avoid contractual penalties for down time and focus less time on HSE improvements. Contractor companies were found poor implementation of safety policies and standards in the rig sites and employees working in unsafe working environment due to improper maintenance of equipment's, lack of resources for maintenance, aging of equipment, lack of Management of change. Contractors should develop and implement safety policies and standards to create safety culture in the organization. The common factors identified in the HFACS national regulatory framework (Level-5) in the Oil and gas upstream drilling industry were failure to implement the inspections of the equipment and safety systems of equipment, well control equipment inspection and testing, regulatory standards. Failure to implement quality standards for critical equipment such as firefighting, H2S and LEL monitors, well control equipment, pressure relief valves for function testing and inspection as per API standards led to major incidents including blow out and environmental incidents. Organizations should maintain the Critical equipment register for inspection and testing and certification of conformity (COC) with valid dates from original equipment manufacturers to ensure the proper functioning of critical equipment to control fire, well blow out and toxic gases release and safety of the employees. Well control equipment pressure testing and charts records to be maintained per API guidelines and IADC (International Association of Drilling Contractors). Oil spills, chemical spills, wastewater generation, mud waste, drilling cuttings were commonly found in drilling operation in rig sites which require compliance to environmental legal authority and reports to be submitted to avoid penalties. Organization ensures oil spill control measures and oil spill kits and pits with plastic linings to avoid pollution of ground water and reporting to environmental authorities as per environmental legal guidelines.

Management should ensure for safe operation of the exploration and drilling and employee safety and environmental protection was required in upstream oil and gas industry due to high-risk activities and potential risk of fire and explosion and environmental pollution. The management of oil and gas industry to take strict measures for implementation of HSE management system to prevent accidents in future to avoid loss of human life, financial losses and environmental pollution. The following accident prevention measures and recommendations should be implemented in the oil and gas industry. Ensure API (American Petroleum Standards) implementation in the industry and strict compliance to the standard as per updated revised standards on regular basis. Ensure all Rig contractors comply with the rig specific EHS plan, rig move plan, rig up, rig down, drilling and work over operation plan, emergency plan approved by the client, approved agency. (Target date – Before commissioning and operation of the rigs). All rig contractors, third party service companies, sub -contractors engaged for drilling and exploration activities employees competency should be evaluated on regular basis (Target date for implementation- Monthly and quarterly). Employer should ensure to develop the skill of HSE management system and operation of the employee through training programs and awareness campaigns (Target date for implementation- continuous basis and evolution of training matrix on monthly basis). Employer should ensure BBS system implementation and analysis, appreciation (Target date of implementation- Daily and monthly analysis and monthly appreciation of employee). Employer should ensure Incident reporting and investigation system and development of software to upload the data of incidents and tracking system(Target date of implementation- on daily basis BBS /accidents and monthly HSE reporting system).Employer should ensure updating and function testing and inspection of critical equipment register (CER) of fire pumps/headers, Blow out preventor, H2S & LEL System to avoid fire and blow out incidents and avoid pollution and accidents resulted into human loss. Employers should ensure implementation of HSE management system procedures and standards, guidelines, best practices and benchmark standards as per API, ISO-45001, ISO—14001, UK HSE guide lines etc.

5.1 Strategies and action plans

Development of procedures regarding well bleed off procedure during work over operation of the wells to prevent fire related incidents, Rig down ,Rig move ,rig up safety procedure, H2S handling procedure, SIMOP(Simultaneous operation for pad wells) procedure, Permit to work procedure, NORM(Naturally occurring radiation Measures) Procedure, rig commissioning procedure, emergency handling procedure for onshore and offshore operation , flaring procedure ,drilling and work over operational safety procedures ,lifting and slinging procedure ,Incident handling and reporting procedure etc. ,Incidents investigation recommendations should be done in the upstream oil and gas industries at Kuwait. Action plans required for implementation of procedures and accident

investigation recommendation for prevention of accident in future. Red Book of accidents should be communicated through training programs with time frame for completion to cover all the employees and contractor employees and third-party service employees including visitors. Accidents investigation recommendation action plan for implementation of accident recommendation with track sheets for all accidents and timeline for completion of actions should be developed and monitoring of close out of recommended actions should be monitored. Monthly meetings with contractors should be conducted by the concerned team to monitor the actions compliance and penalty system to be included for non-compliance of actions on contractors and service contractors to prevent accidents in the future. All accident investigation recommendations actions should be included in the contract clause for fulfilment for new contract and additional contract clause as requirement.

The study is innovative as Human factors analysis and classification system (HFACS) important tool for investigation of accident to find out the human factors causing accidents and significance of the factors. Oil and gas industry itself was highly hazardous and high-risk prone industry. One of the factors causing accidents in oil and gas industry was human factor resulted into the loss of human life, financial loss and environmental impact. The HFACS system focuses on five layers of factors from bottom layer (Unsafe acts) to top layer (Regulatory and statutory Influences) influences the factors causing accidents. Focus on employees' errors and violation through Behavior based system (BBS) to monitor and correct the unsafe acts through BBS card/STOP card/Star Card system. Training on BBS system for all employees to create awareness of human errors and violation, unsafe acts, and safe conditions for prevention of accidents in the oil and gas industry. BBS tool on Human behavior should be implemented and appreciation of employees through certificate/promotion to encourage employee to prevent unsafe acts in the oil and gas industry. Best HSE practices such as safety interlocking system, in built safety system of the equipment's, API standards, fall arrestor system, Mobile type man lifter and scaffolding system, CCTV cameras and recording system in critical areas monitoring.

5.2 Scope for further research

New framework suggesting safety norms could be brought forward based on feedback from various stakeholders for Kuwait oil and gas industry.

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