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Rezvani, Zahra

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Breaking the clay layer: The role of middle managers in safety management

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by the authority of the Rector Magnificus Prof.dr.ir. T.H.J.J. van der Hagen

Chair of the Board for Doctorates

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Friday 2 February 2018 at 12:30 o'clock

by

Zahra REZVANI

Master of Science in Occupational Health, Tehran University of Medical Sciences, Iran

born in Neyshabour, Iran

This dissertation has been approved by the

Promotor: Prof. dr. P.T.W. Hudson

Composition of the doctoral committee:

Rector Magnificus	Chairperson
Prof. dr. P.T.W. Hudson	Delft University of Technology

Independent members:

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Prof. dr. ir. M.B.A. van Asselt	Maastricht University

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Zahra Rezvani

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1. Introduction

1.1 Introduction

In this study, we explore the role of middle management in safety in hazardous industries, in particular the oil and gas industry. To this end, we apply theoretical and empirical grounding processes by conducting both retrospective and real-time studies in order to produce relevant knowledge about the role of middle management in safety and the decision-making principles required to develop a decision-making framework in a hazardous process industry. The resulting decision-making framework can be used to provide both a theoretical and a practical roadmap for researchers as well as managers. Middle managers form a significant group that has attracted relatively little attention in the safety field. In practice, however, they are often blamed by both the top of organisations and the front-line personnel when things go wrong. In practice middle managers interpret and then implement the policy set by senior and executive managers, making decisions that have real consequences. They are often called the 'clay layer', implying that they form an impermeable barrier between well-intentioned executives and the performance of safety-critical activities by the front line while, possibly simultaneously, smothering messages from the operations about what is happening that can have serious safety-critical consequences. These issues have received little attention in the scientific literature that is relevant for safety; this study forms an attempt to discover who these people are, what they actually do and how they make their decisions on a day-to-day basis.

In this first chapter, we briefly explore the theories and models of accident causation and analysis that are related to the management of safety and, in particular, concentrate on the making of decisions. Decision-making itself is not a new domain for study, it started in the 1950s with the von Neumann-Morgenstern Expected Utility Theory for individual decision-making under uncertainty; but there is, as it will turn out in the review, little information about how decisions are actually made in high-hazard industries, especially when we observe how critical decision-making is made when we consider safety and environmental impacts. There is, similarly, little information about the exact nature of those who are the most frequent decision-makers, not those who infrequently make grand strategic decisions, even though they have great consequences, but the day-to-day tactical decision-makers who implement those strategic policies and who can have great impact in the short run. We define the main research question and relevant sub-questions of our study accordingly. Finally, we describe our research strategy to underpin theories and methodologies that serve collectively to address the problems identified.

1.2 Theories and models of accident causation and analysis: Human decision-making models and management models

The objective of the current research is the elaboration of both decision-making in safety and the nature and role of middle managers in that domain. For this purpose, we start by reviewing some theories and models of accident causation and analysis specifically in order to identify the relationship between accidents and decision-making as well as later attempting to uncover the nature and role of the middle managers who make most of those decisions. For this purpose, first the most established theory of decision-making is presented so that we can understand the historical foundations of the study of decision-making. We then introduce some human decision-making models, what is done in practice, as the focal point of our research.

- Domino theory is the first accident causation theory, developed by Heinrich (1941), that describes and attempts to explain the linear and sequential progressive events leading to an accident.
- Taylor's Purposive Risk-taking Model (Taylor, 1976) is a reason-based approach that attempts to justify and understand the actions of individuals; instead of providing a cause-based model. This is closely associated with loss of intentional control. Taylor argued that this model is used when what is gained such as enjoyment or achieving of an individual's intentions is felt to outweigh the observable loss.
- Multi-causality of accidents was introduced by Reason (1990) when he developed a systems approach in accident investigation that considers all the latent errors which can happen at all levels, as well as environmental conditions that provide conditions for unsafe acts of operators (Reason, 2000). Reason and Hollnagel are two leading researchers who have had a great impact in shifting from focusing on the individual level factors to the organisational level factors (Chang & Wang, 2010).
- CREAM - Cognitive Reliability and Error Analysis Method – was developed by Hollnagel (1998) and is a repetitive method instead of a sequential one. This recursive structure represents the cyclic nature of cognition to find the probable causes of an accident by selecting one of the antecedents linked to the error modes (Hollnagel, 1998). This method is aimed towards uncovering the complex interaction between human cognition and the context (Haan & Terwel, 2014).
- Systems-Theoretic Accident Model and Processes (STAMP) is another accident analysis method which is based on system theory Leveson (2004). This method focuses on inadequate controls or safety constraints in the design, development, and operation of a dynamic system. Compared to event-based models, which consider a flow of events causing accidents and are focused on component failures, this method considers a hierarchy of controls to discover inappropriate constraints on the interactions among components (Leveson, 2004).

There is a large literature in the area of decision-making that may prove relevant:

- Expected Utility Theory, developed originally by von Neumann and Morgenstern (1947), is a theory for decision-making under risk and uncertainty that was dominant for several decades. In this theory, an alternative *a* will be preferred to alternative *b* if the expected utility of *a* is greater than the expected utility of alternative *b* where the term utility refers to a general notion of usefulness or value that goes back to Jeremy Bentham. This theory applied mathematical and statistical methods to behavioural science (Shubik, 1958) as a foundation for rational decision-making – what are good decisions and how should we make them? It is based on a number of axioms which are completeness, transitivity, consistency, continuity, and independency (Abrahamsen & Aven, 2008; Durbach & Stewart, 2012; Hammond, Keeney, & Raiffa, 1998).
- The risk perception model (Slovic, 1984; Slovic et al., 1984; Perusse, 1980) was developed by Slovic to ascertain how people perceive, process, and evaluate the probabilities and consequences of uncertain events (Dowling & Staelin, 1994; Slovic, Fischhoff, & Lichtenstein, 1977). This model focuses on psychological underpinnings of individual judgment and decision making (Slovic, Fischhoff, & Lichtenstein, 1984). Various studies in this domain have revealed that risk is perceived by a wide range of attributes such as newness of the hazard, the severity of consequences, knowledge about risk, immediacy of the effects, social effects, perceived benefits, controllability of risk and trust in government (Huang et al., 2012; Slovic et al., 1984). Therefore, it is necessary that regulators, politicians, or citizens consider these components in risk assessment. Their intended policies may be ineffective or even counterproductive without such considerations; Slovic et al., (1977, 1984) stated that uni-dimensional indices like the annual probability of death that have been implemented as aids to decision-making about risk are inadequate. Regulators and policy makers should apply a variety of qualitative and quantitative characteristics that are sensitive to people's underlying concerns.
- The Risk Acceptability model (Litea et al., 1983) focuses on benefit as a factor which is needed for estimating risk; risk is seen as not only a combination of probabilities and consequences but also of benefits. According to this model, the acceptability of a risk increases by increasing the benefits within a range.
- The Heuristics and Biases approach (Tversky and Kahneman, 1974, 1981) considers mental operations that people apply when making judgments and decisions in uncertain situations as a result of reliance on heuristics such as representativeness, availability, and adjustment and anchoring. People usually judge the likelihood of an object or event by the degree to which it represents the evidence, while they neglect or pay little attention to its prior probability (Tversky, 1974). Availability is the process of judging the frequency by the ease with which instances or scenarios are retrieved (Kahneman, 2011). Although

availability is useful for the rapid recall of events, it can lead to judgement biases because the objective frequency of instances that are easily retrieved are, incorrectly, assumed to be greater than the frequency of those instances that are less easily retrieved. Barker and Haimes (2009) argued that estimation of the probability of extreme events, that are critical for estimating the risks associated with rare events, can be estimated incorrectly because likelihood assessment suffers from a range of biases, such as subjectivity and availability due to the sparseness of data. Another disadvantage of availability is that the frequency of co-occurrences could be estimated according to the strength of the associative bond between them (Kahneman & Tversky, 1973). When people consider a particular value for an unknown quantity before estimating that quantity, anchoring effects can easily happen. Any number that you are asked to consider as a possible solution to an estimation problem will induce an anchoring effect which is an adjustment from an initial point (Tversky, 1974).

The range of models of how incidents are caused and how people make decisions suggests that there is no clear consensus on who causes accidents and how decisions that lead to them are made, and by whom. This thesis attempts to come to a clearer understanding that helps put different individuals, especially middle managers, into context.

1.3 Background and Motivation

Safety management is a process including four stages documented today by ISO 31000 - 2009. First, risk assessment consisting of risk identification, risk analysis, and risk evaluation. Second, risk treatment, which includes the selection of risk treatment, treatment plans and preparation and implementation of a treatment plan. Third, monitoring and reviewing the management system to maintain and adapt the risk treatment plans. The final stage is recording of the risk management process. To achieve objectives in safety management, which are primarily the protection of personnel, environment and assets, it is essential to understand the organisational context.

An organisation is constructed from different layers of management with interlinked and complex roles (Mintzberg, 1978). Middle management, who occupies the middle-level positions, is a fundamental management level in an organisation. Middle managers are informed managers, operating between people who have a narrow vision which is limited by their own segments, typically front line operatives, and top/central management who have a broad picture of an organisation that may be unclear as a result of their distance from the operation (Mintzberg, 1995). In fact, the performance of safety management in organisations closely links with the people who are responsible for recognising and making decisions about developing problems *before* they become critical (Hayes, 2012). Most of these people are middle management who, we shall argue, have been overlooked in studies on safety and safety management.

Looking back to the process of safety management, every stage involves decision-making, which can be defined as a cognitive process of choices for alternatives based on some sets of criteria. Decisions in safety include resolving conflicts between different values, uncertainties of outcomes, and ambiguity. In one view safety decisions are made individually or by groups, the majority of which are constituted by middle managers. Alternatively, but not exclusively, middle managers may be seen merely to implement the strategic decisions of top management. So, they can have either a direct and indirect influence on decisions that are made and carried out in practice.

As they perform a pivotal role in safety management, a greater understanding of middle management functions, of their contributions to safety management, and knowing how middle management actually make safety-related decisions when they are confronted with different conflicts, is essential. The decisions of middle managers and their detailed implementation of solutions handed down from the upper management means that middle managers can have a greater influence on an organisation than the upper levels. Middle managers affect the organisation on a weekly or daily basis by solving more immediate problems (Johansen, 2011).

Normally, the top of an organisation has a crucial responsibility in fatal accidents, so a substantial proportion of studies have focused on the failings that might occur at the senior management level. At the same time it seems entirely reasonable to devote considerable attention to research about front-line workers who are placed in the closest position to the final events, those who will inevitably provide the proximate cause of any incident. But there is a considerable distance between the top of an organisation and those at the front line. This gap is populated and managed by middle managers. It is essential to understand the underestimated roles of those middle managers who are removed from the hazards to which their staff are exposed. However, they may also create situations for their workers as a result of the broad targets set by senior management but then left to middle managers to achieve.

