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Modification of the TRACEr model as a tool for analysing accidents in the Oil and Gas industry: The TRACEr-OGI.

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ABSTRACT

Safety the reversed side of an accident is always an integral part of every organisational set up. Hence, risk assessments and accidents analysis in the oil and gas industries is always inevitable. As one of the organizations with highest number of accidents reports, the oil and gas industry has been trying most at times to adopt several established accidents analysing tools/models to address this aspect. Therefore, this paper critically analyses and adopts one of the accident analysing models used in the aviation industry called the TRACEr (Techniques for the Retrospective and predictive Analysis of Cognitive Errors) model to fit into the oil and gas industrial accidents analysis. In achieving this, taxonomies of most benefit from the TRACEr model were adopted while making changes to some key areas to develop the new model called the TRACEr OGI. Accidents reports from various oil and gas industries retrieved from the international association of oil and gas producers (IOGP) database focussing on Russia and central Asia were used to test the reliability of the new TRACEr OGI model. The new TRACEr OGI has seven levels of taxonomies as opposed to the eight levels from the main TRACEr model were the central change been made at the Cognitive level of the operator context. The result of the analysis for reliability test shows that, there exist a reasonable percentage of correlation for the Human-Machine interface and the task errors in the oil and gas industry and hence the TRACEr OGI can be adopted for accident analysis in oil and gas industries.

Keywords: Accident analysis , Oil and gas,; TRACEr-OGI, Taxonomy, Task error.

1. INTRODUCTION

It has been found that human errors and organizational factors were typically the major causes of accidents (Reyes et al. 2015). Therefore, for the safety of any organization, there is need for an absolute understanding for all the possible reasons that might cause accident (Doytchev and Gerd 2009). This need has given rise to the establishment of several models as a tool for accidents analysis to reveal their causative factors. TRACEr which is Technique for Retrospective and Predictive Analysis of Cognitive Errors is one of such tools recently developed for the aviation industry. However, TRACEr model was designed for the aviation industry, this study aims to adopt the model with possible modification in other to fit into the oil and gas industry accident analysis. This idea was assumed to be feasible possible for the fact that analysis for accidents and risk assessment of the two industries most at times look quite similar (Underwood and Waterson 2013). For the modification of the TRACEr model, oil and gas related accident records from 2000 to 2014 reported from Russia and central Asia were obtained from the IOGP data base were used in the development of the new TRACEr OGI model.

1.1 Why accident analysis

Over the years, the cause of accidents has claimed several lives and injured many at various degrees. Because of this, the evolution of safety analysis emanates in some fields such as nuclear, military, civil and space technology (Suokas 1988). Meanwhile research has shown that the cause of many accidents is attributed to human or organizational failures, in the other hand cognisance and precaution play an important role in this aspect to overcome many challenges of accidents occurrence. Accident theories represent an important domain trying to explain the occurrence of accidents and factors affecting them (Suokas 1988). Therefore, the rationale behind the application of accident analysing tools indeed cannot be over emphasised as greater importance is attached in the use of such tools in overcoming the reoccurrence of accidents. Near miss and real accidents reports is an important subject in the oil and gas industry which necessitate the outline of safety rules for taking precaution. Hence both occupational and process safety are a requisite in all oil and gas industrial operations. Shorrock and Kirwan (2002) quoted that "The investigation, analysis and classification of human error offers perhaps one of the best ways forward for learning from such near misses so that accidents remain rare events.

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2. THE ORIGINAL TRACER TAXONOMY

As one of the human error identification techniques, the TRACEr model was originally developed as a tool to analyse accidents in the aviation industry (Shorrock 2003). Basically, the taxonomies comprise of eight sections which defines the human error in context. The hierarchical order of the taxonomy in the original TRACEr model is given as follows;

1. Task error.
2. Information
3. Performance Shaping Factor (PSF's).
4. External Error Modes (EEM's).
5. Internal Error Modes (IEM's).
6. Psychological Error Mechanisms (PEM's).
7. Error detection.
8. Error Correction.

