The impact of Safety culture on safe operations

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The universal relevance of safety culture has led to significant amounts of research being published. Most of these studies focus on what safety culture is and how its various aspects influence safety within Chemical and Process Industries. However, there has been little research carried out to investigate the relative importance of each aspect. Results from studies, which focus on specific areas of safety culture, have been compared to determine the relative importance of each aspect. However, the lack of a common method for evaluation of safety culture makes these comparisons difficult There is a lack of studies which consider the entire range of areas encompassing safety culture and their relative importance within this domain

This work investigates the role that safety culture plays in process safety and aims to establish the relative importance of each aspect of safety culture. Firstly, major safety incidents reports from an online database published by the US Chemical Safety Board were screened to identify those in which safety culture was a major cause of the incident. Eight incidents were selected and their reports were used as case studies. These case studies were then analysed using a qualitative analytical method, qualitative content analysis (QCA), in conjunction with existing literature on safety culture. The analysis was carried out by categorizing areas of safety culture as defined in the literature (e.g. leadership, management) within a coding frame to identify them within the case study (concept-driven analysis). Subsequently, further analysis was carried out this time identifying elements within the text of the cases were not associated to categories as defined in literature but to categories identified in the first batch of analysis (data-driven analysis). The results were analysed from a qualitative and quantitative standpoint to answer the research question and to draw any other meaningful conclusions.

It was found that management is the most relevant aspect in creating a positive or negative safety culture within an organisation and that other aspects are of relatively equal importance to each other. It was also noted that results were consistent regardless of the type of incident, routine vs non-routine. Additionally, areas such as procedures, staff competency and training, which are not defined as part of safety culture in literature, were identified as key elements in these major incidents. Finally, it became clear by analysing case studies occurring over multiple decades that safety culture was previously a neglected topic in the chemical and process industries but has gained recognition in more recent times.

The findings of this work suggest that for any organisation to improve its safety culture it should consider allocating more resources to studying and improving their management. Additionally, although the importance of safety culture to safe operations is more recognised nowadays still more needs to be done.

The findings of this work as well as the methods used can help industries to learn more about safe safety culture and its impact on safe operations within the chemical and process industries.

Keywords: Safety Culture, Safety and Loss Prevention, Human Factors, Management, Leadership, Qualitative Content Analysis

Introduction

Safety incidents in the process industry often lead to injury or even the death of workers, and in some occasions bystanders, as well as damage to the environment and plant equipment. Interruption in production, the negative impact upon a company's reputation and the inevitable financial harm caused are also possible consequences. Most of these safety incidents occur due to human errors (1).

Previously, health and safety has focused primarily on providing solutions to very specific technical problems from the beginning of the design phase to the operation of the plant (2). However, it is clear that humans are a weak point with regards to safety in the process industry. The study of human factors has attempted to gain a better understanding of why humans make mistakes and what measures can be taken to eliminate or reduce the likelihood of these (2).

There are a number of similar definitions of human factors available in the literature. For the purposes of this project we will use the following definition (3):

> *"Human factors refer to environmental, organisational and job factors, and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety"*

In general, human factors can be divided into three interrelated categories (3) (2) as follows;

- the job, which covers the everyday aspects of a job in the process industry such as the environment in which the job takes place, the shift patterns, relevant procedures, workload and design of controls and displays (ergonomics). All of these aspects have an effect on how a human performs with respect to safety.
- the individual, that is associated to factors arising due to the person themselves performing the task, for example, some workers will be more likely to cut corners whilst others will take the utmost care to ensure that their task is completed safely and correctly. Some of the aspects relating to the "individual" such as attitudes and skills can be changed through training and experience whilst others such as personality are fixed (3) (2).
- the organisation, which includes factors such as leadership and management systems, available resources, communication and safety culture within the relevant organisation. The organisation could be an individual plant or an entire company (3) (2).