Middle management plays a crucial role in an organisation with a wide range of different responsibilities. They transmit the demands of senior management to lower levels. They also can help lower levels to adapt to new strategic decisions like change projects or integrated management (Raelin & Cataldo, 2011). They can both lead and build informal strategic networks (Floyd & Wooldridge, 1997). They hire, fire, and reward their staff. Finally middle managers allocate resources for operation, training, and they can set priorities for front-line supervisors to steer how they should devote their time and attention.

Middle managers are engaged in making a variety of decisions. They are regularly asked to strike a balance between different objectives such as operation or safety in their organisations. On the other hand, they try to find a balance among various limits. Middle managers are

capable of recognising dangerous situations before they occur. Failures resulting from the decisions they make can have adverse effects and, sometimes, lead to disastrous outcomes.

Investigation of recent incidents clarifies the importance of the management decisions, particularly those made by the middle management group. For instance, the assessment of the space shuttle accident in 1986 outlines the role of management and communication problems between managers and workers which influenced the shuttle launch decision Vaughan (1997). Several influencing factors, which were political, economical and psychological pressures, affected this wrong decision. One important influencing factor in this accident was management attitudes; managers had abstract objectives which caused them to think in an idealistic manner instead of in terms of realistic objectives (Garrett, 2001). Another influencing factor was the dysfunctional managerial style that existed between managers and workers.

The Montara H1 well blowout in the Timor Sea off the Northwest coast of Australia in 2009 is another example that highlights the role of management in complex hazardous activities and critical decisions for well control barriers (Borthwick, 2010). Hayes (2012), who analysed this incident, argued that a series of poor decisions, as well as a failure of management to recognise the system state, contributed to unsafe situations. The decision makers who approved the test were also the well integrity testers; as a result, they couldn't consider the proper criteria to verify or to reject the test. Besides, work completion formed their first priority; consequently, they were blind to considering other criteria. On the other hand, they relied on every single barrier working effectively (Hayes, 2012). Hayes highlighted that managerial competency is essential to capture and correct inevitable technical errors despite the cost and schedule pressures in the industry.

Finally, Hopkins (2012) evaluated the BP Deepwater Horizon explosion and oil spill that happened in the Gulf of Mexico in 2010. He stated that incorrect decisions made by the Macondo engineers, middle managers, as a result of a delay in the schedule, formed one of the indirect causes of the blowout. Engineers prioritised other risks, such as commercial risks, which resulted in minimising the engineers' sensitivity to the safety risks. He also discussed the consensus decision-making process, which he argued provides an inadequate decision mechanism for technical decision-making (Hopkins, 2012).

This casual analysis of some recent major incidents highlights the importance of the role of different layers of management, in particular middle management, the decisions they made, and the organisational circumstances that influenced their decisions. The purpose of this study is to explore in more detail the role and the influence of middle managers in safety management, particularly in high-hazard industries. The central concept is the decision-making of middle managers. It focuses on exploring how middle managers decide about safety issues in different situations, which means in both normal conditions and abnormal

conditions as well as during and after incidents. On the other hand, since there are different criteria for decision-making such as cost, production, schedule and safety, this study is concerned with understanding the influencing factors and the priority they are given in the decision-making processes of middle management. Finally, it explores the existing rules that middle managers are using for their decisions in order to find a proper model based on existing rules. A better understanding of middle management's roles, combined with more clarity about the decision-making processes of those middle managers, could allow for improvements in safety performance, greater reliability in human error and more development in safety management.

1.4 Research questions and thesis storyline

The goal of this thesis is defined as risk management and safety oriented decision-making of middle managers. To achieve this goal, the first step involves an elaboration of the problem context, which goes specifically first into which of the methods of decision-making are more applicable for middle managers and second into the general roles of middle management within which they are making and implementing those decisions. This thesis addresses the following sub-research questions:

1. *What are the decision-making methods that have been applied in safety management?*
2. *Can these methods be applied in safety-related decision problems of middle management? Why or why not?*
3. *How are strategic objectives prioritised in practice?*
4. *What are underlying factors influencing safety objectives in an organisation?*
5. *Who is a middle manager?*
6. *What are the roles of middle managers in an organisation?*
7. *How do middle managers influence safety management?*
8. *Which managerial decisions do middle managers make or are involved in?*
9. *How are decisions made under various scenarios by middle managers?*
10. *What factors influence managerial decisions?*

1.5 Outline of this thesis

The structure of this thesis is organised as shown in Figure 1.1. Chapter 1 has started with a brief introduction and background about accident causation and decision-making theories to help in identifying the research problems.

Chapter 2 discusses the assessment of a number of accident investigation reports of major incidents in the oil and gas industry. Two main concepts of middle management and decision-making are explored in this documentary analysis. Consequently, two main conclusions are put forward. One is that there is a lack of data about the role of middle managers in these investigations. Second, there is a failure of the accident causation reports in creating insights

into the process of decision-making. If the roles of middle management in safety management and the decisions that they take are felt to be important in safety management, then we will find it is surprising how little attention has been paid to these topics. These gaps are the motivation for the rest of the thesis, which is the evaluation of middle managers' decision-making in order to elaborate the knowledge on safety-related decision-making in process industries.

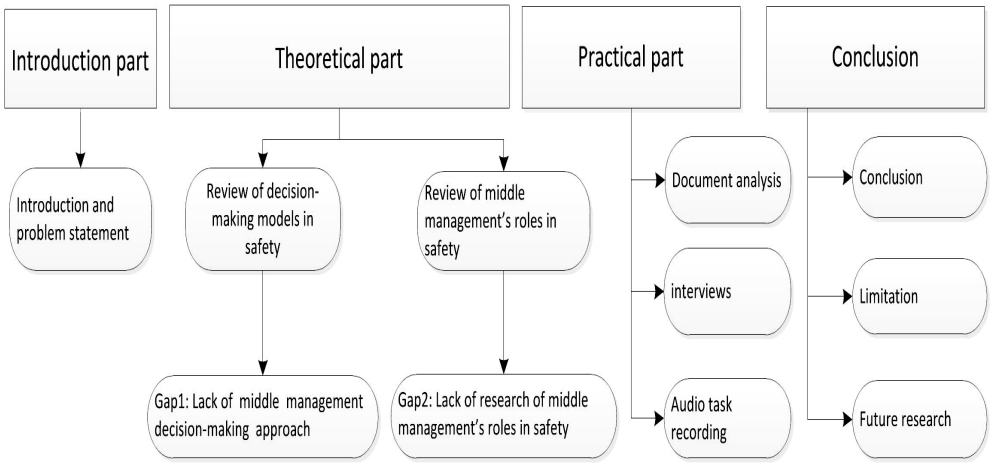

Figure 1.1. *The story line of this thesis*

Chapter 3 describes middle managers and their roles in an organisation as theoretical constructs to answer the main question which is: what are the roles of middle managers in safety? It starts with defining the concept of middle management. Then the roles of middle managers are discussed. By analysing the current literature, it was determined that middle management acts as a crucial link between top level management and lower levels by providing valuable coordination functions. Middle managers decide by solving more immediate and smaller problems on a daily or weekly basis (Johansen, 2011; Rouleau & Balogun, 2011) than do senior managers. They bridge policy makers and policy achievers (Nonaka, 1988). Despite the potential of middle managers to influence safety management in hazardous industries, the lack of any systematic research and the lack of empirical evidence on the role of middle managers in safety performance are outlined in this chapter.

Chapter 4 is the review of the literature on the models and theories of decision-making in general and safety-related decision-making models in particular. The key methods and key aspects of each method within two broad categories of rational decision-making and descriptive decision-making are elaborated and critically evaluated for their contribution in understanding the implementation of decisions by middle management. By analysing the current literature, some primary observations are discussed. First, the common analytical

decision-making methods implemented in other domains have been applied in safety too as quantitative methods to support decision-making in the risk assessment stage of safety management. They assume decision makers have predetermined criteria and options and the task of the decision-maker is solely the selection of an option among other options based on these predetermined criteria. However, those methods are unable to support decision makers in managing disruptions in abnormal and emergency conditions that are inevitable in a hazardous process industry. Second, descriptive decision-making models were concerned with special jobs like fire-fighters, commanders, and doctors, while they focused on decision-making process evaluation, considering environmental factors such as time and resource limitations, without taking into account other roles of decision makers. It seems that they assumed decisions are made in isolation from other activities. We argue that two views of decision-making models should not be seen as independent and separate models. Rather they must be regarded as interconnected. Finally, the lack of any studies that uncover decision-making processes in management and real conditions justifies the current research on real-time decision-making evaluation.

Chapter 5 presents a case study in an oil and gas industry. It starts with describing the context of this industry. The methodology for capturing the information is task recording of one (senior) middle manager for a continuous period of one month by using an audio recorder, which differs significantly from common qualitative research methods such as interviews or questionnaires or even observation. This method is a useful method for gathering detailed and accurate information without interfering with the participants. The main components of an organisation and their links in a complex socio-technical company are presented in this chapter. Every organisation has several strategic goals such as production, quality, safety, and the environment. Striking a balance between them is mostly the responsibility of managers. This chapter provides real information about what actually happens in an organisation between different individuals to achieve strategic objectives and how they can affect those safety objectives. In contrast to studies of how accidents were caused, backtracking to understand what decisions were made and how they contributed to the final outcome, this study actually examined what happens on a day-to-day basis.

Chapter 6 provides information about the roles of middle managers in process industries. The methodology applied for capturing the information is the same as the previous chapter. We also used the interviews here. Various roles of middle managers, both in organisation and safety, are elaborated based on a well-known taxonomy of managerial roles (Mintzberg, 1973) namely: interpersonal, informational and decisional roles. The findings of this chapter again confirm that one important role of middle managers is their decision-making role.

Chapter 7 depicts the process of middle management decision-making. It highlights which kind of decisions they are involved in and shows how middle managers make their decisions

in different situations, which are both normal and abnormal conditions. It also answers the question to what extent middle managers are involved in safety decisions and which factors influence their decisions. Chapter 7 presents a framework based on the conceptualization of the main findings of the research (conflict, communication, type of decision making, function, mechanism and outcome).

Finally Chapter 8 presents the overall conclusions from the findings of the preceding chapters. The applicability, the limitations and a discussion of directions for feature research are discussed.

2. Decision-making in major accidents: Review of accident scenarios in oil and gas industries

2.1 Introduction

In this chapter[1], major accidents in the oil and gas industries are discussed from 1990 to 2016. The accident scenarios were selected from the finalised reports of the United States Chemical Safety and Hazard Investigation Board (CSB), a federal scientific investigation organisation for determining the root and contributing causes of (petro-) chemical accidents in the US. In addition, two accidents were considered that were covered in Andrew Hopkins's books - *Disastrous decisions: the human and organisational causes of the Gulf of Mexico blowout and decisions* (Hopkins, 2012) about BP's Macondo disaster in the Gulf of Mexico and *Failure to learn* (Hopkins, 2008) which deals with BP's earlier Texas City explosion.