According to Shorrock (2002) the TRACEr model taxonomies were divided in such a way to describe the actual content of an incident, the operator and the error recovery in the aviation industry. However, the aim of this paper is not to explain the concept of the original TRACEr model in-depth, but it is important to outline taxonomies of the TRACEr model and their sublevels as given in table 1 below:

Table 1: The main TRACEr Taxonomy used in the aviation industry.

Major Divisions	**Subdivisions**
Context of incident	1Task error
	2. Error Information
	3. Casualty level
Operator context	4. External error mode (EEM)
	Cognitive domains
	5. Internal Error Mode (IEM)
	6. Psychological Error Mechanism
	7. Performance Shaping Factor (PSF)
Error Recovery	8. Error Recovery

Shorrock, (2012)

2.1 Accidents nature of the oil and gas industry

In design of any model for accident analysis, understanding the nature of accidents and personalities of the organization is the first and foremost requirement. Therefore, it is quite important to critically analyse this scenario for better fitting of the proposed TRACEr OGI model. The nature of accidents in the oil and gas sector is little bit different respect to the aviation sector especially in diversity and number of personnel handling major central activities. Although drilling operation will basically be considered in designing the model, but it worth to mention that the term cut across all other activities leading to the success of the drilling. Therefore, starting from site clearing and geologic seismic surveys to the real drilling operation are all considered as the major task in the oil and gas industry associated with accidents. It has been respectively found that the rate of fatality in the oil and gas industry is about 7 times higher than the aviation and all other general industries including construction industry (Witter et. al 2014). According to the report by US department of Health and Human services, the fatality rate statistics in the oil and gas industry shows an uneven result with rise and fall over the years. Figure 1 below represents the result of the statistics from 1993 to 2010.

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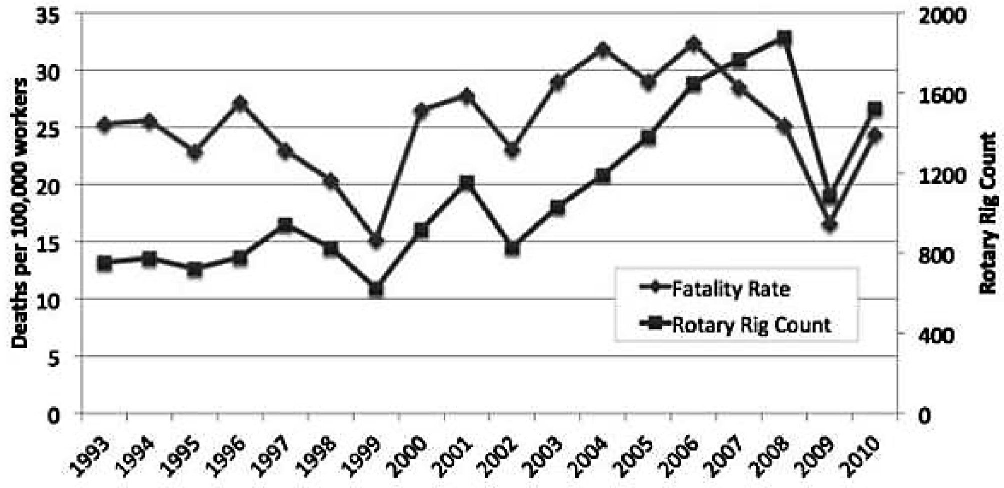

Figure 1: Fatality rate in the oil and gas (US HHS, 2012)

To better understand the trend of the incidents, oil and gas industry operations are commonly addressed into two basic sectors called the upstream and downstream. Upstream considers the exploration and extraction process while downstream represents processing, transport and other activities that follows (Saetren 2007). Besides all, the obvious and most prominent accident is the incident of struck by objects during operations such as drilling and among others. The United States department of labour established a statistical report on general context of accident scenarios likely associated with the oil and gas operation.