Therefore human factors covers the task being carried out (the job), the person/people carrying out that job (the individual), the place in which the task is being carried out (the organisation) and also how all of these factors combined affect health and safety. One aspect of the "organisation" that is important to consider is safety culture. Safety culture describes how the collective believes and attitudes within an organisation influence safety, positively or negatively.

This project will investigate the role of safety culture in safety incidents within the process industry using qualitative analysis of existing case studies and in doing so will attempt to learn more about the significance and relative importance of various aspects of safety culture.

The concept of 'Safety Culture' emerged as such after the Chernobyl nuclear accident, with a number of similar definitions available in literature. For the purposes of this work we use the following definition provided by the HSE (1).

> *"The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures."*

Other definitions found in literature include (4):

> *"the attitudes, beliefs and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems"*,

and

> *"those aspects of the organisational culture which will impact on attitudes and behaviour related to increasing or decreasing risk".*

These definitions vary slightly but share certain aspects. There is a consensus that the culture of an organisation is created by the attitudes of individuals within that organisation which then contributes to a wider group culture that has a significant influence on the behaviour of individuals. The attitudes, behaviours and ultimately the culture can have negative or a positive influence in both individuals and the organisation.

There are a number of factors that are primarily responsible for creating the safety culture within an organisation. These factors include management, investigations, communication and cooperation, laws and codes, and training and competency (1) (3) (2).

- Management Commitment: This refers to how does the behaviour of superiors influence subordinates either directly or indirectly? Does management actively enforce rules and procedures to ensure safe operation or do they tolerate/encourage them being ignored? Subordinates within an organisation will quickly be able to determine the priorities of management. Even if they profess to have safety as a top priority their decisions will send an implicit or explicit message about their true order of priorities. Workers will then act accordingly out of fear of upsetting management. If managers are seen regularly in the field, taking an interest in the concerns of workers and their everyday tasks then they will send a clear message that they do genuinely prioritise safety. Alternatively. if they are removed, difficult to communicate with and spend far more time talking about productivity than safety then it will be clear that safety is not their top priority.

- Communication: Is communication between employees of various levels of seniority made easy and encouraged, particularly for issues pertaining to safety? Does tension exist between employees, particularly different groups, which may compromise teamwork and therefore safety? Does the structure of the organisation hamper effective management of safety? Clear communication about tasks, procedures and general everyday work is essential to safe operation. As is open communication between workers and management so that workers feel that they are not just welcome but encouraged to bring forward any concerns they have and that if they do those concerns will be taken seriously.

- Laws and Codes: Are local/national laws appropriate and adequately enforced? Are industry codes and standards incorrect or misleading?

- Employee Involvement: Effective design and operation of plants is more easily achieved when the thoughts and experiences of workers at all levels are heard and incorporated. Furthermore, this will act to show workers that they are valued. Otherwise, workers will feel removed from the running of the plant and be less likely to take ownership of safety.

- Training/Information: Are all employees properly trained for their respective tasks? Have appropriate measures been taken to ensure competent individuals have been hired to or assigned a job? Employees must be thoroughly and formally trained not just to ensure they are competent but proper training with an emphasis upon safe operation will also engender good attitudes towards safety in general. Easy access to further training and information, especially regarding safety, will also have the same effect.

- Procedures: These should be followed by workers and enforced informally by other workers and formally by management if a good safety culture exists. They must also be audited effectively to account for the concerns of workers as workers who question the effectiveness of them will become less likely to follow them if their concerns are not addressed (relates to communication and employee involvement).

- Investigation/Learning: Are safety incidents investigated and action taken based upon what was learned or is the organisation ambivalent or even wilfully ignorant? When accidents or near-misses occur the safety process has clearly failed in some manner. This points towards a deficiency which an organisation with a positive safety culture would attempt to identify and rectify through investigations and subsequent changes. If accidents are not investigated properly not only will vulnerabilities persist but a clear message will be sent to workers about how seriously safety is taken, furthermore future incidents will become less likely to be reported (relates to management commitment).

