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Development of KBES with Hazard Controlling Factors and Measures for Contracting Health and Safety Risk in Oil and Gas Drilling Process: A Conceptual Action Plan

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Abstarct: In this study, a conceptual framework is presented for development and implementation of an open source knowledge based expert system with novel controlling factors and measures for reducing work place risks and hazards in drilling process at oil and gas industries by using LabVIEW and MySQL software. Execution of this knowledge based expert system is to assist and facilitate the safety engineers and drilling crew to manage the safety protocols according to the health and safety acts and regulations in both domains (on and offshore) and prevent the injuries in hazardous research environments of oil and gas industries because fatality rates are highest during drilling process which demands increased efforts for improved safety plans at drilling sites. As discussed in this conceptual framework, respondent for the data collection for proposed system will be randomly selected health and safety experts and drilling crew of major onshore and offshore oil and gas industries from Malaysia (Petronas), Saudi Arabia (Saudi Aramco) and Pakistan (OGDCL). This conceptual framework will explain about the research methodology that consists of Preliminary and Post research analysis for analyzing the effectiveness and performance of the proposed expert system based on controlling factors. Expected outcome of this study is to implement this proposed conceptual framework for identifying the major controlling factors of accident prevention and effectiveness of proposed expert system for safety training activities in drilling process.

Key words: Health and safety, hazard, drilling process, knowledge base, expert system, oil and gas industries

INTRODUCTION

The oil and gas industry plays an important role in driving the global economy because of its consumption as basic fuel ranging from household to wide spread industries. The utilization of oil and gas has a long and interesting history crossing an enormous number of years. Advancement of oil and gas has evolved over time and its various uses have likewise extended and turned into an essential part of today's worldwide economy. The use of oil inevitably supplanted coal as the world's essential wellspring of mechanical and industrial power in the early twentieth century. The methods and procedures involved in producing and dispersing oil and gas are very unpredictable and critical and require state-of-the-art technologies (Blackley *et al*., 2014). One of the major and most important processes in oil and gas industry is an oil well drilling process. This is the process in which an oil well is bored in the earth that is designed to bring petroleumoil hydro carbons to the surface.

Drilling permits further assessment of the subsurface and if oil and gas exist at a specific drilling site with some dely. The issues which affect the time duration of drilling are weather at site, depth of the drilling, hardness of surface and rocks and distance of the site, etc. (Witter *et al*., 2014). There are a range of drilling techniques and methods and kind of drilling rigs that depend on whether the drilling is for onshore or offshore (Lincoln *et al*., 2013). For onshore drilling, fixed or mobile drillings rigs are used while for offshore drilling, fixed

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offshore Jack up drill rigs, Deep Water Drill Ships and Semi-Submersible drill rigs are included.

Every time, safety experts and drillers have to face new and uncertain hazardous situations during drilling process. Hence, appropriate decision making with in such circumstances is complicated and challenging. There are some software tools that exist for helping the safety officers and drillers regarding research place safety but they are not updated and efficient systems as per international safety rules and regulation for decision making during drilling process and vestibule training of drilling crew (Lincoln *et al*., 2013).

The focus of this study is to develop and implement an open source knowledge based expert system and to identify the controlling factors for reducing research place risks and hazards in drilling process for on and offshore oil and gas industries in Malaysia, Saudi Arabia and Pakistan. Selections of these three proposed countries are due to the variety of risk and hazards with NEBOSH and NIOSH safety standards. Execution of this knowledge based expert system is to assist and facilitate the safety engineers and drilling crew to manage the safety protocols according to the health and safety acts and regulations in both domains and prevent the injuries in hazardous work environments of oil and gas industries. The novelty of this open ended source knowledge base expert system is the ability to be implemented and executed in both on and offshore oil and gas proposed industries by implying novel controlling factors and measures for reducing hazards and risk in drilling process while being an open ended source.

Literature review: Over the last 5 years, an average of nearly 70 people had died and 2500 have suffered major injuries annually as a result of various incidents in oil and gas drilling process due to several underlying causes related to insufficient accident prevention planning and safety training activities. These workers also had high prevalence of exposure to physical and chemical hazards during drilling operation. Such risks and hazards can be controlled by analyzing the underlying cause of accident (Blackley *et al*., 2014). Therefore, it can be established that there are many factors which are still needed to be identified and focused upon (Ronen *et al*., 2012). Along with the identification of related factors, it is also inevitable to develop innovative strategies and approaches to minimize the chance of calamities.