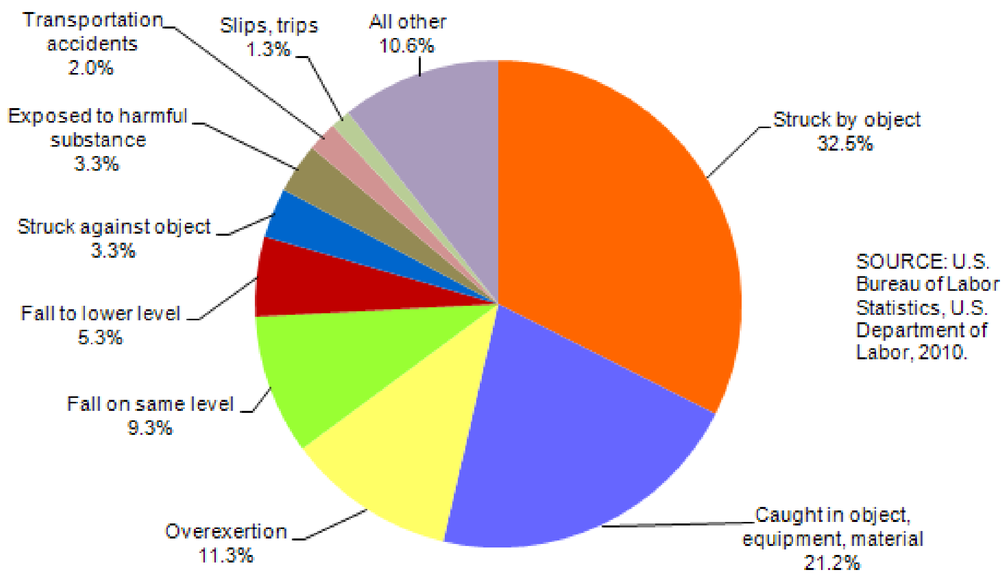

Figure 2: General incidents leading to accidents in the oil and gas industry (US Department of labour, 2010)

2.3 The Modified phases of the TRACEr

As earlier discussed, the main TRACEr model was originally developed to analyse Human Machine Interface (HMI) of air traffic controllers in the aviation industry, but the model taxonomies have been earlier modified by various of authors for different adaptations. Therefore, it is significant to mention some of these modifications as obtained from the literature. Table 2 below shows some of the models derived from the main TRACEr model.

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Table 2: History of the TRACEr model Modifications.

Author(s)	Sector	Studies	TRACEr Version	Key Modification
Shorrock (2002)	Aviation	Error classification for safety management	TRACEr lite	Combined the cognitive error modes and mechanisms as internal error. Finally adopted the TRACEr into six taxonomies
RSSB Limited (2005)	Railway (UK)	Review of Rail safety and standards board report February 2005	TRACEr-Rail (UK)	Separated the taxonomies of error detection and recovery as different units.
Baysari et. al (2008)	Railway (Australia)	Understanding the Human factors contribution to Railway Accidents and Incidents in Australia	TRACEr-RAV	Adopted the TRACEr into nine taxonomies and mentioned Performnace factors as the eigth taxonmy
Schroder-Hinrichs et. al (2016)	Maritime	Applying TRACEr in a maritime context.	TRACEr- MAR	Changes were made by adding contextual information on the task error.

Beside the recent modifications which included the TRACEr-MAR developed for maritime operations by Schroder-Hinrichs et. al (2016), several other modifications have been made on TRACEr taxonomy for the fact that it is comprehensive in classifying cognitive errors related to human-machine interface (Walls et. al 2016).

2.4 The TRACEr-OGI framework

In achieving the goal of formulating the new model, the previous TRACEr taxonomies for the aviation industry were critically analysed in other to utilise taxonomies of most benefit to develop the TRACEr-OGI. The bases of the frame work focuses on the personnel and situation of accidents happening in the oil and gas industry. Drilling in context as a major activity with highest level of accidents probability in the oil and gas sector is most considered in achieving the framework. Based on this prospect, the following outline is proposed for the TRACEr-OGI taxonomy. The original TRACEr model which has eight taxonomies is modified to have seven levels of taxonomy with changes to the cognitive domain of the operator context. This is for the fact that both the Internal error mode and the psychological Error mode were aspect of cognitive functions, hence they both tend to provide understanding of the cognitive failure (Soares et. al 2014). Hence, the TRACEr OGI model taxonomies were proposed as in table 3 below.

