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Patterns and characterization of accidents and incidents reported in oil and gas industry in Norway

Keywords

accident, incident, correspondence analysis, trend analysis, risk management, oil and gas

Abstract

Understanding the safety level of processes in any industry or any sector requires a situational analysis of current and future activities. This analysis includes identifying the hazards and sequence of events that can harm and lead to specific losses. Safety and risk levels are closely related to accident statistics. Accident/incident statistics and reporting systems enables enterprises and companies to identify risks, implement corrective measures' and comply with the national requirements and standards on health safety and environment.

The study describes how the accident statistics can be used as a basic tool for measuring the safety performance in oil and gas industry. The state of art in the literature in the field will be highlighted and analyzed with the summary of personal injury related statistics in Norwegian continental shelf is highlighted and analyzed.

1. Introduction

Numerous definitions of the term *accident* are mentioned in the literature. An accident is defined as an event which results in unintended harm or damage. Heinrich defines it as an unplanned and uncontrolled event in which the action or reaction of an object, substance, person or radiation, results in personal injury or the probability thereof [20]. World Health Organization (WHO) defines an accident as an event that results or could result in an injury [39]. Accidents may include anything in the daily work life or external environment.

An accident is normally perceived as some sudden and unexpected event, leading "down stream" to harmful consequences, such as injuries [2], [3]. Accident can be the result of a contact between an object and a source of energy (kinetic, mechanical, electrical, thermal, chemical, acoustical, radiation, etc.) [31] or involve the transfer of energy in such ways and amounts, and at such rapid rates, that animated or inanimated sources are damaged [18]. Accidents are of different types, they result from a combination of factors that, in some combination, cause an accident. These combinations remain difficult to detect using traditional safety analysis logic [1].

A physical injury is a physical damage to a human body that is subjected to intolerable levels of energy. It can be a bodily lesion resulting from acute exposure to energy in amounts that exceed the threshold of physiological tolerance, or it can be an impairment of function resulting from a lack of one or more vital elements (i.e. air, water, warmth) [22]. Accidents resulting in personal injuries include a wide variety of events, such as burns, falls, falling overboard, mechanical impacts, suffocation, asphyxiation, etc. or in a change of or interfering with a normal body function (asbestosis, cancer, blindness, deaf, repetitive strain injury, etc.). Besides the direct consequences on injured persons, injuries might have direct effect on the social interaction and working conditions for the whole unit or company.

Some accidents might result in damages to properties or surrounding environment.

Accidents appear to be caused by direct exposure to the energy source or by side effects of decisions made by different actors distributed in different organizations, at a different level of society, and during activities at different points in time [30].

The regulations in the oil and gas industry make it compulsory to report incidents to the national authorities. The companies in this industry are also required to submit an annual condition report concerning load bearing structures summarizing operational experience and inspection findings. Based on these data, several types of statistical analyses are conducted to determine the safety level of specific companies. Trend analysis is one such analysis triggering an investigation, whether trends are present in the data. Trends are determined by data showing an increase or decrease over time beyond random fluctuations [5]. The information from oil companies are therefore compiled and analyzed with various statistics and trends reported for learning purposes, for enforcement of legislation and for triggering preventive actions.

The data from various database assessed with analyzing of the trends in the data from Norwegian petroleum safety authority. The results demonstrate clear decline of injuries and injury rates in the Norwegian continental shelf in the last years. These indicators and trends declare the usefulness of the accident data collected by various institutions. The frequency of severe accidents are limited and incident rate varies by activities and type of the installations, The decline of the injuries and injury rates in Norwegian continental shelf can be a result of successful safety management programs in part of companies and high focus on safety culture and safety promotion in part of public and authorities.

In analyzing data based on severity and type of operations. We found variations in the scope based on the main activities and installation type. In mobile installations the injury rate is higher in drilling and well operations than other types of operations; in permanently placed installations the injury rate is higher in operation and maintenance than other types of operations and activities.