On the other hand, periodic emergency training of drilling crew poses a significant role in the overall reduction of loss in case of an accident (Gonzalez and Ysolds, 2013). The trained research force can facilitate the industry to operate more productively while avoiding any risks related to them (Soeder *et al*., 2014). This process, however, takes long time and costs more to the industry which is intended to produce high profits. During times of high demand, new workers are brought into drilling industry and these are workers may not have relevant training cause critical injuries and deaths," said Ryan Hill, head of the Center for Disease Control and Prevention's (NIOSH, 2014). During America's drilling and fracking frenzy from 2008-2012 oil-field deaths reached 545 with Texa's 216 reported fatalities, leading the nation. Pennsylvania and North Dakota are also recording dramatic increase in worker deaths during oil and gas extraction process, according to updated workplace fatality figures recently released by the Bureau of Labor Statistics. Form previous studies many health and safety analyst have said that this rapid increase in the number of oil and gas worker deaths is largely due to the neglecting hazard preventing safety factors and deficiency of effective and planned health and safety training activities of drilling personals.

The US Chemical Safety Board and other safety advocates suggested that strict safety rules and training practices are required to be applied at drilling sites. Inexperienced and untrained workforce, on one side are prone to harm their own selves while often can result in bigger losses on the other side including environmental and monetary losses. These losses can range from several hundreds of thousands of dollars to millions For example, the cost of a blowout (as a result of improper/no oil well control) can easily reach several millions of US dollars (Centner, 2013). This damage can be controlled to a larger extent by providing vestibule training to the drilling staff. Vestibule training activities involve the emergency training in a simulated environment for a specific accident. This advance training may lead the drillers to respond efficiently in case of an incident as it happens in the field.

Knowledge Based Expert System (KBES) based on novel factors in combination with the training capabilities can be a vital solution in order to cater this issue (Yang *et al*., 2014). Decision support systems and experts systems are widely and efficiently used in oil and gas sector for calculating annual revenue, environmental and climate prediction, hazard reorganization at site (Akram *et al*., 2014). These expert systems are also employed in some area of drilling operation in world's renowned oil and gas industries like maintenance, electric research and vibration calculation

but have been reported insufficient in terms of performance and competence due to limited database and hazard identification methods (Akram *et al*., 2014). Expert systems that already exist in the drilling industry are of closed nature. It means that only the vendor that provides the KBES can update and modify their system. These vendors usually also are paid to organize workshops to brief about their system accordingly. Such training workshops are not prioritized because they cost large amounts of financial investments to the organizations (Witter *et al*., 2014). Consequently, the training activities are not arranged periodically. The training practices even then are not arranged at the field which makes it hard for the learner to experience the real challenges. On the contrary, open source experts systems can be employed along with the existing systems to train and teach the drilling crew on site within their respective sections. Due to the openness of the system, it is very convenient for the on-site manager or supervisor to modify and update the system at his own disposal and according to desired setting. This advantage can help the work force to become familiarize with the related risks and hazards at a better level (Ronconi *et al*., 2015). These systems can also be installed for and made accessible to the drillers so that they can acquire any piece of information on their own while the supervisor is not present on field (Saad *et al*., 2014).

Problem statement: Drilling process is the most important process in oil and gas industries while being hazardous and challenging. High fatality rates among oil and gas drilling crew has been reported for more than a decade, because of lack of health and safety awareness of drilling process (Mannan *et al*., 2014). In the year 2007-2012, the occupational fatality rate of the oil and gas drilling industry was 2.5 times higher than the construction industry and 7 times higher than general industry (BLSGA, 2012). This industry's fatal injury rate is correlated with fluctuations of industry activity as measured by the number of active drilling rigs (BHOIC, 2010; BLSGA, 2009; Mode and Conway, 2008; NIOSH, 2014). Fatality rates are highest during drilling process which demands increased efforts for improved safety strategies at drilling rigs (Mulloy, 2014). Many of the workers that survive in such disastrous incidents are vulnerable to other health concerns. These health effects include dizziness, headaches, drowsiness, nausea and vomiting as well as dermatitis and deep skin tissues infections from repeated skin contact with the drilling fluids. Some of the mildly refined base oils have also been associated with cancer as a result of the aromatic compounds in the oil mists. According to Saudi Aramco Oil Refinery statistical analysis from year 2008-2013, the highest rate of critical injuries were reported in drilling process.