Table 3: The TRACEr-OGI Taxonomies

Major Division	TRACEr-OGI subdivisions
Context of incident	1. Task Error
	2. Error Information
	3. Causality level
Operator Context	4. External Error Mode (EEM)
	5. Cognitive Error Domains (CED)
	6.Performance Shaping Factors (PSF's
Error Recovery	7. Error Detection and Recovery

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2.5 Description of the TRACEr-OGI Taxonomies

The use of the taxonomy is on a hierarchical order describing both predictive and retrospective instances starting with the overall goal task (Stanton et. al 2003). This is because the human cognitive structure contains link to series of events happening at the beginning middle and end (Tulving 1972). The process of the taxonomy goes on Hierarchical task analysis (HTA). And since the model has been organised to address incidents before and after, the term predictive and retrospective were normally used to classify the taxonomies. The scope of main TRACEr was quite limited especially regarding the number of personalities and locations involved (Schroder-Hinrichs et. al 2016). Hence a wider scope of personality and location has been considered for the TRACEr-OGI especially in the area of task error description. The set of operators list that can be obtained from an onsite and offsite oil and gas industries can be summarised as follows;

The on-site OGI operators

1. Drillers.
2. Mud logger.
3. Drilling crews.
4. Electricians.
5. Light and heavy machine operators.
6. Cleaners.
7. All other roustabout.

The off-site OGI operators

1. Basically, includes all set of drivers on road transport.

Therefore, in the cause of the diverse personalities relative to accident error analysis in the oil and gas industry, the TRACEr-OGI classify task operators as OGI-Operators depending on incident description.

2.5.1 Task Error

This describe the actual context of the OGI operator for any task not performed in order. A retrospective category of the taxonomy expressing the range of incidents due to OGI operators. Task error incidents by OGI-Operators occur both on-site and off-site. For example, communication error between drilling crews, Poor gauge or valve reading, input and function errors, and error due to lack of supervision and training were at times very common as a cause for the accidents in the oil and gas industry.

2.5.2 Error Information

The source of user equipment leading to the cause of accidents are classified as error information. Considering size, dimension, location, etc. (Graziano et al. 2016). Hence, examples of the OGI equipment that may likely incline to cause accidents may include; the Blowout preventer, rigs, pipes, trucks, Drilling table etc.

2.5.3 Casualty level

Determining the causal level of the incident is described by the casualty level as either causal or not (Soares, et. al 2014). It helps to express the contributory level of the operator towards the error. Hence mostly represented as contributory, non-contributory or compounding.

2.5.4 External Error Mode (EEM)

These are predictive out of cognitive function aspects of an incident **(**Shorrock 2002). External factors that could lead to the error of the operator are classified as External error modes. Hence, they are observable form of the error (Embrey, et. al 1994). These may include; poor selection of valves, gears, or application of brakes etc. They are usually categorised in terms of selection, timing ang communication (Soares et. al 2014).

2.5.5 Cognitive Error Domain (Modes and Mechanisms)

This is basically the cognitive function which defined the nature of the incident. Internal and psychological error modes defined the cognitive domain (Soares et. al 2014). Example include; memory failure, misidentification, insufficient learning, expectation bias, and distraction etc. Hence this represents decision making process leading to an accident

2.5.6 Performance Shaping Factors (PSF's)

Groth, (2009) asserted that these are factors which can influence the performance of the human leading to an error. Therefore, to maintain reliability of human operation, system and task design should correlate with personnel performance (Mackieh and Cilingir 1998). Examples of Performance shaping factors include; environmental noise, smell, or temperature, personal fatigue etc.