Many studies already published on the topic of safety culture focus on attempting to measure safety culture within a given organisation and in some cases asses how it changes with time. The methods most commonly employed to achieve this include quantitative techniques, primarily surveys, and qualitative ones, primarily interviews and observations. These studies are all similar in that they attempt to measure safety culture by learning about the perceptions of people within the relevant organisation (3) (4).

Extensive research regarding which aspects of an organisation should be considered as part of its safety culture, or not, has been carried out and is generally in broad agreement with only slight variations found between definitions of safety culture in literature (4) (5). Many studies which focus on specific parts of safety culture have been published and comparisons have been drawn between these studies in an attempt to determine the relative importance of each part. However, the lack of a common method for evaluation of safety culture makes these comparisons difficult (4). There appears to be a lack of studies which consider the entire range of topics that combine to form safety culture and then draw a conclusion regarding their relative importance (5).

The work presented here aims to investigate how safety culture is related to serious process safety incidents, focusing on the aspects mentioned above, to determine the role each one played in the development of an incident and their relative importance. The research uses a qualitative analysis of existing publicly available case studies of major safety incidents in the chemical and processes industries to learn more about the importance and significance of the various aspects of safety culture.

Methodology

The selection of sources of raw information and the selection of a methodology for extracting data from those sources and subsequently analysing it is an important decision in this case as the reasons and triggers for an incident to take place are normally difficult to quantify. In general, information about safety culture can be gathered through a number of methods either quantitative (e.g. surveys), qualitative (e.g. interviews, focus groups, observations and written documentation) or both (6). As this work is focused on the relationship between safety culture and safety incidents the use of case studies of safety incidents is the best source of information to use.

Case studies are an excellent source of information regarding the safety culture within an organisation as they often amalgamate information about the organization (i.e. individuals involved, standard practices, behaviours and other organisational information presented in a concise manner. These would best be studied though qualitative methods such as qualitative content analysis (QCA) (6).

Specifically, case studies published by the US Chemical Safety Board (CSB) were selected due to their reliability, and availability in large numbers which increased the likelihood that many different types of cases could be studied allowing for broader conclusions to be drawn. However, it also presents the problem that only cases which occurred within the US were studied and this somewhat restricts the extent to which any conclusions can be generalised beyond the US.

The analysis of these case studies is carried out through the method of Qualitative Content Analysis (QCA). QCA was chosen as it offers a systematic way of analysing the contents through the use of a coding frame reducing the subjectivity of the analysis and providing a reference through which the analysis can be understood and checked (7).

QCA involves reading through various types of content, in this instance case studies of industrial incidents and “coding” instances of each category within the written document.

The coding of each case study was carried out using the NVivo software package (8) which is aimed at the qualitative analysis of text rich material. 100 case studies of major safety incidents were downloaded from the CSB website onto NVivo to begin. The initial search through the CSB cases was carried out to find in which cases safety culture played a significant role so that we were able to eliminate the case studies which were not relevant. Cases which were identified as potentially relevant were verified as being relevant through the process of coding. This process identified eight case studies which were relevant for analysis.

The original coding frame as presented in Figure 1 was constructed based purely upon literature and the factors mentioned above that are associated to safety culture as per the definition used in this work. The relevant case studies were then read and coded using this coding frame in the first instance. Excerpts can then be presented as specific example or can even be interpreted in a quantitative manner by examining the total number of coded instances in each category.

Coding Frame

Figure 1 shows the hierarchy of categories and process for selecting the case studies to be analysed.