In order to explore how safety-related decisions are made in abnormal and emergency conditions, as well as examining how what in hindsight can be regarded as poor decisions resulted in incidents, one technique could be accident analysis for uncovering the accident scenarios. An accident scenario describes the critical events, the actors, their goals, and the sequence of actions, as well as the background information (Go & Carroll, 2004). Accident scenarios may be quite abstract, such as a broad description of the dynamics of general cases such as fires, explosions and environmental releases, but they can also be much more detailed, allowing us to examine the roles and actions of individuals. In the context of this chapter, accident scenarios are specified types or classes of accident stories where causes and effects are described in detail and are used to construct a sequence defining the event logic. The more detailed approach allows us to examine the role of executives, managers and operational staff in some details, details that are generally overlooked in more generic scenario analyses. So, the real accident scenarios, based on historical data about what happened in a specific environment, are discussed here, rather than very general considerations of what might be broadly appropriate scenarios (Rezvani, Swuste, & Hudson, 2011).

To start building up a sense of how, from a retrospective point of view, decision-making models and theories were turned into practice, three sub-research questions are posed in the context of these major accidents in the oil and gas industries, namely:

- What information, related to decision-making, appears in these accident analysis reports?
- What factors influenced the decision-making processes in these accidents?

[1] This chapter is partly based on Rezvani. z, Hudson p. (submitted article, 2017).

- How were middle managers involved in these accidents based on the content of these reports or books?

2.2 Method

A document analysis, as an initial qualitative enquiry, was performed which started by scanning the completed accident investigation reports in the US oil and gas industry, as reported by the CSB from 1990 to 2016. The CSB documents form a proper source for this research since the information for incident investigation has been gathered from interviews, records, and security camera videos which enable the confirmation or corroboration of each other (Miles and Huberman 1994); consequently, they promote a great understanding of the case (Baxter & Jack, 2008). CSB reports provide the nearest we can obtain to definitive investigation reports, at least in the United States – as we shall see many of these reports still turned out to be inadequate and had to be left aside, but there were sufficient to test the hypotheses.

The attempts to retrieve the related information led us to find eleven completed documents over the 25 year time period. Among them, seven investigation reports contained data about decision-making and middle management. They consist of the following major incidents:

1. The vessel over-pressurization at the Sonat Exploration Company (1999);
2. The refinery fire incident in Tosco Avon (1999);
3. The LPG fire at the Valero-McKee refinery (2007);
4. The rupture of a heat exchanger in the catalytic reformer unit in Tesoro (2010);
5. The pipe rupture in the crude unit of the Chevron Richmond Refinery (2012);
6. The fire and explosion at BP's Texas City refinery (2005)
7. The blowout and fire on the Deepwater Horizon (2010)

Although BP's Texas refinery explosion (2005) and the blowout in the Gulf of Mexico (2010) were on the CSB's list, the analysis here has been based primarily on Hopkins' analysis. The criterion for originally choosing Hopkins' books was primarily the title of one book, which showed it contains information about decision-making that is in direct line with the purpose of the current study.

In the next stage, we went through the documents to investigate the incidents in depth, examining the fit of what was obtained within the context of this study (Miles, Mattew & Huberman, 1994; Patton, 2002). This approach to the document analysis enables us to illustrate the influence of decision-making as an essential factor in human errors, at all levels, as well as explicitly uncovering the roles of the middle managers in these incidents. To have a comprehensive understanding, the information related to decision-making was reconstructed. In what follows, the accident scenarios for each case are described briefly; the research results are then presented for each case; followed by a discussion and conclusion.

2.3 Results

2.3.1 Catastrophic vessel over-pressurization at Sonat Exploration Company

On March 4, 1998, one of the two separation trains that were in operation in a new well, near Pitkin Louisiana, at an oil and gas production facility owned by Sonat Exploration Company, failed catastrophically during purging. The failure of the separation vessel led to the release of flammable gas. The flammable hydrocarbons ruptured from the separator and produced a massive fireball that damaged nearby piping, the released additional flammable materials that subsequently also ignited. Four workers, who were in the vicinity of the vessel, died. The separator, four personal vehicles, and a backhoe were destroyed, and oil and water storage tanks were damaged (CSB 2000).

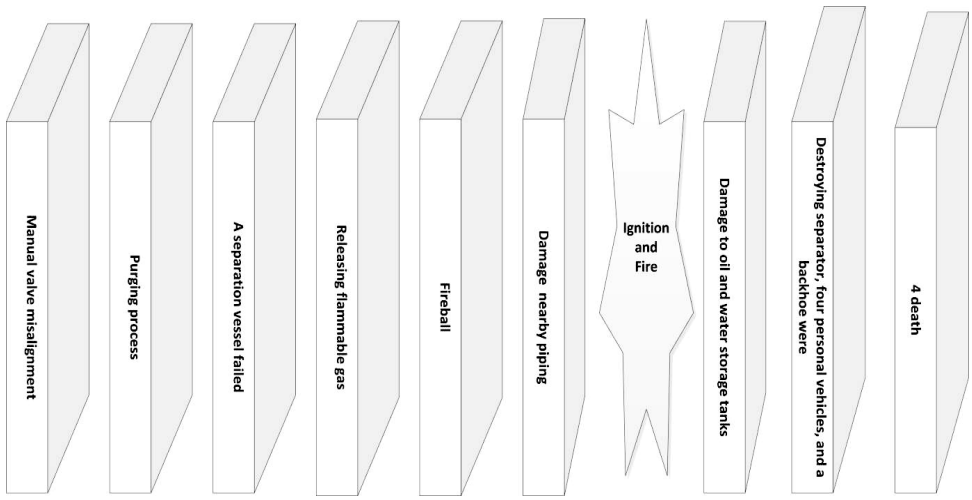

Figure 2.1. *The sequence of events at Sonat Exploration Company (1998)*

Table 2.1. The decision and the managerial failures in different phases that gave rise to vessel over-pressurization at the Sonat Exploration Company (1998).

Phase/ Schedule	What should have been done?	What was done?	Why?	Who did it?
Design and operation	Provide written checklists and diagrams to verify proper valve positions for purging	Manual valve misalignment	There was not any written procedure about it	Operator
Design	Separator equipped with pressure-relief devices	Did not happen	Management oversight	Management
Operation	Provided written operating procedures addressing the alignment of valves during purging	Did not do	Management oversight	Management

2.3.2 Tosco Avon Refinery fire incident

The refinery fire in the crude unit at the Tosco Avon refinery on February 23, 1999, which led to four deaths and one critical injury, occurred as a result of a sequence of activities. It started with the detection of a pinhole leak in the upper section of the naphtha piping on February 10. The emergency responders isolated the line to stop or slow the leak without shutting down the crude unit. Then, the operations supervisor ordered an emergency work order on the same day. The inspection revealed that the piping was severely corroded, so technical staff recommended the replacement of the entire line from the valve A to the naphtha stripper (CSB, 2001).

The leak re-occurred on February 13 and 17, while the naphtha piping was warm to the touch; so the piping isolation valves (A and B) were retightened resulting in subsidence of the leak. At the same time, the level of the liquid in the naphtha stripper rose to the high level on seven occasions, while operators lowered it by opening the naphtha to storage flow control valve. On the last occasion, the valve was left open to the storage tank to prevent build up; this valve remained open until the day of the fire. One day before the incident, an operator discovered another leak against the original leak point and the piping was hot to the touch. The shift supervisor plugged the hole, and then it was removed after finishing the hot work (CSB. 2001).

Several attempts were made to drain and replace the piping, but these efforts failed. On February 23, the work permit was signed even though both maintenance and operations groups knew that the piping contained liquid naphtha and draining was needed (CSB. 2001).

On the day of the incident, the maintenance supervisor first directed workers to cut a short section of the line. Then, the second cut was done 26" below the location of the first cut. During the drainage of naphtha from the flange, the naphtha suddenly released from the open piping. contacted the hot fractionator and then ignited and engulfed the tower structure and personnel, leading to four deaths and a serious injury (CSB, 2001).

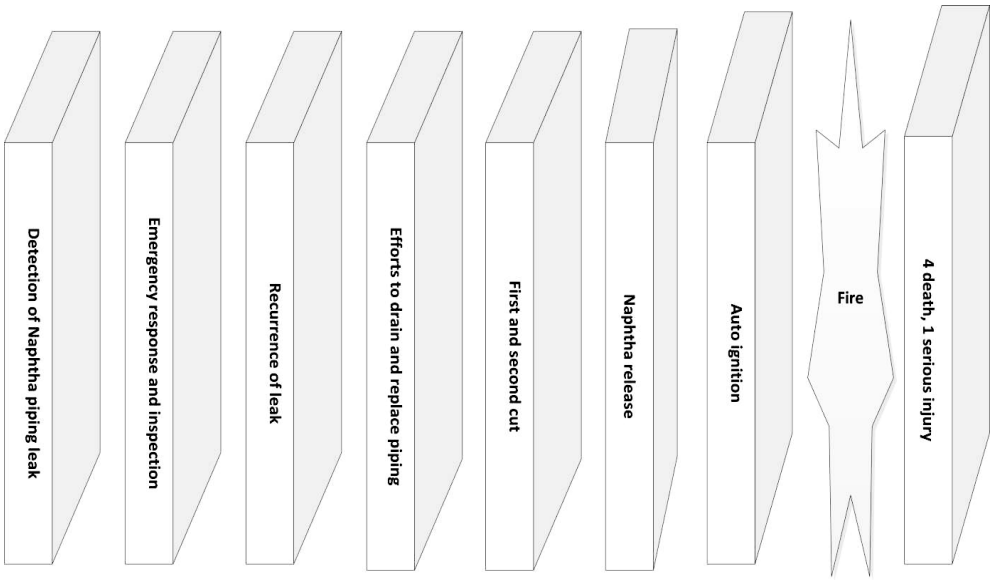

Figure 2.2. *The sequence of events in the Tosco Avon Refinery fire incident (1999)*

2.3.3 LPG fire at Valero-McKee refinery

Liquid propane was released under high-pressure from a cracked control station near ground level at the No.1 extractor tower in the propane de-asphalting (PDA) unit of Valero's McKee refinery at 2:09 p.m. on Friday, February 16, 2007. Plant personnel quickly directed workers to evacuate. The propane vapour cloud, resulted from the propane release, escaped from a high-pressure system and was ignited by an ignition source which was probably the boiler house. Then the flame impinged on piping around the extractor resulting in additional propane release and damage to the unit piping and equipment. A non-fireproofed structural support for a pipe bridge was located on E-W pipe rack north of the unit, close to the process units. The support collapsed, leading to a considerable rise in the size of the fire. Three workers, including a contractor, were seriously burned; a firefighter also received minor burn injuries; 10 others were treated for minor injuries; the refinery was shut down completely for two months, and rebuilding of the PDA unit lasted one year (CSB, 2008).

Table 2.2. The decisional and the managerial failures in different phases gave rise to the Tosco Avon Refinery incident (1999).