At the beginning of the past century [9] Blanchard stated that, in general, there were no statistics on the number of industrial accidents throughout the United States except for certain states have gathered such valuable data.

In the same study [9] showed that, a careful record of the disabling injuries occurring in a large steel plant from 1900 to 1911 shows the positive effect of a developing safety program. These accidents were reduced from 370 per one thousand, 300-day workers in 1900 to 109 per one thousand in 1911, a decrease of over 70 per cent. He went on to state that, the reduction in accident frequency is the most immediate and striking result of safety work.

The characteristics of accidents vary in different types of industries, installation and companies [30]. For industrial installations that have a potential for large scale accidents, the acceptable frequency of accidents will be low [31]. In the last decades along with higher energy consumption there has been a trend of increasing number of severe accidents resulting in fatalities and morbidities and gas industry. According to the previously published data on accidents the energy sector has been recognized as one of the main contributors to man-made disasters in the field of energy production. It was estimated that about 25% of the fatalities caused by severe accidents world-wide in the period 1970−1985 occurred in the energy field [14].

And in Norway prior to 2002 the positive results in HSE performance on the Norwegian continental shelf has declined. Indicators of this negative trend are: incident and accidents occurring in the offshore oil and gas industry in Norway have become more frequent and severe, and the operator’s ability to prevent the next accident could be questioned. Since several of these incidents and accidents have been reoccurring events [24]. In some areas of the industry work to improve safety is well advanced. As an example, twelve years ago one of the major oil companies set what were then challenging targets to reduce the 5-year average Fatal Accident Rate (FAR) for air operations within the company from a level of 15 per million flying hours to less than 5 by the year 2000. Two years ago, the company reviewed its goals and set intermediate targets to reduce the 10-year average FAR from 4.0 per million flying hours at the time, down to less than 2.0 by 2008 and to less than 1.0 by 2013 [10].

Objectives:

- To highlight the main factors contributed to accident occurrence in the last decades,
- To analyze the patterns of severe occupational accidents reported to the petroleum safety authority in Norway during 1975 to 2009, and
- To study the characteristics of the occupational accidents and provide scientific evidence for prevention and control strategies.

Methods:

A review of relevant literature in the field conducted together with presenting a summary of several theoretical models of accident causation and searching websites for existing data and information on accidents in medium and large oil and gas companies.
Assessing the type of the data collected in each of the main databases studied in terms of variations and content. And assess if these data provide information about the future risk?
The accident data have been collected from various sources as WOAD database [1, 2, 15] and incident registration from Norwegian petroleum authorities during the period 1975-2009. The data are analyzed with descriptive methods using PASW software.

2. Statistical analysis

In this study we used the Correspondence Analysis as a descriptive/exploratory technique designed to analyze simple two-way and multi-way tables containing some measure of correspondence between the rows and columns. The method is a visualization method for picturing the associations between the levels of a two-way contingency table [28]. It provides insight into the dependence of two categorical variables by examining the deviations from the independence model in a way that allows detection of patterns in these deviations.
These methods were originally developed primarily in France the original name ***analyse des correspondances*** have their root in the work of Benz´ecri and coworkers in (1973). Kenett and Raphaeli [25] describe the method in details, the observed association of two traits is summarized by the cell frequencies, and a typical inferential aspect is the study of whether certain levels of one characteristic are associated with some levels of another.
An implementation of correspondence analysis using MINITAB is presented in figure 1 and 2. For more details on correspondence analysis see Greenacre (1993) and Fienberg (1987). In our study, the distance between the row points is a measure of similarity between the row-frequency profiles - the severity degree and the installation type are far from each other because their profiles are different. Distances between the points representing years are interpreted in the same way – each year point represents the profile of that year across the various severity degree.