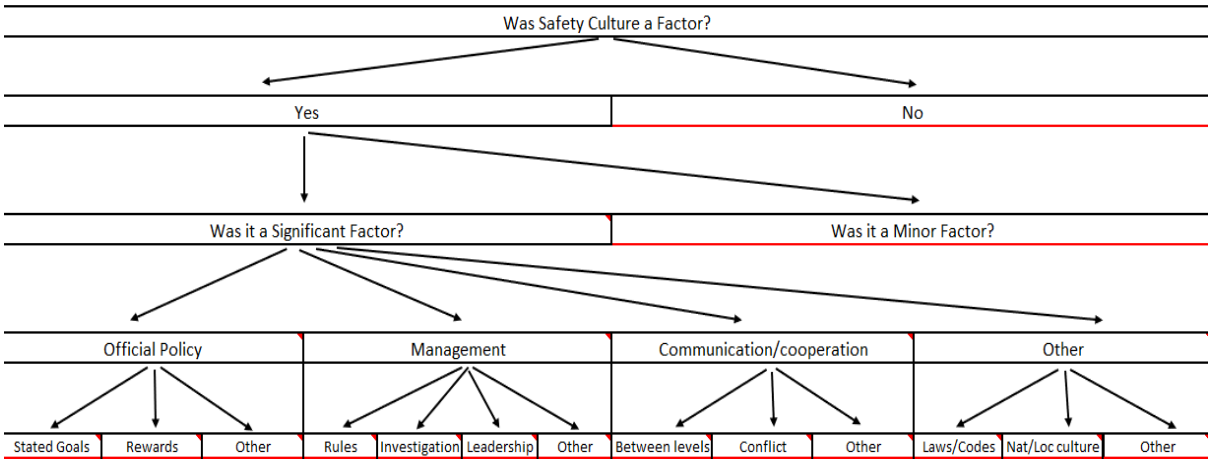

Figure 1: Initial Coding Frame

In this work the following definitions were used for each category to be coded in the text.

Official Policy: Covers any official policies which could impact safety at a corporate/company level or at an individual plant.

> Stated Goals: Includes things such as targets for safety either as a written declaration such as do no harm to any person or a target to meet regarding a certain safety indicator. Also includes stated goals regarding other thing such as profitability/value and how this could impact safety.
>
> Rewards: What is rewarded, how does this influence the behaviour of employees and how could that in turn impact upon safety.
>
> Other: Anything which falls under official policy but is not covered by the other categories.

Management: Covers how the behaviour and decisions made by management at any level impacts safety, such as the enforcement of rules/procedures.

> Rules: Covers how the enforcement of rules and procedures by management or the lack of appropriate rules and procedures impact safety directly or indirectly.
>
> Investigation: Covers how managements approach to incidents/near-misses impacts safety i.e. do they or do they not carry out a proper investigation.
>
> Leadership: Covers how action taken by management indirectly influences subordinates e.g. do they lead by example when it comes to safety or do they set an example of prioritising profit over safety.
>
> Other: Anything which falls under management but is not covered by the other categories.

Communication/Cooperation: Covers how communication between different parts/individuals in an organisation as well as well they cooperate can influence safety

> Between Levels: Covers how communication between various levels of seniority can impact safety e.g. is there an open-door policy, are less senior workers opinions dismissed or taken seriously.
>
> Conflict: Does tension/conflict exist between employees/groups that could compromise safety in anyway e.g. do operators and those responsible for safety see each other as obstacles to their own goals and do therefore not function well as a team.
>
> Other: Anything which falls under official communication/cooperation but is not covered by the other categories.

Other: Covers factors identified which do not fall into the other 3 categories

> Laws/Codes: Are laws, regulations, industry standards, codes of best practice etc effective and designed with safety as the top priority or do they set a misleading example.
>
> National/Local Culture: How does national/local (state, country) culture view safety e.g. developing countries generally place a lower priority on safety than developed countries, the same is true when comparing US states.
>
> Other: Anything which falls under other but is not covered by the other categories.

Once the first coding stage was completed for all the case studies a better picture of safety culture began to emerge. Through an iterative process some of the categories where re-structure from the initial frame generating different high level categories. Each case was then re-coded using the high level categories as the methodology requires iteration to ensure that each code is unique and they are not repeated. This process could be iterated many times if necessary. Results related to the first level of categories are presented in here as further analysis is required to identify sub-categories within the main categories emerging from the first level analysis. In order to ensure reliability of the coding and avoid double coding of instances or duplication of

categories the coding has been done by the two authors independently. Double coding occurs when the same piece of information is coded twice, as repetition commonly occurs throughout a case study, which can result in a misleading total of instances for each category.