Phase/ Schedule	**What should have been done?**	**What was done?**	**Why?**	**Who did it?**
Operation	Shut down the process unit during the naphtha piping repair	Not done	Production has more priority than safety	Operations supervisors
	A higher degree of management scrutiny and approval were needed	Operations supervisors were authorized for repair and maintenance work	Management oversight	Nobody, but it should be performed by the superior management
	Supervision of job execution by operations supervisor and health and safety personnel	Not done	Management oversight	Nobody
	Workers stopped unsafe work activity	Not done	Pressure to get the job was greater Workers did not oppose instructions from a supervisor Idling the job after starting could result in significant financial cost; so, more pressure to prevent a delay	Nobody
	Pre-job safety planning for effective isolation	Job planning was performed in stressful environment of job execution	Time pressure, emergency condition	Maintenance and operations supervisors
	Did not schedule the pipe removal	Scheduled	Tunnel vision, priority of production to safety objectives	Operations supervisors
	Did not operate the third-stage separators that lacked adequate pressure-relief systems	Third-stage separators operated without adequate pressure-relief systems	Management oversight	Management
	Performed the process hazard analysis	Did not do	Did not perform effective process safety management	Management
	Written checklists to verify proper valve positions for purging	Manual valve misalignment	There was not any written procedure about it	Management

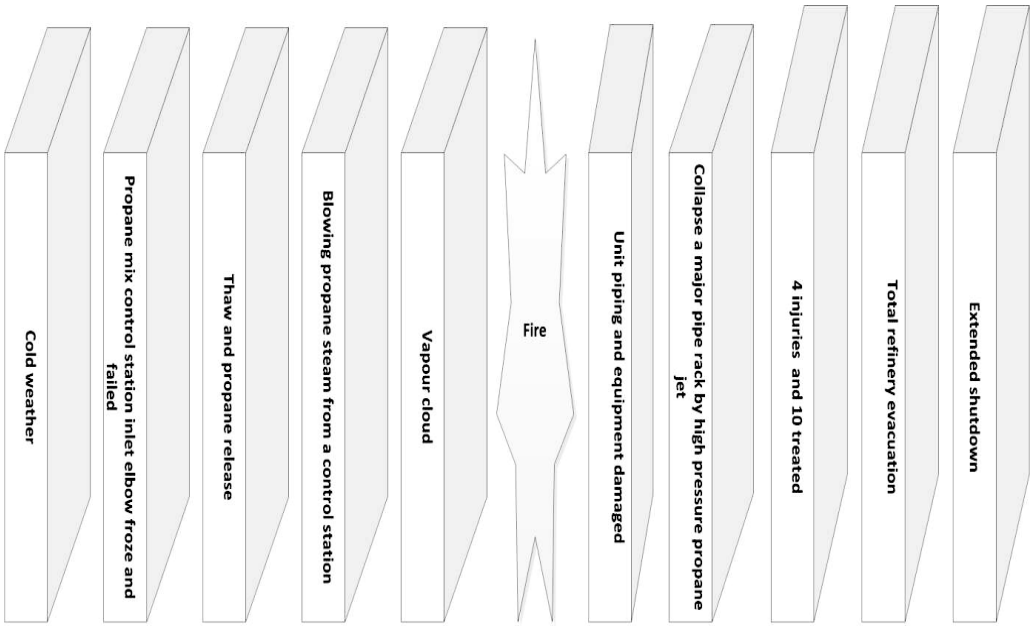

Figure 2.3. *The sequence of events in LPG fire at Valero-McKee refinery accident (2007)*

2.3.4 Rupture of a heat exchanger in the Catalytic Reformer unit in Tesoro

On April 2, 2010, Tesoro, a Refining and Marketing Company in Washington experienced a catastrophic rupture of a heat exchanger in the Catalytic Reformer/Naphtha Hydrotreater unit. The High-Temperature Hydrogen Attack (HTHA) caused highly flammable hydrogen and naphtha at more than 500 degrees Fahrenheit (ºF) to be released from the ruptured heat exchanger. Subsequent ignition caused an explosion and an intense fire burned for more than three hours. The rupture fatally injured seven Tesoro employees (one shift supervisor and six operators) who were working in the immediate vicinity of the heat exchanger at the time of the incident (CSB, 2014). Figure 2.4. shows the sequence of this accident.

This accident was the largest fatal incident at a US petroleum refinery after BP's Texas City accident in March 2005. The accident happened in the final stage of the start-up activity when the Tesoro workers put the three banks of heat exchangers in service, following cleaning, while other heat exchangers remained in service during this operation (CSB, 2014).

Table 2.3. Decisions in different phases that gave rise to LPG fire at Valero-McKee refinery (2007).

Phase/Schedule	What should have been done?	What was done?	Why?	Who did it?
Operation/ start-up	Shut off the flow of propane	Operator was unable to do	ROSOVs [2] were not installed	Refinery management
Design	Retrofit the ROSOVs in the PDA unit	Not done	The guidance did not provide specific criteria for the design, location, and use of ROSOVs	Refinery management
Design, operation and installation	Proper distance between manual firewater deluge valve to the PDA unit	Not a proper distance	Did not provide criteria for design, operation or location of firewater deluge valves	API [3]
	LPG storage sphere failed	Did not establish firewater deluge for butane sphere	Butane sphere firewater deluge not established	Refinery management
	Enough distance between rack and near process units	Not done	Sufficient criteria for distance between racks and near process units with high pressure flammable material was not provided	API and Valero standards
	Provide detail guidance on freeze protection programs	Not done	Detail guidance was not provided for special equipment leaving them in vague condition for decision-making	API, Process safety management
Maintenance	Periodic survey for potentially freeze-prone dead legs, infrequently used piping system, and areas where water could collect	Not done	Did not set a minimum standard for freeze protection programs (criterion)	API, Process safety management
	The P& ID detected the propane mix control station dead leg	Could not detect	The criterion for identifying the dead legs was visually apparent or physically removed dead legs, not for dead legs closed by block valves	P& ID
Operation	Using safer biocides than chlorine	Using chlorine as a biocide		Management

[2] Remotely Operable Shut-Off Valve

[3] American Petroleum Institute

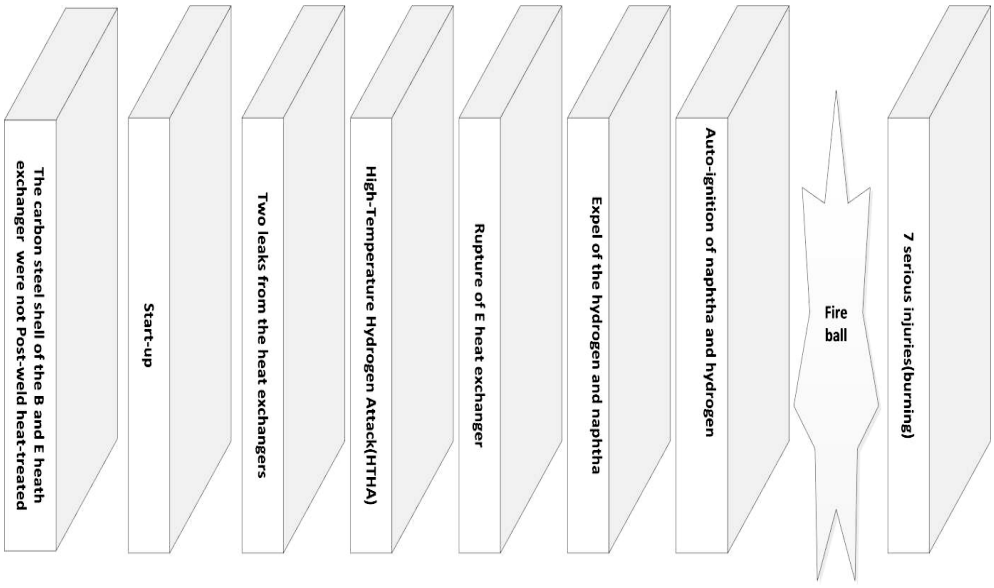

Figure 2.4. *The sequence of events in Tesoro incident (2010)*

Table 2.4. Decisions in different phases giving rise to the Tesoro accident (2010).

Phase/Schedule	What should have been	What was done?	Why?	Who did it?
Design	Inherent safety design	Did not apply inherent safety design	There was not a transparent method showing the process of design decisions	Management
	Demonstrate ALARP in safety management	Not done	Risk analysis was activity-based rather than a risk reduction target Lack of technical competencies in risk assessment Not effective involvement of the workforce in safety management	Management
	Instruments in exchangers should measure temperature and pressure	Did not illustrate	Instrument did not work efficiently	Design
Operation/start-up	Shutdown	Continue start-up	Not a written decision-making protocol for a shutdown in non-routine works	Operator manager
	Field operator (Tesoro procedure)	Seven employees presented in the vicinity	Procedure did not exclude the number of present employees The producer was not based on operator capability Only one criterion (minimising exposure) was considered in this procedure	Operator manager
Inspection	Implement a reliable method	Applied an unreliable method for inspection	Document was permissive Not provided a minimum requirement to prevent HTHA failures	Inspection department
	Any change should be managed	Management of change was not performed properly	Company did not evaluate new risks	Management

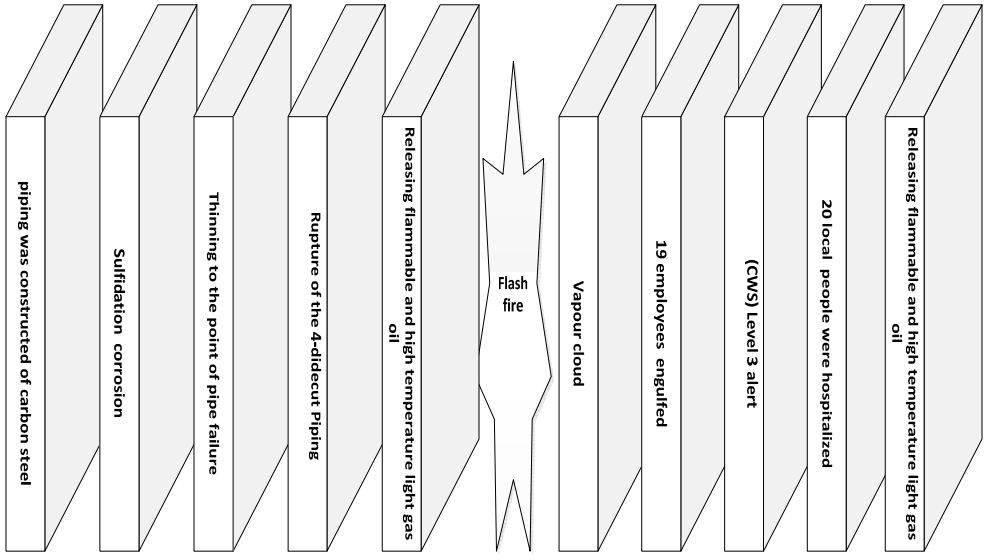

Figure 2.5. *The sequence of events in Chevron accident (2012)*

Table 2.5 provides a summary of the document analysis on the decisions in different phases, which led to this accident. In total, there was more focus on the causes related to decisions in the Chevron accident compared to the Tesoro investigation report. This document also did not illustrate the influence of middle managers in the incident. However, we can notice that those managers who were involved in risk management and the manager of the inspection department can be described as middle managers.