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2.5.7 Error Detection and Recovery

Represents how the operator become alerted of the error. Error recovery can also mean barriers provided to prevent the accident or error occurrence. Usually categorised into for different classes viz;

1. Physical barrier: Material types such as walls, doors and covers.
2. Functional barrier: Barriers such as valves, brakes, phone and alarms etc.
3. Symbolic barrier: Symbols of danger and other warning signs.
4. Incorporeal barrier: Barriers related to ethics and training.

3 Application of the TRACER-OGI

The model of the TRACEr-OGI taxonomy provides that error analysis will be accomplished on a hierarchical order. The trend of the hierarchical order represented in figure 4 below.

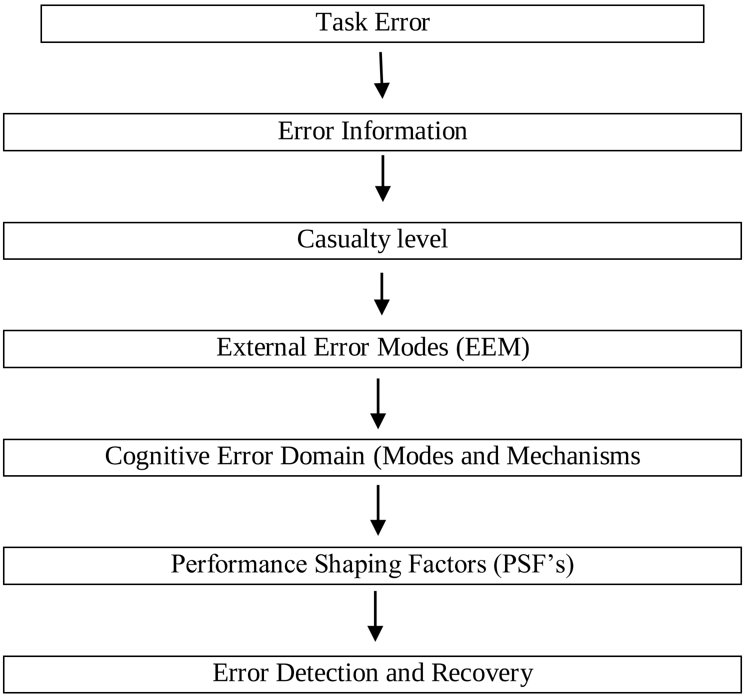

***Figure 3:* Hierarchical order of the new TRACEr-OGI model**

There exists a loop connectivity between all the taxonomies as adopted from the previous TRACEr aviation model. Shorrock and Kirwan (2002) revealed that, understanding the concept of the relationship between the TRACEr taxonomies is very vital in applying the model for accident analysis. They formulate a connective relationship which expressed the loop between the taxonomies as shown in figure 4 below.

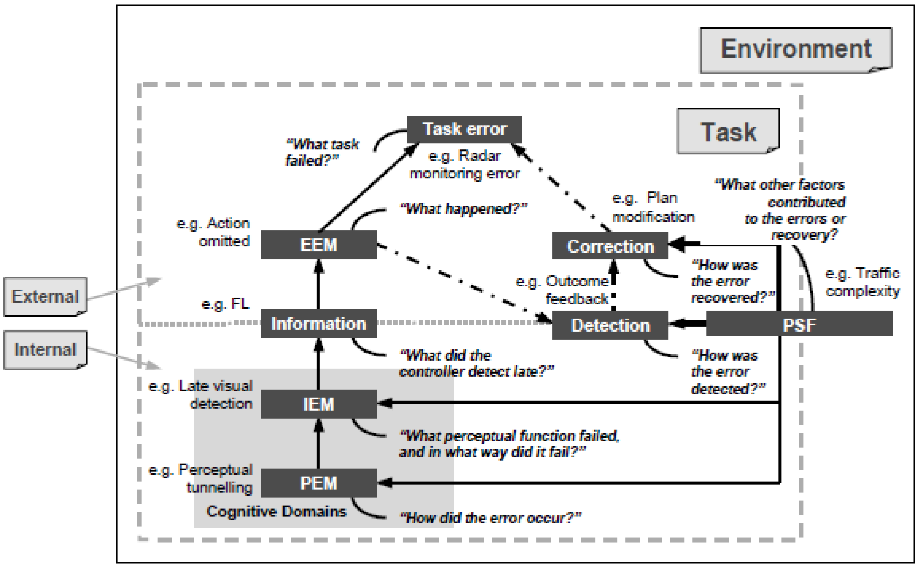

Figure 4: The relationship between the taxonomies of TRACEr (Shorrock and Kirwan 2002)