Firstly, there are many factors involved in high rate of drilling fatalities and critical accidents and injuries. Due to the rapid change in environment, drillers and safety engineers have to face new challenges every day regarding health and safety for this reason there is a need to identify new controlling measures and factors for reducing work place risk and hazards in off and onshore oil and gas industries in an effective manner (Saad *et al*., 2014). Improved occupational health and safety surveillance will help to capture the effectiveness of injury and illness prevention interventions (Mulloy, 2014).

Secondly, Lack of proper and effective health and safety training causes high rate of work place risk among drilling operators and affect the performance of drilling crew during drilling operation. For the elimination of variety of hazards and risks in drilling operation, there is a sheer industrial need of an efficient and intelligent expert system for safety training of off and onshore drilling personnel with updated knowledge and hazard controlling factors according to international safety rules, regulation and protocols (Akram *et al*., 2014). Health and safety expert system can also be used for academic purpose in universities and training centers to train workers for safe drilling operation as per industrial demand of oil and gas (Witter *et al*., 2014).

It is intended to tackle the aforementioned issues by identifying new controlling factors for reducing workplace risk and hazards in drilling process at on and off shore oil and gas industries. An open ended knowledge based expert system based on those identified factors is proposed in this study to facilitate the prevention and reduction of accidents at drilling sites. The proposed system can also be employed at drilling sites to enhance health and safety drilling training activities.

Proposed objectives: The main purpose of this study is to develop and implement a knowledge based expert system for reducing the workplace risk and hazards in offshore and onshore oil and gas industries in drilling process in Malaysia, Saudi Arabia and Pakistan. Main objectives of this study are:

- To identify the major controlling factors for reducing the workplace risk and hazards in drilling process at onshore and offshore oil and gas industries to assist and facilitate the health and safety officers and drillers

- To develop an open source knowledge based expert system by utilizing the identified controlling factors for accident prevention and safety training activities for reducing workplace risk and hazards in on and off shore drilling process
- To analyze the impact of proposed open source knowledge base expert system based on hazard controlling factors for accident prevention at onshore and offshore drilling process
- To evaluate the effectiveness of hazard controlling factors of proposed open source knowledge base expert system for accident prevention and safety training activities in drilling process at onshore and offshore oil and gas industries
- To assess the performance of drilling crew for vestibule safety training activities by utilizing proposed open source knowledge based expert system based on hazard controlling factors

Research questions: The main purpose of this study is to seek answers of the following research questions:

- What are the controlling factors for reducing workplace risks and hazards in drilling process for accident prevention and safety training activities at onshore and offshore oil and gas industries?
- How can these controlling factors contribute to decrease the workplace risks and hazards in drilling process for accident prevention and safety training activities at onshore and offshore oil and gas industries?
- How proficient is this open source knowledge based expert system for accident prevention and safety training activities based on hazard controlling factors to contract the workplace risk and hazards in drilling process at onshore and offshore oil and gas industries?
- What is the effectiveness of hazard controlling factors in the open source knowledge based expert system for accident prevention and safety training activities in drilling process at onshore and offshore oil and gas industries?
- What is the impact of the proposed open source knowledge based expert system depending upon hazard controlling factors for accident prevention at onshore and offshore drilling process at oil and gas industries?
- What is the safety performance of drilling crew after vestibule training activities provided through the proposed open source knowledge based expert system?

Approach of research: In order to attain the goal of this proposed study, a mixed method by utilizing both, questionnaires and focus group interviews will be used. The target population of this research consists of 03 oil and gas industries from Malaysia, Saudi Arabia and Pakistan with respondents including drilling crew, safety officers. The survey questionnaire design will include measurement level based items. Accordingly, questions for focus group interviews will establish based on the findings from the questionnaire results. In this study, sequential explanatory research design will be used, where the quantitative and qualitative data analysis are analyzed separately. Upon completion of data analysis from both the quantitative and qualitative methods, researcher can easily indicate the similarities and difference in both results.