Table 2.5. Decisions in different phases gave rise to Chevron incident (2012).

Phase/Schedule	What should have been done?	What was done?	Why?	Who did it?
Inspection	Inspect piping before August 2012	Not done	Decision made based on turnaround management program instead of applying priority ranking system	Turnaround management
	Apply a priority ranking system for sulfidation corrosion prevention	Not done	ETC was a separate business entity without authority to influence the monitoring and control of corrosion	Turnaround management
	Gather all relevant information before making a decision	Rely on a fraction of data to make a decision	Availability heuristic	Turnaround management
	Replace the pipeline	Decided to not replace the piping	Normalisation of warning signs	Turnaround management
Operation	Employ stop work authority by lower level	Not done	Safety culture	Supervisor
Emergency response	Identify the extent of safety hazard caused by low-silicon piping components	Failed to identify the extent of hazard	Lack of knowledge	Fire-fighter commander

2.3.6 BP Texas City refinery explosion

An operator overfilled a distillation column on March 23, 2005; therefore a mixture of liquid and gas flowed out through the emergency overflow and discharged from a vent located several hundred feet away from the distillation column. Since there was no flare in the vent, a mixture of gas and liquid was discharged into the atmosphere resulting in a hydrocarbon vapour cloud that was ignited by a vehicle engine, which led to an explosion. It destroyed a number of mobile offices close to the plant, killed 15 people and injured more than 170 persons. This disaster was the worst industrial disaster in the US in more than a decade in terms of fatalities and injuries (Hopkins 2008).

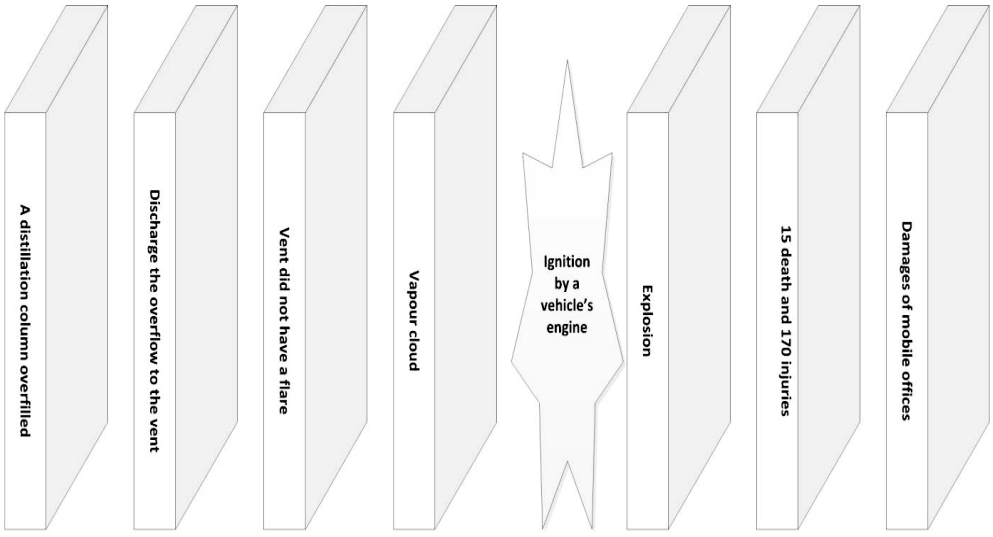

Figure 2.6. *The sequence of events in the BP Texas City refinery explosion (2005).*

Hopkins in his book started with illustrating the differences of this case with other cases, while in fact, he highlighted the similarities of this disaster with other accidents particularly the Esso Longford gas plant explosion in Victoria Australia. He pinpointed that although accidents were investigated and documented extensively in organisations, and the causes of those incidents are all remarkably similar, companies fail to learn from major accidents.

What Hopkins demonstrated as contributing factors that led to BP Texas City Refinery disaster are similar to the contributing factors that gave rise to BP's Deepwater Horizon Blowout in the Gulf of Mexico; these were mainly a focus on personal safety instead of process safety, cost cutting, organisational structure and functioning which led them to make poor decisions. Table 2.6 illustrates these failures.

Table 2.6. Failures in different phases giving rise to the BP Texas City explosion.

Phase/Schedule	What should have been done?	What was done?	Why?	Who did it?
Training	Monitor the efficiency of computer-based training	Applying computer-based training without monitoring	Cost cutting	Management of training
Safety	Carry out the non-compliance surveillance	Not done	Safety group was severely under-resourced/Cost cutting	Safety manager
	Operationalize the established safe operating limits	Not done		Safety manager and operational manager
	Process safety had a champion at a high level within the corporate	Not done	There was no direct line of reporting to the functional units	Senior management
	Incentive systems for individuals must be designed accordingly	Individuals were not aligned with the incentive structures of the organisation	Senior managers diverted attention from process safety	Senior management
	Consequence-based decision-making	Risk–based decision-making	Senior management policy	Senior management
	Emphasis on process safety indicators	Emphasis on personal safety indicators	Blindness to major risks	Senior management
	Applying Precursor events for major accidents	They applied precursor events for personal injury	Emphasis on personal safety	Safety management
	Apply proper indicators for process safety	BP interpreted improving personal injury rates as an indication of acceptable process safety performance	Blindness	Safety management
Operation	Opting for new hardware	Rely on more people-dependent and	Increasing expectations and costly regulations	Operational manager

Phase/Schedule	What should have been done?	What was done?	Why?	Who did it?
		operational controls		
	Follow procedure	Deviated from procedures	Production has more priority	Operational manager
	Operating with a smaller safety margin for a shorter time	Operating with a smaller safety margin for longer time	Normalization of risk	Operational manager
Design	Standard design of the column to measure liquid levels over a much greater range	Not performed	Failure to design	Design
Trailer location/safety	Rule-based decisions	Individual risk-based decision	Policy	Risk management team
Management of change	Centralised organisation	Flatter organisation	Decentralised organisation	Senior management
	Staff cuts and training cuts change should be managed	Company did not evaluate new risks caused by cost-cutting	Cost-cutting	Senior management

2.3.7 Blowout in the Gulf of Mexico – Deepwater Horizon

A blowout happened in the huge floating drilling rig in the Deepwater Horizon in the Gulf of Mexico on the evening of 20 April 2010. The subsequent explosions and fire led to 11 deaths, the sinking of the rig, damages to the environment and the livelihood of residents (Hopkins, 2012). This incident is known as the most disastrous environmental event in US history.

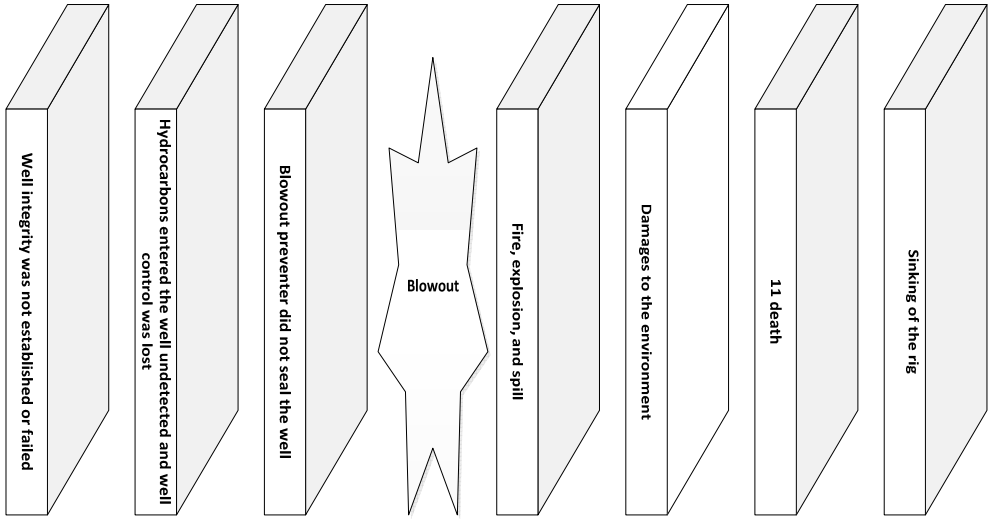

Figure 2.7. *The sequence of events in the Deepwater Horizon accident after Hopkins (2012)*

Hopkins in his Disastrous Decisions book argued that there were a series of critical failures in critical defences (Figure 2-7) which led to this event. He highlighted that the wrong decisions and influencing factors led BP (the client) and Transocean (the drilling contractor) down a path to disaster that was the blowout of the Macondo well. He took into account human and organisational causes such as the process of decision-making, engineering's tunnel vision, confirmation bias, falling dominos, the failure of defence in depth, process safety indicators and incentives, organizational issues, failure to learn, regulation, and accident normalization. Table 2-7 represents the decisions and the driving factors in different phases gave rise to the blowout in the Gulf of Mexico (2010).

Table 2.7. Decisions on the rig[4] in different phases that gave rise to the blowout in the Gulf of Mexico (2010).

Phase/Schedule	What should have been done?	What was done?	Why?	Who did it?
Operation	Consider safety risks	Focus on commercial risks	Tunnel vision	Macondo engineers
	An individual decision	A consensus decision	A comfortable method	Macondo engineers
	The group of decision makers should be separate from approving group	Combined seeking information with decision makers group	Verifier and decision–making group was the same	Macondo engineers
	Gathering all relevant inputs	Seek a fracture of data	Confirmation bias	Macondo engineers
	Consider alarm signals	Did not do	Normalisation of warning signs	Macondo engineers

2.4 Discussion

Our purpose in this chapter is not only to identify decision-making errors and contributory factors in accident scenarios but also to give an insight into middle managers' roles in these accidents. The results revealed that accident scenarios are useful tools for the analyst since they enable them to explore the causes of accidents systematically. They provide a way of dealing with different aspects of a problem simultaneously. Unlike specifically technical failure analysis, scenarios allow for a combination of the heterogeneous factors that experience shows they describe how accidents happen. In addition, scenarios can structure uncertainty when they are based on reality and they help decision-makers to recognize their mental model of reality (Weick, 1985). The real scenarios that were used in this study enabled us to understand how decisions were made in practice in different sites but still similar processes comprised interconnected factors. The actual accident scenarios do not have the shortcomings of the artificial scenarios such as abstract and unrealistic examination, the lack

[4] There were considerably more management errors onshore (Hudson, 2011) that Hopkins did not consider as they only became evident in court and after the publication of his book.

of external validity, and not reflecting the real world (Jarzabkowski, Bednarek, & Cabantous, 2015) of decision-making.

The data analysis also revealed that the main difference between the CSB investigation reports and Hopkins' books is the depth of accident analysis and direction of analysis. Hopkins went through to more root causes of accidents in terms of organisational and human error causes; while the CSB was more focused on the technical causes of accidents than making an organisational assessment. The CSB report still suffers from ambiguity and vagueness about what decisions were actually made, and by whom, as well as what decisions could and should have been made, including failures to carry out previous decisions (often policy or standards). For instance, the CSB considered managers as one group, while they failed to consider that there is a boundary-spanning role (Floyd & Wooldridge, 1997) based on organisational structures (Aldrich & Herker, 1977) which can influence both the level and type of management activities (Floyd & Wooldridge, 1997). Therefore, the extent to which managers contribute to an incident depends on their positions in a managerial ladder.