3. Theoretical framework

An accident is defined as unexpected, unplanned, or unwanted events that may cause damage, injury or illness to people. An accident may interrupt the production and flow of the work process. Accidents caused by the transfer of an excessive amount of energy from other objects or substances. Occupational accidents are accidents, which have consequences on the working process, work site, defined area of work and may cause injury and mortality but are often having no potential to cause fatalities outside the immediate area of the incident.
Accidents are mutually independent events, two accidents cannot occur at the same time. Accidents can be classified based on different classification systems and definition.
Accident data are collected for personal injuries, occupational illnesses, fires, explosions, crashes, property damage, and environmental damages.
Accident statistics are considered to be one of the basic tools for measuring the safety performance of a company [34]. Although the data are historical data, they would usually provide a good picture of what to expect in the future [5]. The selection and implementation of appropriate safety measures require much more detailed information than the compilation of statistics. The database should therefore, contain uncoded information (i.e., written free-form descriptions of accidents for prevention purposes) [26]. All accidents occur in oil and gas industry can be classified as occupational accidents. Most oil and gas companies collect data on accidents and injuries among their employees and others working for them.
Medical Reports are vitally important in identifying causes of injury morbidity (non-fatal injuries) [8]. Personal injury and occupational illness data are collected and maintained for all operators in the North Sea (Norway + UK). However, accident data are reported in the organizations internal system to the related national authorities. This is a requirement containing basic information on the event, the type of the accident, severity, consequences, type of operations and country of operations.
Good injury surveillance requires a standard system for classifying injuries, together with a system for keeping records on individual cases and producing summary statistics [22]. Gordon (1998) emphasizes the importance of standardized accident reporting and analysis of human factors' causation for meaningful data analysis, and points out that a major challenge facing oil companies in analyzing accident trends to avoid future oil spills is that the available data set of major accidents is very small. Whatever the level of surveillance and whatever its scope, it should be borne in mind that, most often, injury

surveillance is limited to the tip and middle portion of the morbidity iceberg [27].
Each potential source of data will have its own set of advantages and disadvantages [22]. Personal injuries, property damages and production loss accident data may be used for other purposes as insurance and claims. In the last decades different databases established by major authorities and stakeholders to have an overview over the scope and magnitude of the incidents and accidents in oil and gas operations onshore and offshore.

4. Accident categories

Accidents leading to injuries and injuries cannot occur without the action of specific agents. These agents are the several forms of injury, varying and interacting with the characteristics of the host and the environment [19]. Different types of accidents have different mechanisms of causation.

- External source of energy
- Potential energy
- Internal overload
- Internal overuse

The energy causing an injury may be [22]:

- mechanical (e.g. an impact with a moving or stationary object, such as a surface, knife or vehicle)
- radiant (e.g. a blinding light or a shock wave from an explosion)
- thermal (e.g. air or water that is too hot or too cold)
- electrical
- chemical (e.g. a poison or an intoxicating or mind-altering substance such as alcohol or a drug).

In addition to categorizing data and accidents by classification (severity), a scaling system most commonly used for classifying injuries is AIS (Abbreviated Injury Scale). Based on the system the injuries can be classified as: minor, moderate, serious (not life threatening), severe (life threatening, survival probable), critical (survival uncertain) and Maximum injury (Virtually un-survivable) [35]. Accidents are also categorized by operational or activity categories. These include; installation type, operation type and ownership.

Work related accidents in general, and fatal accidents in particular, can be classified and grouped according to a variety of causal factors as many of the features of working conditions may present hazards by not being sufficiently adapted to workers' physical and mental capacities. The descriptions of exposure characteristics in injured individuals, and are useful for detailed in-depth initial investigations of potential factors in injured subjects [6].

The quality and amount of data depend on the willingness of individuals to report witnessed accidents, which is often a challenge if the witness is the same person that committed the offense. The solution is to create a "reporting culture" where individuals can report without fear of blame. The reporting system should create an environment where witnesses are encouraged, not discouraged, to report. However, accidents are not always preceded by a wake-up call (Turner studied 85 different accidents and disasters, noting a common pattern: each had a long incubation period in which hazards and warning signs prior to the accident were either ignored or misinterpreted. He called these "failures of foresight" [36].