Whilst providing a coding frame with accompanying definitions reduces the subjective nature of qualitative analysis, it cannot be eliminated completely and every piece of text which is coded requires a level of interpretation which is unique to each individual. This issue was also addressed by checking the coding against another individual's with experience of using QCA and with expertise with regard to safety in the process industry. This was carried out through both individuals coding an agreed section of a case independently then meeting to compare results to ensure that the coding frame is clear and that both agree on its application. Any problems with interpretation or the coding frame were then corrected for any coding which had already occurred. A further data session was held in which both individuals reviewed results category by category to once again check their accuracy.

The upper level in the tree shown in Figure 1 (top three tiers) are simply used to screen cases for those which are relevant from those in which safety culture was not considered a major factor. The first high level categories are then (fourth tier) are then used to analyse the cases identified.

Results and discussion

As described in the methodology the cases which were coded were selected based upon the significant role which safety culture played in them. The selection of these cases is also useful in learning about safety culture. Ultimately 100 cases were available from the CSB, of which 8 were coded because safety culture was found to have played a significant role. These cases were:

- Williams Geismer Olefin Plant, Reboiler Rupture and Fire (7)
- Tesoro Martinez Refinery, Sulphuric Acid Release (8)
- Chevron Richmond Refinery, Pipe Rupture and Fire (9)
- Tesoro Anacortes Refinery, Catastrophic Heat Exchanger Rupture (10)
- Texas Tech University, Laboratory Explosion (11)
- Exxon Mobil Baton Rouge Refinery, Isobutane Release and Fire (12)
- BP Texas City (13)
- Deepwater Horizon Drilling Rig Explosion (14)

Whilst the great reduction from 100 to 8 cases suggests that safety culture is not commonly found to be a significant factor once the dates of the cases are considered, 7 out of 8 cases occurred between 2010 and 2016, the only exception being BP Texas City in 2005, its increasing importance is clear. Since 2010, 30 cases have been published showing that culture now plays a significant role in almost a quarter of recent cases. Only 1 case out of 71 published between 1998 and 2010 found safety culture to be a significant factor. This drastic change could suggest that safety culture has undergone a substantial deterioration, however this seems unlikely compared to alternative explanations. As more conventional improvements to safety, such as improvements in design and technology, have been implemented whilst accidents continue to occur the more complex nature of accidents and the role of more obscure factors such as culture have become clearer. In other words, culture has always played a significant role in process safety, but its importance has only recently come to be more fully appreciated.

Figure 2 shows the frequency of category analysed in the data corpus. Observing the overall quantitative results, it is clear that, off the tier 1 categories, management is the most significant, occurring more times than all other categories combined as well as being the most frequently occurring code in seven out of eight cases. This shows that whilst culture is a pervasive attitude found throughout an organisation, it is driven and controlled by superiors and their influence upon their subordinates. Thus, if we wish to improve the safety culture within an organization, management should receive the most attention. Comparing the remaining tier 1 categories we can see that no other category stands out above the rest suggesting they are of equal importance and worthy of equal attention.