Proposed conceptual framework: Conceptual framework is adopted and modified from Conde *et al.* (2005) climate hazard impact assessment. ADDIE model of planning and training strategies will be used for the development of this open source expert system with accident prevention and training activities for reducing work place risk and hazards in drilling process for oil and gas industries. Conceptual framework of this study is shown in Fig. 1. According to the conceptual framework of Conde *et al.* (2005), the impacts of support system and hazard controlling factors are measurable outcomes and are typically modulated by changes (Conde *et al*., 2005).

In this study, main variables that will be included are, accident prevention activities in drilling, health and safety training activities in drilling, effectiveness of KBES based on controlling factors, impact of KBES based on controlling factors, performance of KBES based on controlling factors. For the identification of major hazard and risk controlling factors for accident prevention and analyzing the effectiveness of proposed expert system for safety training activities in drilling process, sequential explanatory mix method research design will be adopted. For qualitative research, focus group interviews will be used, while for quantitative research, Survey instrument methods will be utilized. SPSS 20 Software will be employed for descriptive and inferential statistical techniques and Nvivo Software will be used for qualitative research. To implement this study, a variety of phases need to be observed in terms of study design, respondents, data sources, study instruments, system development and data analysis.

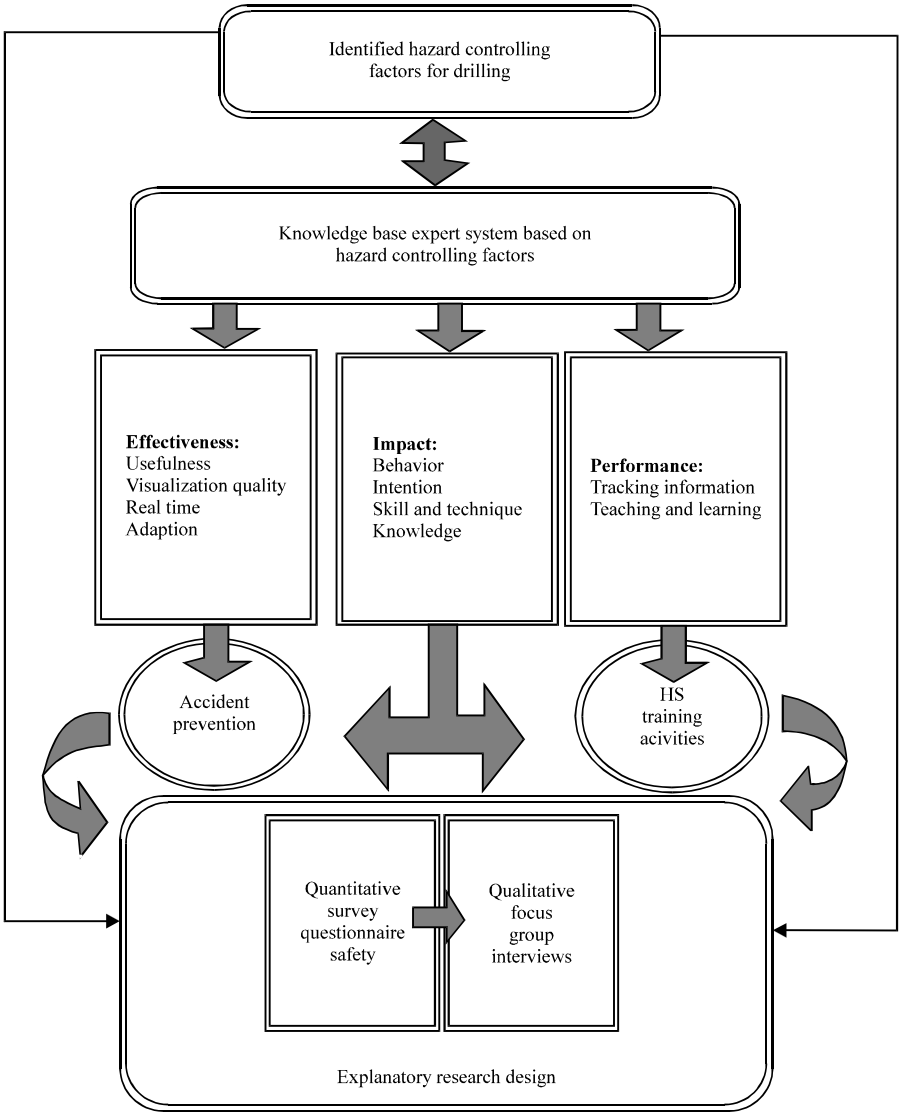

Fig. 1: Proposed conceptual framework

MATERIALS AND METHODS

In the proposed methodology, MySQL and LabView software will be used to achieve the system development objective of this study. MySQL will be used for the development of system database which will handle the oil and gas health and safety expert's opinion base data of offshore and onshore identified hazard controlling factors and measurs of reducing work place risk during oil and gas drilling process based on preliminary research phase findings. MySQL will be used due to its user friendly environment and ability of handling almost any amount of data, up to as much as 50 million rows or more (Ronconi *et al*., 2015). LabView software will be used for the development of user interface of the system and will be connected with data base which will be the knowledge base of the proposed system by calling data base connectivity tool kit function in LabView software. Block diagram of proposed system is as shown in Fig. 2. In this study mix method research approach will be used to answer proposed research questions. The Comprehensive preliminary and post research planning of this study is shown in the flow chart as depicted in Fig. 3. It shows the flows and methods that will be used for finding and analyzing data regarding the project related.

Plenty of preparation should be done to produce a best quality of research study in order to ensure all plans can be done in an orderly and systematic manner. To