Results:

In the total of 6033 incidents registered items; accidents accounted for 39.7%, incidents 43.4, near miss 6% and 10% were insignificant.
The database of the Norwegian Petroleum Safety Authority (PSA) has 1223 cases registered for personal injuries covering the period from 2 January 1997 - 29 April 2009. The reporting of incidents and accidents increased from 2004, the increase partially is due to including the incidents from onshore facilities reported to the Norwegian petroleum safety authority.
The data on the severity of incidents based on the PSA criteria showing the decrease of incidents with at great potential for major accidents or mortalities, and similar decline is seen in the last years for incidents with severe consequences.
The consequences and severity of injuries varied based on the type of installations; 1.4% accidents where incidents with a great potential for major accidents or resulting in death, 14.6% classified as severe incidents, 63.9% of the incidents reported are of the classified group which requires easier follow from management and operators.

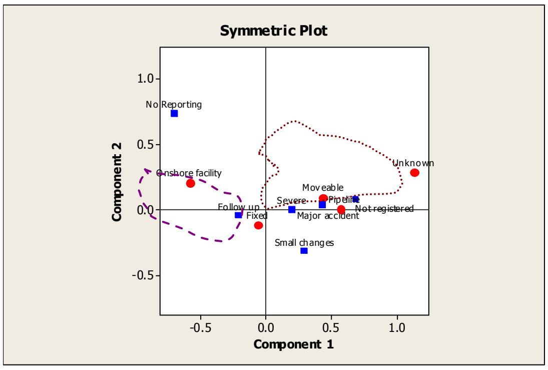

Figure 1. Incidents registered per installation type and severity.

In analyzing data based on severity and type of operations. We have analyzed the data based on the main activities and classifications. The data on the activity type was not complete out of 1223, there were 405 cases not classified by activities accounting for 33.1% of the database and other 358 cases were registered as other not classified representing 29.27% of total cases registered.

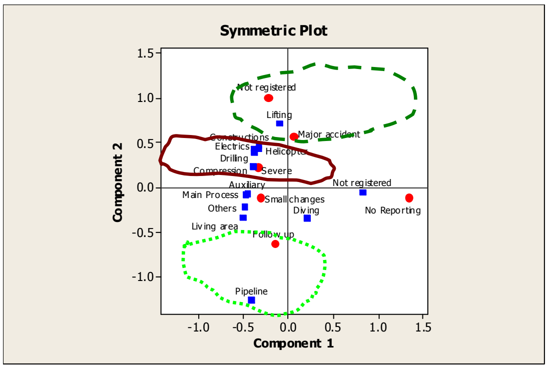

Figure 2. Incidents registered per severity and type of operations

Occupational injury is characterized in this study through various indices; It first indicates the category, second indicates the frequencies of the injuries while the third refers to the severity of the injury and fourth refers to actual consequences based on DFU (defined hazard for accidents) classifications.
Data related to DFUs as actual consequences are based on existing databases in the PSA which is based on data collection carried out in cooperation with the operating companies.

These DFUs has been classified and each type had been given a recognized number.

Table 1. Incidents registered per severity and DFU

Actual consequences	Not subject to reporting	Easier follow-up	Potential with small changes	Severe	Great Potential/major	Not registered	Total
DFU01 HC leak, non ignited				1			1
DFU02 HC leak, ignited					1		1
DFU04 Fire		1					1
DFU10 Personal injury	32	732	15	149	16	194	1138
DFU11 Work related illness				1			1
DFU14 Radio active sources		1		1			2
DFU15 Falling objects		20	2	16		1	39
DFU17 Lifting incidents		11		9			20
DFU18 Diving incidents		1					1
DFU36 others		15		2			17
DFU99 No consequences		1					1
Not registered			1				1
Total	32	782	18	179	17	195	1223