As can be seen from the analyses of the individual incidents there are roles identified for senior management, site management and safety departments as well as for external bodies such as the API for standards setting. The picture that emerges is one in which the role of the individual operator or low-level supervisor, while necessary in the scenario, can only be understood in the context of failures going higher up. Likewise there are more than just senior managers involved.

The documentary analysis also disclosed that one essential factor in decision-making, which in turn led to accidents, was a lack of a clear criterion or criteria for decision-making in these cases. For instance, absence of a transparent method for design decisions; lack of demonstrating robust controls and inherent safety design in decisions to achieve ALARP level; not providing a written decision-making protocol for determining the time to shut a process down for executing repairs; absence of criteria for performing work safely in non-routine tasks; or lack of a minimum requirements to prevent HTHA failures. These cases demonstrate that decisions in high hazard process industries, like the oil and gas industry, are not necessarily made based on clear consideration of a variety of predetermined and rigorously evaluated criteria; rather there is either no criterion at all or the criteria are vague and misleading.

Incidents such as Tosco Avon (1999), BP's Texas City refinery explosion (2005) and the blowout in the Gulf of Mexico (2010) confirm the presence of multi-objective decision-making in these cases, with revenue generation commanding the top most priority in these companies. Alteration of the focus of individuals in the companies towards profit resulted in a different trade-off against safety and actually increased the likelihood of catastrophic outcomes. These challenges in daily practice led to normalization, tunnel vision and

confirmation bias in decision-making – past success did not, as it turned out, guarantee future performance. Individuals sought for information that confirmed production objectives while they accepted individual safety barrier failures like leakages and thinning of the pipeline. People at different levels commonly failed to notice the alarm signals or they ignored these alarms as a result of giving more priority to economic risks than safety risks. They preferred to rely on a fraction of data, which confirmed continuity of the start-up, postponing the pipeline replacement, unwilling to employ Stop Work Authority or continuity of the drilling. Therefore, safety hazards were missed or under-estimated (Hudson, 2011), and poor decisions were made.

The analysis showed that decision-making for safety issues was often performed as a risk-based decision, often on single cases, rather than using rule-based decision-making that takes a broader view of the risks. Implementing this unreliable method for decisions left technicians, engineers and other experts in complicated situations to make decisions without giving specific criteria to their decisions (Hopkins, 2011). Therefore, converting decisions from risk-based decisions into rule-based decisions appears to be more appropriate in cases like non-routine works that happen a lot in process industries, such as start-up and shut-down. This would help in preventing confirmation bias, since people have a tendency to underestimate the specific risk in order to confirm that their decision, on a one-off basis, will still be safe. Second, risk-based decision-making, when it is coupled with a set of budget priorities, makes it very difficult to give a greater weight to possible, but unlikely, problems with process safety compared to inevitable issues of extra expenditure if extra steps are taken, consequently leading to less competent risk assessments. Third, in a risk-based approach, a risk is a product of likelihood and consequence, therefore, this approach fails to show the accurate level of risk in some process risks when their overall likelihood is extremely low; for instance the sensitive transitional periods make up a very small portion of the total time contributing to the probability estimation unless one is directed in that direction. For instance an 8-hour transition, once a year, means that the transition covers 1 thousandth of the total time of operation, three orders of magnitude that can be used to impact a less than rigorous risk assessment. Finally, there is always a level of uncertainty about risk assessments even they are made by expert and competent people (Hopkins, 2012) whereas extra costs and loss revenue appear much less uncertain.

One influential managerial factor identified here, helping to make fateful decisions, was organisational structure. Evidently, both Chevron and BP had a more decentralised organisational structure where engineers reported to line managers who were themselves at a low level and were relatively cost-focused managers. The Tosco incident provides evidence that mixing the decision and confirmation of a decision was done in the lower levels of management and those lower level managers were authorized to make decisions about safety-related decisions. In cases like the Tosco incident and the Macondo disaster, the decision and

approval of decisions were mixed and lower level managers were authorized to make decisions about safety-related decisions. In addition, higher management put the responsibility of decisions for implementation of preventive methods in the shoulder of lower employees who did not themselves have the authority for decision-making and funding (CSB, 2015).

Hopkins argued that in a decentralised organisational structure, differences in opinions are settled at the base level and the lower-level managers are ultimately responsible for their decisions. This structure is more time-efficient and decisions in this level are the best place to make a balance between competing for commercial and engineering priorities (Hopkins, 2012) and the span of control for those managers is greater (Hopkins, 2008). However, where engineering integrity is important, the more centralised organisational structures are superior because managing such issues is performed rigorously and effectively. The centralised organisational structure is more appropriate for the oil and gas industry with multiple hazardous activities because decisions and verification of decisions are performed at different levels. So, differences can elevate to the higher level and then the chain of scrutiny can provide assurance about the accuracy of the proposed course of actions and this structure can decrease the confirmation bias and tunnel vision bias in decision-making. A specific example of how a centralised structure performs these trade-off tasks better is provided by Exxon-Mobil's decision, in 2006 before the Macondo disaster, to shut in the Blackbeard well, also in the Gulf of Mexico, after running out of drilling margin, despite being an 'elephant' a particularly valuable oil reservoir. The decision in Exxon's case was devolved upwards and was taken by the CEO, Rex Tillerson. In BP's case the CEO, Tony Hayward, claimed to have had no knowledge of Macondo until after the blowout, despite several chances for critical information[5] to be directed upwards (Hudson, 2011).

Another shortcoming that caused poor decisions in these accidents was inappropriate management of change. Tesoro changed the risk-based inspection technology while the company did not manage and did not evaluate the new technique to ensure that safety and health risks arising from this change were controlled. BP made several cost-cutting exercises in its refinery division, including Texas City, but did not manage the outcomes of cost-cutting in safety. "Many changes in complex organizations had led to the lack of clear accountabilities and poor communication, which together resulted in confusion in the workforce over roles and responsibilities" (Hudson, 2011). This evidence signals that these "dinosaur companies" did not adjust to sudden environmental changes (Weick, 1985).

[5] In the month prior to the blowout there had been a major kick that resulted in a sidetrack. The cost of the drilling equipment that was destroyed and the extra costs of the sidetrack exceeded the threshold for a Major Incident Announcement. BP's corporate policy required such a MIA to be notified to London and to two committees on which the CEO sat. No report was made to London from BP's Drilling and Completion department in Houston (Hudson, 2011)

The safety culture also created confusion over roles and responsibilities; consequently poor decisions were made or rather, not made when they should have been. For instance, Chevron managers at the lower level were not willing to employ Stop Work Authority because of its impact on the work progress and causing a delay. Furthermore, they thought that managers at a higher level of the organisation who have more authority can decide and would then be accountable for it. In the case of Macondo Stop Work authority was exercised when a 2 lb. winch handle, which must have fallen from the derrick, was discovered on the rig floor. In BP's and Transocean's case, however, authority appeared to be limited to personal safety priorities because no Stop Work action was taken the previous day when there was a fire (reported in the daily drilling report) on the rig (Hudson, 2011).

The analysis also revealed that inadequate situational awareness was another bias that occurred in decisions. For instance, a fire-fighter commander failed to identify the extent of the safety hazards caused by low-silicon piping components. This lack of knowledge resulted in a wrong decision that the commander limited activities to the hot zone without considering the heightened possibility of the pipe rupture that eventually exacerbated the incident. Consequently, more people were physically placed into the dangerous situation.

2.5 Conclusion

In this chapter a documentary analysis has been done for exploring information about decision-making, contributory factors, and the role of middle management in these accidents. This chapter has led us to the following results:

- It is not entirely clear what the roles of middle managers are in these accidents. Only in Hopkins' assessment of the BP disaster in the Gulf of Mexico was there evidence that explicitly illustrated the middle management involvement in decision-making and the obstacles that they faced to come to a decision. In CSB reports there is evidence that shows middle management involvement in these accidents, but the CSB did not consider any boundary for different levels of management.
- The accident causation reports have failed to give much, if any, insight into the *process* of decision-making. However, they do provide valuable information about the failures that subsequently gave rise to poor decisions. It can be an ambiguity in providing the criteria for choosing the proper safety measure, transforming from safety objectives to other objectives, and internal and external factors that led to circumstantial decisions. Yet, there is a clear gap to adequately illustrating the decision-making processes in these accidents.
- Safety-related decisions are made in different steps. First, decisions that are taken a long time before incidents or pre-accidents, or in other words, decisions made under normal and routine activities that are taken to stay in stable conditions. In these decisions, decision makers can analyse decision problems with enough time. Accident investigation

reports have lots of proof about failure in decision-making at this stage, which finally led to those disastrous accidents (see e.g. Reason, 1997). Second, decisions have to be taken under abnormal conditions such as shutdowns or start-ups, when some parameters of the process deviate from the normal conditions and decision makers are faced with increased uncertainty and lack of resources or other influencing factors. In these conditions, time pressure, and the lack of resources to control the conditions are higher, so it might increase the probability of errors in decision-making. Finally, in emergency conditions, when something wrong suddenly happens, which can result in incidents and managers try to overcome and control the conditions with less amount of losses, at the same time they are faced with more pressure on both time and other resources. All of these decisions are important and have different characteristics that should be studied, while there is still an obvious gap in this scope for research.

- To sum up, a possible solution to the current situation could be more study on the middle managers' roles in safety, and the process of middle managers' decision-making, coupled with contributory factors in their decisions in actual conditions instead of solely post-hoc incident analysis

3. Who is a middle manager (a literature review)?

3.1 Introduction

Accident causation analyses in the previous chapter revealed that although middle managers play crucial roles in organisations, middle management's roles were not given much attention in accident investigations. For instance, the BP blowout accident provides evidence that highlights the prominent role of middle managers, when middle managers' decisions were taking them a step on the path to a disaster. The Macondo team, which included engineers, well team leader and rig-based well site leaders, who were mostly middle managers, made the flawed decisions as a result of the organisational structure of BP's engineering activity, economic pressure, focusing on personal safety instead of process safety, and consensus decision making.

The analysis of accident investigation reports also revealed that there is information about management failures in the CSB reports; however, the CSB did not take into account that different levels of management in organisations have different degrees of power, authority, accountability and responsibility. The breath of authority and responsibility in an organization depends on the structure of the organisation and a clear definition of management level which is defined based on the spread of authority, accountability, responsibility, reporting relationships, supervision, decision-making, and information needs (Tenah, 1986).

Currently, most industries have established occupational health, safety, environmental and quality management systems (HSEQMS). To successfully implement an effective HSEQ system in an organisation, resource allocation, employee participation (Nytro et al.1998, Bhattacharya and Tang 2012) and the commitment of individuals from top management to front line level is essential. This implies a high level of interdependency between different levels in an organisation, as well as the importance of various managerial levels in an HSEQ management system. Since one management level that engages in many unique tasks within an organization is middle management, it is essential to identify the concept of middle management and to define their functions. In this chapter, we answer the research sub-question: who is a middle manager?