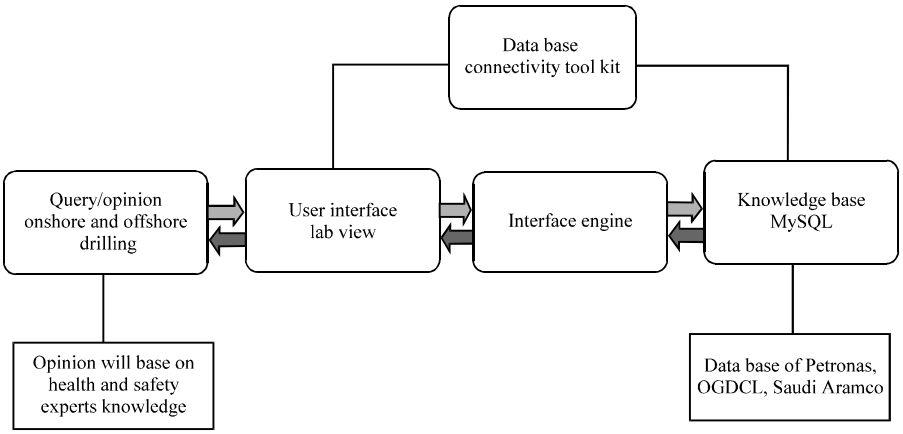

Fig. 2: Block diagram of proposed system

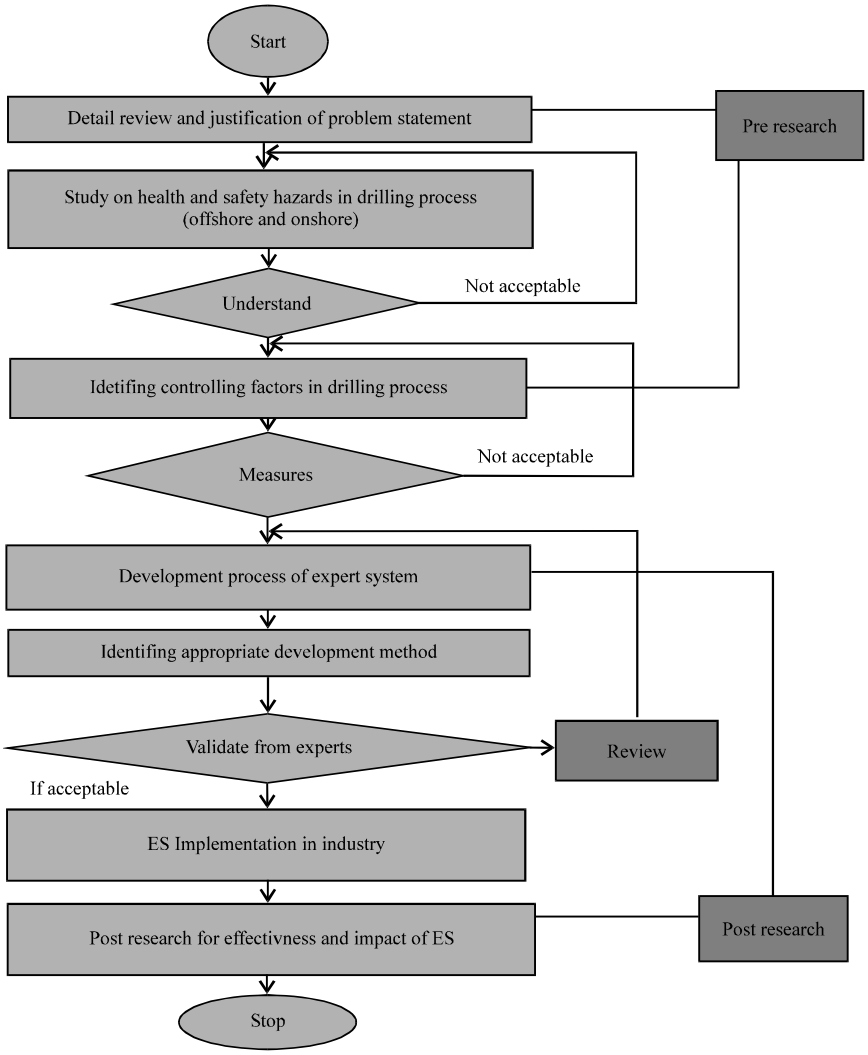

Fig 3: Methodology flow chart

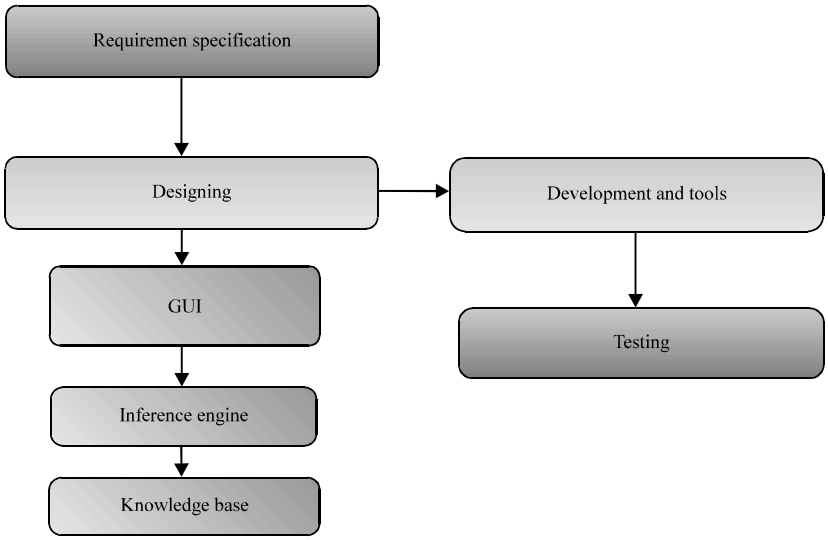

Fig. 4: Expert system development process

implement this study, various parts need to be observed in terms of study design, respondents, data sources and study instruments, flow of research, structural operations and data analysis.

Sampling: The research samples of this research study will be a group of health and safety experts and drilling crew of major onshore and offshore oil and gas industries from Malaysia (Petronas), Saudi Arabia (Saudi Aramco) and Pakistan (OGDCL). These three countries and industries are chosen for data collection because of the variety of environmental aspects and different international safety act and regulation bodies like NIOSH and NEBOSH. Explanatory mix method approach will be adopted for this study to achieve the research objectives, for quantitative study 120 respondents will be chosen for answering the preliminary and post research questionnaires for evaluating the performance and effectiveness of proposed expert system for reducing workplace risk in drilling process from drilling crew of each industry. And for Quantitative study from each industry group of 06 Health and safety expert respondents will be selected for focus group interview for the identification of hazard controlling factors and the technical assessment of proposed system as shown in Table 1.

Table 1: Proposed respondent

		No. of respondent	
Country	Industry or company	Quantitative	Qualitative
Malaysia	Petronas	120	06
Pakistan	OGDCL	120	06
Saudi Arabia	Saudi Aramco	120	06
Total		360	18

Study instrument: Study instrument or measuring instrument of study is essential to achieve the objectives of the study. For this study, the instruments which will be used are two questionnaires; this research study will adopt both qualitative and quantitative methods of data collection. First one is preliminary research questionnaire which is used for identifying the hazard controlling factors and justifying the problem statement. In preliminary research quantitative and qualitative research methods will be use (questionnaire set and focus group interview). After identifying the major controlling factors for reducing workplace risk and hazards in drilling process, knowledge-based expert system will be designed and developed. Once the complete system is developed, then a post research will be conducted after implementation of expert system in the oil and gas industries of nominated countries. For post research both data collection methods (qualitative and quantitative) will be used (questionnaire set and focus group expert interviews) for analyzing the effectiveness and performance of proposed expert system based on identified hazard controlling factors. Research questionnaire development phases from Frazer and Lawley (2000) will be adopted for both questionnaires development and Rubric assessment tool which will be used for the validation of questionnaire.