There were totally 1223 incidents in the database and 1138 of these classified as personal injuries, 149 cases as severe accidents and 16 of them as having a high potential for major accidents and death.
The data from PSA showing that, the total injury rate in NCS was declining for all activities, and types of installations. For mobile and movable installations the total injury rate declined from 32.8 injuries /mill hours in 1999 to 8.7 injuries/mill hours of work in 2008. And for permanently placed installations, the total injury rate declined from 26.5 injuries / mill hours of work in 1999 to 10.7 injuries/mill hours of work in 2008.
In mobile installations the injury rate is higher in drilling and well operations than other types of operations in 2008 the rate was 12.9 injuries/mill hours worked, at the same time as in permanently placed installations the injury rate is higher in operation and maintenance than other types of operations and activities, it was 15.1 injuries/mill hours worked.

Discussion:

Risk, risk assessment and accident statistics are closely related. In the last decades, lots of data collected and numerous reports and tables are produced showing the number of fatalities, injuries and damages as a result of accidents. These data are stored within relational databases, where quantitative data are stored in columns and rows that are easily queried to quickly and effectively find desired information [11]. These reports and statistic analyses covered limited number of accident data assembled by different stakeholders and classified by different categories. These accident data classified within different consequence categories (fatalities, personal injuries, material damages, environmental impacts, etc.), and they could be related to different types of activities such as; lifting, diving, transport, processing, accidents, etc.

Accident statistics are used by industry, they are seen as an essential tool for management and obtain regular updates on the number of injuries (suitably defined) per hour of working, or any other relevant references, for the total company and divided into relevant organizational units [5]. These data are historical data and when using these data correctly for risk analysis, we need to classify personal injuries based on occupations and operations as the risk of personal accidents depends strongly on the occupations of the workers involved.

The classical statistical approaches to deal with accident statistics in oil and gas industry are ineffective for low frequency, high consequence events because of their rarity. Gordon (1998) recommends that the oil industry combine accident databases with those of other process industries (e.g. nuclear, chemical) to draw on a broader data set. However, this would require standardized accident reporting across industries.

Accident statistics are one of the basic tools for measuring the safety performance of a company [34]. Although it is impossible in practice to prevent every accident, it is fully possible to prevent many and perhaps most of them [23]. A successful accident prevention program must accurately determine the cause of previous accidents and focus safety efforts in the areas where hazard remediation can have the greatest effect on the future likelihood of serious industrial accidents [40].

Oil and gas accident statistics reveal that workers' potential for injury or death from occupational accidents is at least as high as that associated with explosions, fires, and other major incidents [4]. The control over the severe occupational accidents is urgent. The trend of the characteristics of severe occupational accidents is centralized in the high risk industries, poisons and jobs [30]. The North Sea can be regarded as unfriendly environment for offshore activities and the nature of activities in these circumstances may lead to severe offshore accidents. Total damages due to severe accidents in the energy sector are very small in comparison with natural catastrophes but also when compared with the impacts of air pollution originating from the energy sector [21]. The accident frequencies in high reliability organizations are so low. The reasons for the low accident frequencies of high reliability organizations may lie in the effective barrier systems implemented and the organization's ability to recover from problems once they occur.

The purpose of accident analysis is to look for the events and conditions that led to the outcome and that is to find the set of probable causes [41]. Understanding causation helps identify the factors surrounding an occurrence, particularly the organizational and human factor elements. In view of that, the initiating events can be divided into various categories as: human or operational errors, technical failures, production disturbances, organizational instabilities, external events or loads, and latent failures from design.