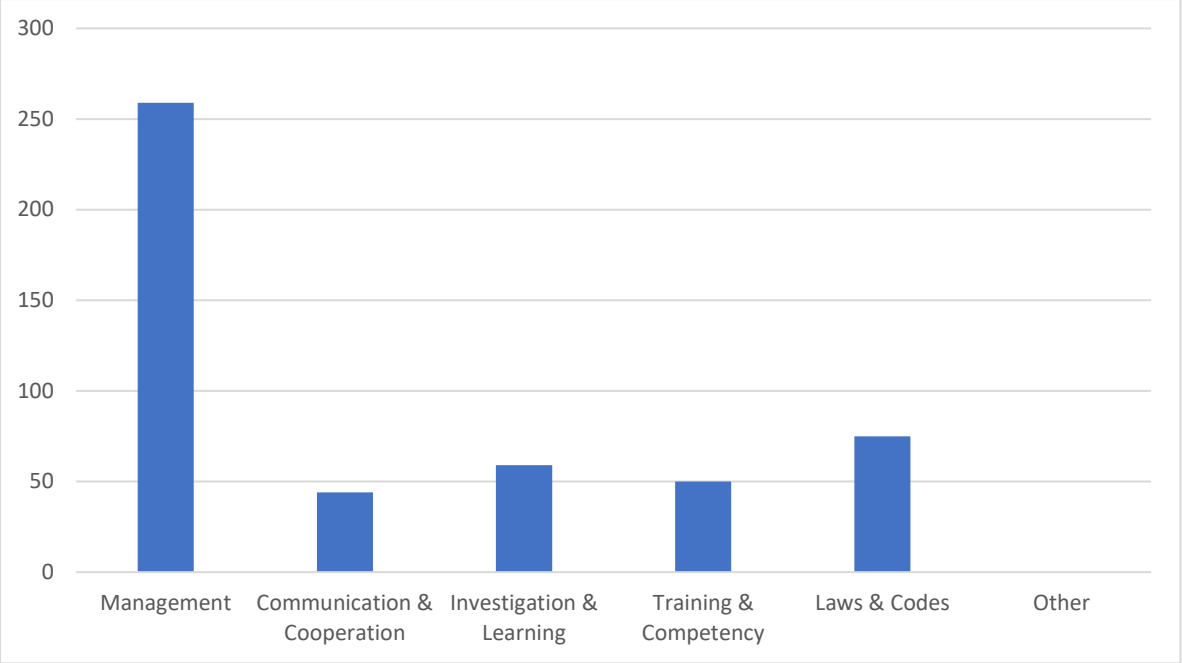

Figure 1: Frequency count for high level categories.

The environment in which a case occurred, refinery, university laboratory or drilling rig, as well as the type of operation which was occurring, routine or non-routine, can also be used to compare the cases and their respective results. In the case of the environment we have 6 cases which occur in refineries but only 1 example from university laboratories and drilling rigs. The lack of the latter 2 makes it difficult to draw and meaningful comparisons of the results between different environments.

Each case was selected from the CSB website and thus occurred within the United States of America (USA). This clearly creates the potential for biased results in each category of the code as a large variety of attitudes towards safety can be found across the world particularly as we move between countries each with their own perceptions and ideas which may vary slightly or greatly from those commonly found in the USA. Thus, generalising these results beyond the USA must be done carefully and the further a countries attitudes towards safety deviates from that of the USA the more difficult this becomes. Results regarding laws are particularly susceptible to this as these undoubtedly vary between countries however the formal and documented nature of laws still make it possible to draw conclusions even if these are not necessarily the same ones which were found in the USA, for example the CSB regularly recommended a less prescriptive approach to safety was adopted within the USA and an approach such as the United Kingdom's (UK) ALARP system (as low as is reasonably practicable) would be more desirable. This could be used to draw positive conclusions regarding the UK's legislative approach to safety.

Further coding and analysis is required to provide a description and more complete picture of the aspects of safety culture that are related to safety incidents in the chemical and process industries.

Conclusions

A qualitative analysis of case studies of safety incidents has been carried out to link safety culture and the factors associated to safety culture their relative importance when considering incidents causes or triggers. We have found that 'Management' is the most important aspect with the highest relative importance in safety culture which suggests that in order to generate a positive safety culture this must be given the most attention. Other aspects of safety culture are of approximately equal importance, and whilst still less significant than management, can, if not handled properly, compromise safety. They must also receive attention to foster a positive safety culture.

The results obtained, for the case studies considered here, for different types of operations; routine and non-routine, showed no significant difference in which categories contributed to accidents in each type of operation. Thus, no difference in the approach towards culture for both types of operation is required.

The significance of the role safety culture plays in accidents in the process industry, at least in the USA, is becoming increasingly clear as obvious or simplistic causes have been replaced by more comprehensive descriptions. Advances in safety resulting in the elimination of previously common problems have exposed culture problems which may have been previously overlooked.

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