We assess current literature on middle management that enables us to illustrate the concept of middle management and specific features of middle managers (research question #5). Furthermore, four other sub-research questions are scrutinized namely:

- What are middle manager's roles, their main responsibilities and their effects in organisations?
- What are middle management roles and their influence in safety management?
- Whether decision-making is an important role of middle management?

- If so, how do middle managers make decisions based on literature review?

In what follows, we will summarize the scientific literature and use the findings to provide answers to these research questions.

3.2 Method

Before beginning to test causal hypotheses, an investigator has to make sure that the collected data conforms to the conceptual structure postulated in advance. For this reason, we reviewed and summarized the relevant published studies about definitions of the term 'middle manager'. At first, since our interest was primarily on the role of middle management in safety management, a systematic search was conducted on the table of contents of academic journals in the safety field (e.g. Safety Science, Accident Analysis & Prevention, the Journal of Safety Research) in order to find data about definitions of middle management and their roles in safety. There was not, however, any definition regarding this term in those journals so, we extended the scope of research to three academic databases, which were Google scholar, Scopus and Web of Knowledge (Science), to search for identifying the middle management terms and definitions as well as the roles of middle management. The bibliographies of references were also searched as well as the Wikipedia and management encyclopaedia.

3.3 Result

Primary literature review in the safety field revealed that there is a tendency to concentrate study on senior management, assuming that senior, executive management has the highest responsibility in safety management (Roger, Flin, Mearns, & Hetherington, 2009) or focusing on the operational level (Hayes, 2012; Kirwan, 1998; Mumaw, Swatzler, Roth, & Thomas, 1994; Patterson & Shappell, 2010; Shorrock & Kirwan, 2002) . The operational or front-line individuals are those who are directly involved in field work, so that they are the closest people to accidents and most likely to be the victims as well as invariably providing the proximate causes – those who are always the last to touch the equipment etc. However, there is a general lack of information that addresses the concept of middle management, such as a definition, encompassing those who are to be found between these two extremes. There was a small number of articles regarding to the role of middle management in safety journals (Bhattacharya & Tang 2012; Flin 2004; Hayes 2012; Littauer, et al. 1976; O'Dea & Flin, 1998, 2001; Petersen 2000).

In total, we reviewed 60 articles, dating from 1975 to 2015, which had some information about the definition of middle management, middle management roles or the influence of middle management in an organisation. The results revealed that investigators have currently more tendency to search in middle management but still in the general management scope, while this essential group is given little attention in the safety domain.

Prior to delving into the literature review, it is essential to illustrate that the term 'middle management' was not defined consistently in the literature. Not only there was not any exact definition for a middle manager that is applicable for all organisations but also there was not even a clear-cut point between this managerial group and other management groups. It is even harder to be precise where organisations have developed flatter hierarchies with blurred boundaries (McConville & Holden, 2010).

Various criteria have been applied for identifying this managerial group. Functions or assigned responsibilities provide the first criteria for distinguishing this managerial group. Torrington and Weightman (1987) identified three functions for middle managers, namely administrative, technical and managerial functions. Another criterion is the position of middle managers in the organisational hierarchy. They are positioned at a level where there are at least two levels of staff below them (Currie and Procter 2005; Pugh et al. 1968; Smith 1997; Staehle and Schirmer 1992; Wooldridge et al. 2008); this definition excludes immediate field supervisors. The organisation structure or the context of an organisation is another essential factor which influences the definition of middle management (Currie & Procter 2005; Dopson & Stewart 1990; McConville & Holden, 2010). Even, the purpose of researchers was found to affect the definition of this managerial group. For instance, on the one hand, Currie & Procter (2005) considered location managers as middle managers who were far from the operational core of the organization and even though there was only one level of staff located below them, because they considered other contextual criteria. First, they were managing under leadership of a multidisciplinary team; second, the organisational structure was less elaborate; third, they reported to assistant directors who were positioned at the corporate headquarters. On the other hand, Brewer (2005) considered middle managers in the federal government as frontline supervisors when he studied supervisory tasks. He argued that middle managers have similar or greater supervisory tasks (Brewer, 2005). In Appendix A, we provide a summary of findings about descriptions, important characteristics, and the roles of middle management in more details that deserve special attention.

3.4 Discussion

The literature review reveals two prominent trends in research on middle management. The first concentrates on the strategic contribution of middle management in organisations. The most systematic and widely cited attempts to explore the strategic roles of middle managers were carried out by Floyd and Wooldridge (Floyd and Wooldridge 1992, 1996, 1997, 1999, 2000, Wooldridge et al. 2008, Currie and Procter 2005). The second trend has been about either the roles of middle management in organisational change or changing the roles of middle managers as a result of organisational change, (Balogun 2003, 2007; Beck and Plowman 2009; Besson and Mahieu 2011; Brubakk and Wilkinson 1996; Buss et al. 2011;

Chang and Bright 2012; Dutton et al. 2001; Manville et al. 2012; Raelin and Cataldo 2011; Rouleau 2005).

Managerial roles are defined as having various responsibilities and requirements associated with enacting their managerial job. These roles are more than just required activities; instead, they encompass the activities, knowledge, skills, and traits that are required to enact a managerial job. The literature review revealed that managerial roles vary depending on the context of the organisation. In other words, studies show that the requirements of the managerial role appear stable over decades; nevertheless, the importance of a specific role depends on the context of the organisation (Dierdorff, Rubin, & Morgeson, 2009) and managers can play one or several roles within a given point in time.

The lack of consistency in a holistic typology of middle management roles is evident (Rainey and Watson 2007, Wooldridge et al. 2008) and there is a considerable overlap between elements of roles. However, the purpose of this chapter is to illustrate the role of middle management particularly in safety. Therefore, Table 3-1 outlines middle management roles which can subsequently be categorized into 5 prominent roles: strategic roles, administrative roles, leadership, decision-making and communication. They can then be divided into sub-categories that are illustrated in Figure 3-1 and Table 3-1. It is important to remember that the extent of these roles depends on the context of the organisation, time and the attitudes of middle managers.

The strategic roles of middle managers encompass championing, synthesizing, facilitating and implementing (Floyd & Lane, 2000). In the championing role, middle managers present innovative ideas and business opportunities to top management. Categorizing and blending both strategic and hands-on information (Nonaka 1988, Wooldridge et al. 2008) as well as selling issues to top management (Dutton et al., 2001) are activities for carrying the synthesizing role. Direction of communication in these roles is upward, while facilitating and implementing roles have downward directions. In their facilitating role, middle managers nourish divergent adaptability to strategy and changes. They share information (Mintzberg, 1978) and they can guide adaptation (Chakravarthy, 1982); for instance, they can facilitate adequate prioritization of safety goals and learning. Middle managers implement the planned strategy or strategic decisions (Buss et al., 2011). They transfer the broad and long-term strategic objectives from the corporate centre to individual performance plans and short term operational objectives which are then implemented by local managers in the field (Currie & Procter, 2005). For this purpose, they motivate, coach and inspire their subordinates (Floyd & Lane, 2000).

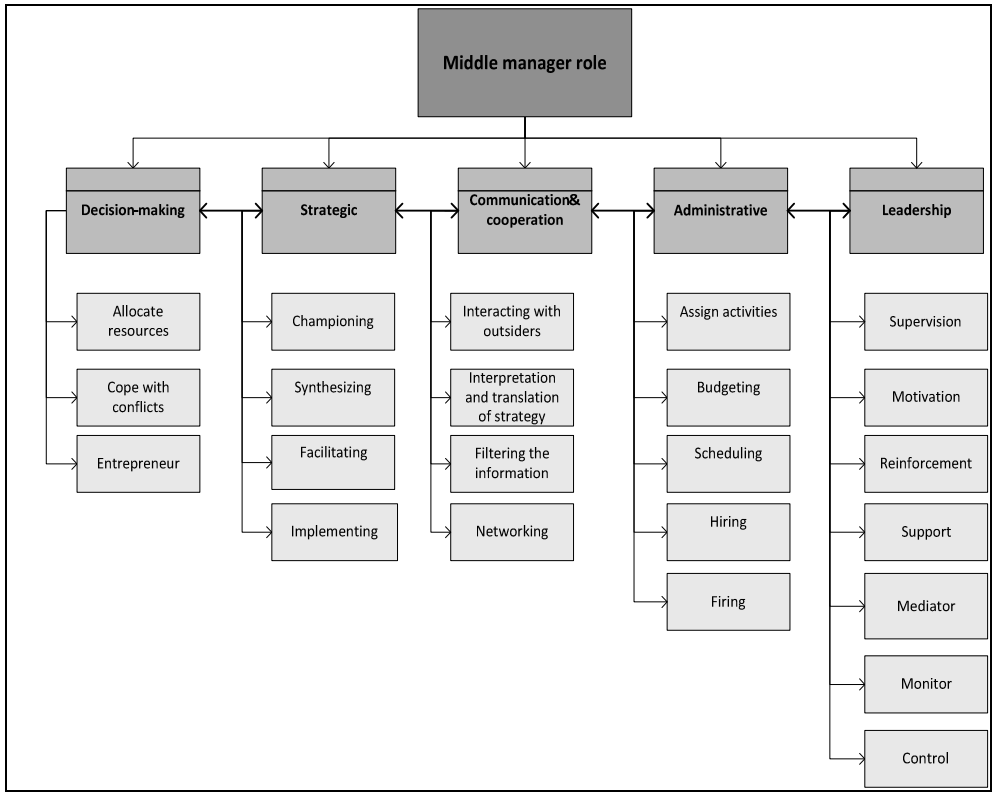

Figure 3.1. *Middle management roles according to a literature review*

Communication and cooperation is another essential role of middle management that consists of interacting with outsiders, interpretation and translation of strategy, filtering the information, and networking. Their particular positions in the social network contribute to both inter-organisational collaborative relationships and intra-organisational relationships. In addition, they interact with top management, as well as front line managers; consequently, they influence an organisation both vertically (Rouleau & Balogun, 2011) and horizontally. Therefore, they possess the potential for interaction between multiple levels or they can influence a network more effectively. Middle managers share the common corporate ground as well as the operational disruptions arising from the external environment in order to cultivate organisational objectives (Kodama, 2005) . Many studies on middle management concentrate in the informational roles and strategic roles of middle managers, while they left aside other important roles like administrative and technical roles.