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4.1 Accident coding and analysis

An excel spread sheet was used to analyse the reported accidents obtained from the IOGP database. The new TRACEr-OGI was formulated based on the analysis of the records of the accidents. For this purpose, the oil and gas accidents were categorised into either on-site and or offsite location. On site accidents represent all the categories of accidents that usually occur during the industry operation hours and within the working environment of the industry. Meanwhile, offsite represents those set of accidents that occur outside the working hours of the industry operation. Oil and gas personalities mentioned in the cause of the incidents included the driller and his crew, electricians, drivers, land clearing operators and other roustabouts. At the end of the coding process, a total summary of the data obtained were presented in tables and graphs for further discussion. Comprehensive list of the accidents analysed were also presented in the appendix section of this paper.

4.2 Results and Discussion

The result of the analysis for reliability test shows an influence of the Human-Machine Interface relative to the task errors in the oil and gas industry. More than 45% of the accidents were contributory due to human-machine interface. Based on this, the cognitive error modes and mechanisms and other levels of the taxonomy were drawn on scale in support of the hypothesis to modify the cognitive error mode section of the previous TRACEr aviation mode. Figures 5 and 6 shows the Causality levels from the list of the analysed accidents were the non-contributory and compounding causalities represents 23% and 29% respectively. Results of the reliability test shows that model can be used to analyse oil and gas industry accidents However, limitations of the TRACEr-OGI model include; lack of specific coding guide for the various accidents and difficulty in classifying task errors based on the error information. Hence, there is a need for further research to provide a comprehensive guiding list and specific descriptions of all the possible oil and gas accidents with respect to the model.

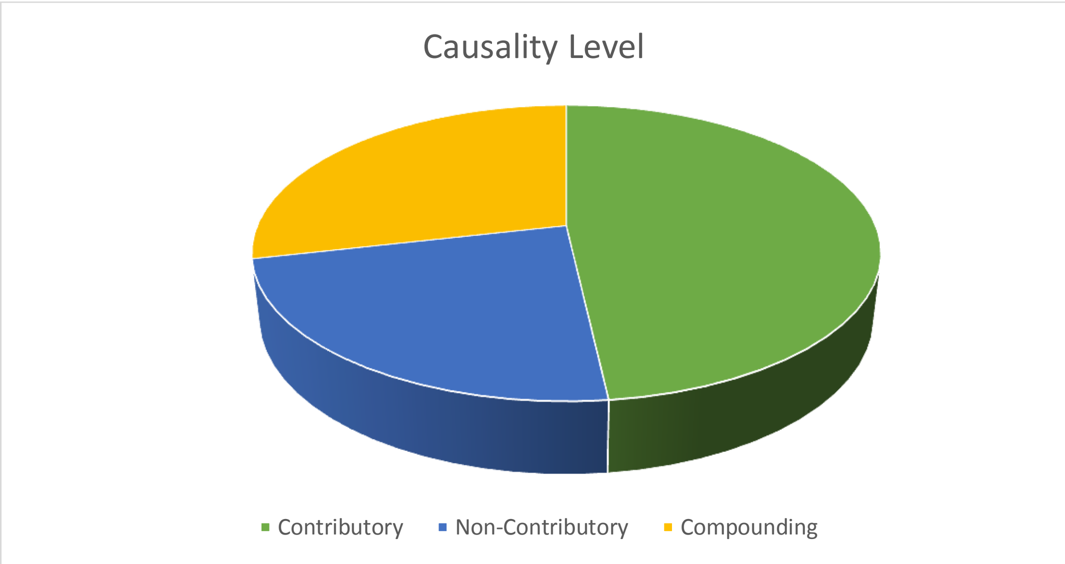

Figure 5: Contributory level due to human-machine interface.