Proposed expert system development methodology: In this study, expert system development methodology is adapted and modified from Yasser Abdulhamid as shown in Fig. 4. According to the proposed method in this study knowledge based expert system development activities will go through different stages, these stages are:

requirements specification, design, development and testing. The approach which will be applied for system development is a combination of rapid prototyping and incremental approach. Rapid prototyping will be used to reach an agreement on the initial set of the system requirements by adding a better user interface and more explanation. It will then be incrementally developed and tested for maturity.

Requirements specification: The initial step in acquiring knowledge for an expert system is to characterize the important aspects of the problem. This involves identifying the participants, problem characteristics, resources and goals. In this proposed system, knowledge will be acquired from experienced health and safety officers and drilling crew members that are experts in drilling safety procedures for reducing workplace risk and hazards. After selecting the domain experts, this study can proceed toward identifying the hazard controlling factors in on and offshore drilling process. This stage will involve an informal exchange of views on various aspects of the problem and issues which will be briefly discussed in research design of proposed study. The objective of this stage is to support knowledge structure so that the development of the knowledge base part of system may begin.

Designing stage: In this study designing involves mapping the acquired knowledge from the previous stage into the representational structure associated with the tool chosen (Mosa *et al*., 2013). The designing stage is based on the internal functionality and gathered knowledge data base of proposed expert system. The proposed system design will be divided in three parts and all of them are interconnected with each other:

- Graphical user interface
- Inference engine
- Knowledge base

Graphical user interface: The Graphical User Interface (GUI) is a main element of an expert system that must provide a simple and efficient interaction between the user and the system. In this proposed expert system, there will be two way interactions. In the user-expert system interaction, the user (Drilling crew) will ask queries and problems to the expert system(based on Health and safety experts) as an input data. In the system-user interaction, the system will provide the most appropriate solution of user problem according to the knowledge base of the system as an output result.

Inference engine: The inference engine is the core processing component of the expert system (Mosa *et al*., 2013). Proposed expert system will be mainly consisting on knowledge baseand an inference engine. The knowledge base store facts and knowledge through experts from oil and gas industries. The inference engines of system will apply logical rules like (IF-Else) to the knowledge base and deduce relative information accordingly (Kahlon, 2014). It will be responsible for gathering the information from the user, by asking various questions and applying it wherever necessary (Spiegelhalter *et al*., 2013). It seeks information and relationships from the knowledge base and to provide answers, predictions and suggestions the way a human expert would.

Knowledge base: In proposed system knowledge base is a part of expert system which holds all the information and knowledge of the system. It contains facts and rules about the task domain (Laudon, 2002). Task domain is the area of expertise that the expert system is designed to work within (Altunkaynak, 2014). In proposed expert system, knowledge base will be divided in two parts. First one will be the knowledge base of expert opinion for accident prevention and training activities and the second knowledge base for international health and safety rules in on and off shore drilling process.

Development and tools In this stage, the proposed system will be developed by using appropriate development tools and techniques (Altunkaynak, 2014). For the development of each design phase of system, different suitable software will be adopted according to the previous research studies. For the development of data base which will base on knowledge and opinion of health and safety experts from proposed oil and gas industries, MySQL will be used due to its openness and ability of handling almost any amount of data (Cruz *et al*., 2014). In this study, MySQL will be used for the development of knowledge base of proposed expert system which will be divided in to two main parts Lab 1 (data base 1) and Lab 2 (data base 2). Lab 1 will be based on offshore drilling risk and hazards data with experts opinion and recommendations which will be collected from proposed industries experts during preliminary phase of qualitative research (interview) and similarly, lab 2 will be used for Onshore drilling risk and hazards during oil and gas drilling because it will be convenient whenever drilling crew will need required information according to the particular domain will be separately accessible. Similarly, for inference engine, rule base (If-else) method will be