hazards and their causes. The low rate of accidents however, makes it difficult to discover repeating patterns of these factors [25]. To understand all these factors, we need to gather the correct and detailed data on incidents and accidents. This helps us recognize and understand the main barriers and elements that contribute to prevent and/or control these hazards and undesired situations [23]. As Gordon (1998) recommends, it may be possible for the oil industry to combine accident databases with those of other process industries (e.g. nuclear, chemical) to draw on a broader data set. This may include the qualitative data, by looking over the textual forms. We can state that, single accident investigations, mainly the major ones as the Three Mile Island [29], Bhopal [33], Challenger [38] and Chernobyl [32] accidents provided a rich information and data source for researchers. In industries, where potential hazard consequences can be severe, incidents produce the extra amount of data required to obtain a clear picture of potential

The quality of accident data has been questioned in several studies. The major problem faced by injury studies, which rely on existing data collection systems or are by design longitudinal, is the presence of missing data [6] and continuity of data collection over a long period in combination with the lack of matching data on the composition of the workforces, distinguishing onshore and offshore installation and within offshore distinguishing mobile and permanent placed facilities.

The decrease in the severe and fatal accident rates in oil and gas industry is mirrored in levels of safety activity over recent years. There has been a steady increase in the number of inspections carried out by different national authorities as; STF, PSA, SRT inspectors, and an increase of the focus on safety issues by HSE professionals, safety representatives and the public through media.

5. Conclusion

The results from this study would serve as a reference document for incident and accident data classification and analysis. Accidents are distinguished from incidents in that accidents involve personal injury and/or property damages while incidents include both accidents as well as non injury/damage events.

Accident data should be collected and analyzed properly, in compiling statistics of accidents and injuries, various sources of information should be used in order to provide a full picture as possible of the situation at a given point in time and to give an estimate of any under-reporting, which may occur. The data should not be collected if it is not analyzed for understanding trends and draw strategies to prevent future injuries, illnesses or property damage.

In line with modern theories of accident causation, which emphasis the importance of factors upstream of the accident event, and modern techniques for data collection and observation, we recommend more focus on standardization of type of data collected, beside encouraging legislator, researchers and HSE professions to focus on events and actors at the organization level.

In the oil and gas industry, the frequency of severe accidents is limited as it; does not generate sufficient data for learning opportunities or sharing of knowledge. We need a substantial amount of data to enable the test to reveal changes in the safety level [5]. To increase the amount of data, we may include extra data of less severe incidents, near misses and deviations from established procedures. In the last decades, many organizations have set up a system in which near misses being highlighted, reported and analyzed [37]. Such information of near misses and undesirable events can give a relatively good picture of where accidents might occur, but they do not necessarily give a good basis for quantifying risk.

The fact that numerous literature on occupational accidents was based on the concept of the “Accident Pyramid” which based on dependency of several of common serious injuries on a certain number of minor-serious injuries and near misses. The top of the pyramid and iceberg representing a very serious or even fatal accident, and these events on the top of the pyramid takes the more attention and resources. In the industry like oil and gas industry, the occurrence of a fatality or serious accidents would affect the safety statistics of the company for the year in which it occurred as it would need to be considered in all analyses and formats used (incident rate, accident frequency, etc.), and it will take a vast amount of resources for investigation and making correction actions afterwards.

To assess the most suitable methods of accident data collection and analysis, it is important to identify the range of scenario information that is required by all stakeholders.

As the frequencies are low and datasets are limited, it is possible to make a statistical estimate of the uncertainties in the resulting risks. These uncertainties may result from the choice of the databases and the question of whether these databases are complete and representative.

To minimize the uncertainties, data reporting should be emphasized on, and data collection should cover all available sources. When data collected from different sources it is important to ensure that the concepts, definitions, coverage and classifications use by the different sources are consistent.

We believe our results demonstrate the clear decline of injuries and injury rates in the Norwegian continental shelf in the last years. These indicators and trends declare the usefulness of the accident data collected by various institutions: National legislations and guidelines encouraged increase of incident reporting and our results for the accident and person injury trends showing decline. This decline can be a result of successful safety management programs in part of companies and high focus on safety culture and safety promotion in part of public and authorities.

Sharing information and experience are in our view regarded as essential in the learning process from previous accidents and accidents and we hope this paper will contributes to that.

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