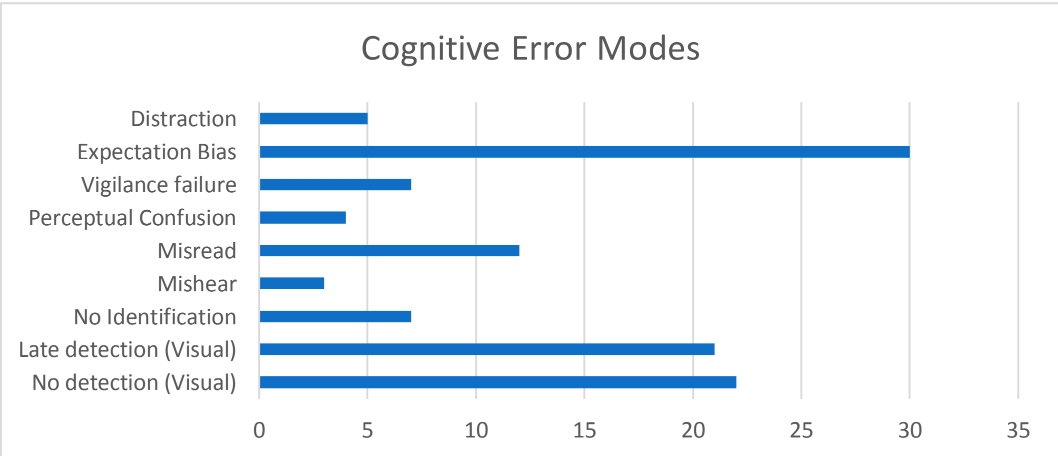

Figure 6: Cognitive Error Modes and Mechanisms.

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5. CONCLUSION

As a result of the increasing growth of technology leading to opportunities for distinguished roles and personalities in the oil and gas industry, similar health and safety models would also be required to further address accident challenges. James Reason and Michael Maddox (1978) quoted that "Since people design, build, operate, maintain and manage potentially hazardous technologies, it is hardly surprising that their decisions and actions contribute in one way or other to virtually all unwanted events". TRACEr-OGI is developed with the aim to analyse the various sets of accidents in the oil and gas industry. The TRACEr model used in the aviation is modified to fit into the analysis of accidents from the oil and gas industry. The central change was been made at the cognitive level of the operator context. An influence of the Human-Machine Interface relative to the task errors in the oil and gas industry is the central idea of the new TRACEr-OGI model. The result of the analysis for reliability test shows that, there exist a reasonable percentage of correlation and that the TRACEr OGI can be adopted for accident analysis in oil and gas industries.

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Appendix:

List of accidents analysed as obtained from the IOGP accident database. 188 fatal incidents leading to 195 employee fatalities were found on the Russia/ Asia database records. A total of 36 incidents were analysed and used for the coding and development of the TRACEr-OGI were presented from tables 1-8 below.

Table 1: Incident reports from 2000-2014

Year	Incident Description	Sector	Main cause	Incident ID
2000	Violation of safety rule by not checking the closure of connector.	On-site	Violation	8199
2000	Company factor required to travel without notice & under the influence of alcohol.	On-site	Cognitive failure	8230
2000	Use of improper protection equipment leading to gas poisoning.	On-site	Lack of Training	8055
2000	Crushed between equipment while dismantling a rig.	On-site	Negligence	8080
2001	Digging a trench and collapsed on the process.	On-site	Insufficient Training	8076
2002	Collision of Truck and a private Car on road transport.	Off-site	Insufficient Training	8036
2003	Death of mechanic because of poor job training and safety violations.	On-site	Insufficient Training	7871
2003	Falling of a steel pipe section of a tower because of poor welding and lack of training for sawing.	On-site	Negligence and Violation	7872
2003	Driver crushed to death between two trucks trying to stop the movement with hand.	On-site	Negligence & Poor training	7962
2003	Death of electrician because of poor training and inadequate supervision	On-site	Insufficient Training	7960
2004	Assist. Driller died of electrocution because of violation and use of malfunctioning equipment.	On-site	Violation	7787
2004	Ignition during a well workover operation because of spilled oil and gas left careless.	On-site	Negligence &Violation	7790
2004	Mobile crane failed to climb a hill leading to an accident. (Violation of work procedure)	Off-site	Violation	7798
2005	Contract painter fall into a manhole because of taking out the wood covering.	On-site	Violation	7683
2005	Poor visibility condition leading to vehicle accident collision with a service rig parked by the road side.	Off-site	Violation & Negligence	7726
2006	During pipe lifting operation because of procedure violation.	On-site	Violation	7614
2006	Pipe breaking out of hammer because of poor judgement.	On-site	Negligence	7616