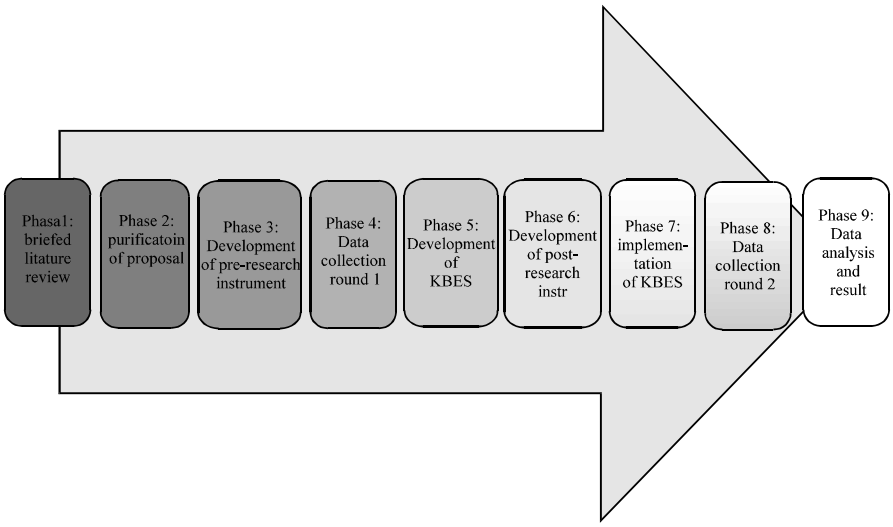

Fig 5: Flow of research

Table 2: Expert system development tools

Development	Tool and method
Graphical user interface	LabView
Inference engine	Rule base method (if and else)
Knowledge base	MySQL (Lab 1,2)

adopted because rule base method provides natural knowledge representation and deal with incomplete and uncertain knowledge (Spiegelhalter *et al*., 2013). Labview software will be use for the development of user interface of the system and will be connected with the knowledge base of the system by calling data base connectivity tool kit function in Lab view software. The graphical user interface of the system will be used for input which contains user Origin, Query and Domain (Offshore/Onshore/Both), Output will based on the experts opinion and recommendations as per required drilling domain (Table 2).

Testing: The last stage, testing, involves finding and fixing any errors and omissions (Berclaz *et al*., 2014). It will cover the verification of individual relationships, validation of program performance and evaluation of the utility of the software package through post research phase. Testing guides reformulation of concepts, redesign of representations and other refinements. In this study testing will be performed at proposed oil and gas industries during post research.

Flow of research: It is aimed to divide this research study in seven major phases as depicted in the flowchart Fig. 5:

- Development of preliminary research instrument (based on literature review)
- Data collection round I (for justification of problem statement and hazard controlling factors identification from health and safety experts)
- Development of KBES (tool and technique depends upon brief literature review)
- Development of post research Instrument for evaluation and testing of KBES in proposed industries
- Implementation of proposed KBES in proposed industries
- Data collection round II (after implementation of KBES post research instrument will use to evaluate the performance of proposed KBES
- Analysis of collected data and final results

RESULTS AND DISCUSSION

Expected results: The expected outcome of this proposed research is to develop and implement an open source knowledge based expert system and identifying the major controlling factors of accident prevention and effectiveness of proposed expert system for safety training activities in drilling process for reducing work place risks and hazards for on and offshore oil and gas industries in Malaysia, Saudi Arabia and Pakistan. Execution of this knowledge based expert system is to assist and facilitate the safety engineers plus drilling crew to manage the safety protocols according to international health and safety regulations in both domains and prevent the injuries in hazardous work environments of oil and gas industries. The novelty and significance of this Knowledge based expert system is that, it will be able to implemented and executed in both on and offshore oil and

gas proposed industries by novel controlling factors and measures for reducing hazards and risk in drilling process while as an open ended source.

CONCLUSION

This conceptual framework discusses the significance of hazard controlling factors for reducing work place risk and hazards in drilling process in off and onshore oil and gas industries. Respondents of this study based on conceptual framework will be the randomly selected health and safety experts, drilling crew, safety officers from major onshore and offshore oil and gas industries from Malaysia, Saudi Arabia and Pakistan. For the development of expert system LabVIEW and MySQL software's will be used and for data analysis SPSS 20 software will be used for descriptive and inferential statistical techniques and Nvivo will used for qualitative research.

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