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2006	Accident caused because of moving a dozer without receiving signal procedure	On-site	Violation	7665
2007	Accident during reverse process because of no mirror and reverse alarm systems.	On-site	Violation	7488
2007	Taking journey without Company permit & Intoxication leading to an accident.	Off-site	Violation	7482
2008	Tree cutter manual labourer died during tree cutting fall on to him.	On-site	Poor Training	7362
2008	Fell into ice during seismic survey.	On-site	Violation	7371
2010	Operator engulfed to accident because lacking safety fitted guard.	On-site	Violation	7239
2010	Accident occur because of dismantling temporary flow line under residual pressure.	On-site	Violation	7242
2010	Falling of dead tree on clearing site	On-site	Insufficient Training	7243
2010	Died on drilling truck because of electric shock.	On-site	Insufficient Training	7245
2010	Died during well workover because of breaching technical rule	On-site	Violation	7249
2010	Falling of BOP from a hoisting system.	On-site	Violation Insufficient training	7172
2010	Driver got road accident by colliding with another truck.	Off-site	Insufficient Training	7252
2011	Gas explosion during cleaning operation.	On-site	Violation	7174
2011	Drill assistant crushed by a drill collar.	On-site	Violation	7175
2011	Tractor driving on winter lost control of gears	Off-site	Equipment Failure	7181
2012	Reduced visibility leading to roadside accident.	Off-site	Violation	7092
2012	Uncontrolled downhill of crane during operation.	On-site	Equipment Failure	7147
2013	Accident because of poor training using vacuum unit	On-site	Insufficient Training	7051
2014	Improper welded plug tearing off during well construction.	On-site	Violation	6994

Source: (IOGP, 2017)

Tables 2: Task Error Locations from TRACEr-OGI analysis

ON-SITE AND OFF-SITE OPERATIONS	
Location	**Number**
On-site	25
Off-site	11
Total	36

Table 3: Summary of Personalities involved

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PERSONALITIES INVOVED	
Personality	**Number**
Driller	11
Driver	13
Mechanic	1
Electrician	1
Others	10
Total	36

Table 4: Equipment Leading to Task Error

EQUIPMENTS INVOLVED	
Equipment	**Number**
Rig	12
BOP	3
Crane	17
Truck	11
Others	11
Total Occurance	54

Table 5: Cognitive Error modes and Mechanism

COGNITIVE ERROR MODES & MECHENISMS	
Error	**Total**
No detection (Visual)	22
Late detection (Visual)	21
No Identification	7
Mishear	3
Misread	12
Perceptual Confusion	4
Vigilance failure	7
Expectation Bias	30
Distraction	5
Total	111

Table 6: Summary of incident causes

SUMMARY OF INCIDENTS (Causes)	
Cauase	**Number**
Violation	20
Insufficient Training	12
Neglignce	6
Equipment Failure	2
Total	40

Table 7: Performance Shaping Factors.

PERFORMANCE SHAING FACTORS (PSF's)	
Factor	**Number**
External Env'tal Factors	12
Organisational Factors	4
Personal Factors	16
Total	32

Table 8: Causality Level of the incidents

CAUSALITY LEVEL	
Factor	**Number**
Contributory	27
Non-Contributory	13
Compounding	16
Total	56

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