Table 3.1. The roles of middle managers

Main role	**Sub-roles**	**Direction of information transfer**
Strategic	Championing	Interpersonal/Upward
	Synthesizing	Interpersonal/Upward
	Facilitating	Interpersonal/Upward
	Implementing	Interpersonal/Upward
Administrative	Assign activities	Interpersonal/Downward
	Budgeting	Interpersonal/Downward
	Scheduling	Interpersonal/Downward
	Hiring	Interpersonal/Downward
	Firing	Interpersonal/Downward
Decision-making	Allocate resources	Personal/interpersonal
	Cope with conflicts	Interpersonal and personal
	Entrepreneur	horizontal and vertical
Leadership	Supervision	Interpersonal/Downward
	Motivation	Interpersonal/Downward
	Reinforcement	Interpersonal/Downward
	Support	Interpersonal/Downward
	Mediator	Interpersonal/Downward/ upward
	Monitor	Interpersonal/Downward
	Control	Interpersonal/Downward

Middle managers form a highly experienced segment of an organisation. While supervisors have good technical skills they are typically less well developed in managerial skills. Senior managers, in contrast, perform almost exclusively managerial roles, while remaining far

removed from technical skills even if those skills are what got them to their current position within the organisation. Middle managers, in contrast, may be required to perform both technical and managerial roles. They perform administrative roles such as assigning activities, budgeting, scheduling, hiring and firing while, at the same time, being required to have sufficient knowledge about technical issues in their units.

Leadership is another essential role for middle management and consists of supervision, motivation, reinforcement support, monitoring, controlling and acting as a mediator. Middle managers are leading their departments to achieving organisational gaols (Chang & Bright, 2012). Middle managers are embedded leaders or second-tier leaders who are leading others, while at the same time they report to another high level leader (Caughron and Mumford 2012; Reeves et al. 2012). Middle managers are expected to demonstrate both transformational and transactional leadership. They utilize transformational leadership by reinforcement, monitoring and control to reinforce their subordinates while also obtaining the support of their subordinates through transactional leadership (e.g. motivation, mediation, making rewards contingent on performance) (Rainey & Watson, 2007). Middle managers expand the higher-level leaders' influence over lower level employees. They also set rules and guidelines for lower level employees (Morgan, Bacon, Bunch, Cameron, & Deis, 1996) and they are responsible for the maintenance of stability, as well as the improvement of existing services and policies (Chang & Bright, 2012).

The literature review revealed the lack of describing and developing decisional roles of middle managers in the papers studied. However, middle managers are semi-autonomous under any circumstances (Currie & Procter, 2005). It means that they have, on the one hand, authority to make decisions; on the other hand, they are faced with constraints for taking decisions. Middle managers can decide about what to peruse and what not, when is the proper time for performing something or even when to sell the issues to senior managers.

Managers experience the conflict of priorities because of handling different tasks (Nordlof, Wijk, & Lindberg, 2012). They perceive conflicts of interest (Wooldridge et al., 2008) and making decisions to resolve conflict is one essential part of their main roles. Entrepreneurship relates to how middle managers identify and generate new ideas that can influence the capacity of innovation in organisations. They can be the primary source of entrepreneurial initiatives or they can improve entrepreneurship in frontline managers by supporting and coaching new ideas developed by those frontline supervisors (Wooldridge et al., 2008).

3.5 Conclusion

Our objective in this chapter is to provide a brief overview of research on the definition of middle management and the roles of middle management in organisations and safety. This

literature review on safety and other scopes has provided us with the following insights into middle managers, their definition and their roles in organisations:

- Middle management is almost entirely overlooked in safety. At least the academic literature on safety has long neglected the role of middle managers, while there are a fair number of studies about the role of top management in safety. There are many reasons to believe that middle managers are actually key actors who play important roles in organisations and safety. The main reason is their multiple roles in organisations. At the same time, evaluation of adverse events like the accidents reviewed in Chapter 2 revealed that accidents occurred as a result of systemic and organisational factors such as inadequate strategic decision making, weak management, insufficient training, poor communications, and improper procedures, all of which can be closely linked to middle managers who are located in pivotal positions and who perform crucial multiple roles.
- Assessment of other articles did not indicate the clear definition of middle management that clarifies the boundary between this group and other management groups and is applicable for every organization. However, critical assessment of current literature shows that all authors agree that this intermediate management group are between top level/central management and lower level/outer edges management, which is at best a very broad definition. In addition, identifying the middle management group from other managerial groups depends on three main criteria namely function, context of the organisation and the researcher's interests. In the current study, every manager who is higher than front-line supervisors and lower than the direct representatives of the CEO in the HSEQ system is considered as a middle manager. These boundaries are aligned with other definitions of middle managers that consider four criteria as function, position, context of the organisation, and the purpose of the study.
- The review provides evidence that middle management impacts organisations in various ways by performing their different roles; middle managers perform multiple roles in organisations. According to the literature review, we concluded that middle managers perform 5 essential roles - strategic, administrative, leadership, communication and cooperation, as well as decision-making. Researchers reporting in the literature surveyed were more focused on just two categories, which are the strategic and communication and cooperation roles, while other roles, particularly the decision-making role of middle management, are often overlooked in the domain of management studies. Decision-making includes recourse allocation, entrepreneurship and disturbance handling (Mintzberg, 1973). Certainly middle management is continually faced with conflicts that can give rise to deviation from normal conditions. It can be a conflict as a result of technical disturbance or disturbance between other elements of organisation like individuals in different levels or even conflict can occur between an organisation and other organisations which have a relationship with the main organisation. Because

middle managers are located in the middle part of organisation between the operating core, the strategic apex, support staff and the technological structure (Mintzberg, 1973), they can be faced with more disturbance and they have to resolve those conflicts. Middle managers, nevertheless, have limited authority to allocate resources and their span of authority might be influenced by the context of the organisation. Yet, they have authority to prioritize one objective that can be production over other objectives, for instance safety; consequently, they are responsible for decisions within their authority.

- Two prominent tendencies have been identified in this study on middle management: first, the strategic roles of middle management and second, either the significant contribution of middle management in management of change or their dysfunctional roles in changes within organisations. As mentioned in Chapter 2, not managing change was one of the hidden reasons of both the Tesoro accident and the Texas City explosion.
- Finally, given the limited number of studies on middle management in the safety domain and decision-making of this managerial group, more study is needed to examine the role and influence of middle management in safety management, specifically in safety related decision-making. This is covered in the next chapter.

4. What is the best decision-making model for middle managers? A literature review

4.1 Introduction

In Chapter 2, we concluded that decision-making errors were one of the driving factors led to catastrophic events. Also, in Chapter 3 we outlined that decision-making was one prominent role among multiple roles of middle managers. In this chapter[6], a further step is taken to identify the best model of decision-making for middle managers among the extensive literature on decision-making.

Decision-making is becoming an essential scope of safety which scientists and managers should take into account for the safe and efficient running of complex Socio-Technical systems (Jenkins et al. 2010). A comprehensive knowledge is essential that addresses different decision-making methods that have been applied or can be implemented in safety management. It is also necessary to determine both benefits and disadvantages of these methods to apply them effectively and successfully. Also, there is a need to investigate whether these methods satisfy the requirements of operational safety management at various levels, such as executive management and middle management. Senior management makes decisions regarding policy and strategic issues. In contrast, middle managers are concerned with the implementation of more tactical issues that typically require more details and the identification of compromises that may not be obvious at strategic levels.

Decisions in organisations generally involve Multi-Criteria Decision-Making (MCDM) methods that simultaneously take into account a range of criteria such as cost, productivity, quality, flexibility, reliability, and safety. These decisions are characterized by various alternatives, such as using one or another intermediate chemical pathway in production or whether to contract out maintenance activities, and the use of a number of different criteria that sometimes may be difficult to measure using purely quantitative methods. For instance, because there is no historical empirical data, some degree of estimation and expert judgement may be required. The outcomes of such decision-making processes are mostly uncertain, in the sense that no one clear unequivocal outcome comes out of the decision-making process. The act of decision-making can happen in different circumstances, such as when the price of oil changes from the beginning of a project to the point when decisions need to go 'hard'. Decision-making can be spread over different locations, such as corporate versus operational sites, and by different people at different levels of a company, such as plant managers and junior design engineers. Besides, it will often be the case that different decision makers with conflicting objectives, such as marketing and production engineering, and complex relations,

[6] This chapter is (partially) based on *Rezvani Z, Hudson P, Swuste P. (2014).*

such as maintenance and design engineering, are all involved in making the decisions. Such complex decisions will invariably result in compromises where safety and reliability may be traded off against commercial interests. If the decision-making process is sub-optimal then there is a greater possibility of failures that may increase the likelihood of catastrophic outcomes.

In this chapter, we focus on the following sub-questions to answer research questions #1 and #2:

- *What are the common methods of decision-making that have been used in safety-related decisions or risk assessment?*
- *Which of them are most often applied to safety management?*
- *What are the advantages and disadvantages of these methods*
- *Which model of decision-making is the best model for middle managers?*

The implications of these findings, together with the recommendations will be discussed below.

4.2 Method

To understand the complex phenomena of decision-making in safety, we reviewed and summarized relevant published studies to identify some different models and their associated potential facilitators and obstacles to the implementation of effective decision-making in safety management particularly by middle management. The primary assessed databases were Google Scholar, Scopus, Web of Knowledge (Science), and Mandalay.

The literature review started with a general keyword *decision-making*. To date, the number of documents which have this term in their text, consisting of journals, books and reference works in several databases are as follows: Scopus (536,039), Science Direct (1,232,441), Mandalay (1,225,766), and Google Scholar (1,560,000) from 1938 to 2016. Figures 4.1 and 4.2 illustrate the analyses of search results taken from the web page of Scopus representing the relationship between decision-making and year as well as the document type.

This graph shows the growth of publications in decision-making from 1938 to 2016 on the Scopus webpage. The number of documents gradually increased from 1938 to 1998, and then dramatically increased until 2004 and stayed in stable condition until 2007. The number of documents increased sharply again from 2007 to 2014 which arrived at the largest number of publications (37,808) in 2014. Following year, the total of records went down to about 2552 in 2015. These results show an increasing tendency to study the topic of decision-making topic, and it might be expected that we can find the best model of decision-making for middle managers among a striking number of studies in decision-making.

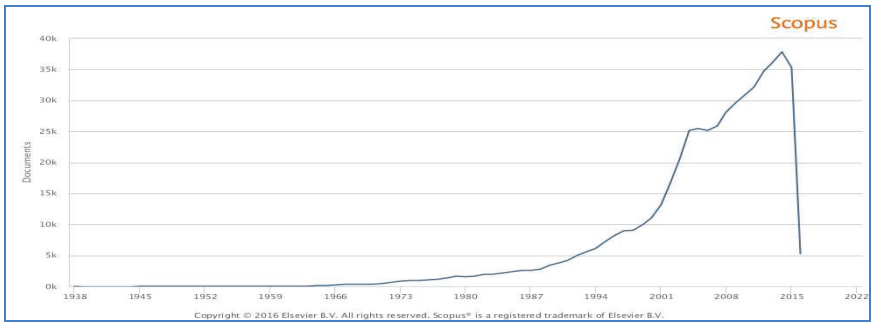

Figure 4-1 *decision-making growth of interest in academic research. Data sources: Scopus, 2016*

Figure 4-2 shows the percentage of publications about decision-making in various subject areas that were divided into 11 segments. The largest area of decision-making studies was in medicine (43.1%) followed by engineering (16.1%) and social sciences (13.8%). However, it is not possible to find that safety was categorized in the social sciences segment or other related subject areas segment (37.4%). However, when the keyword changed from decision-making to decision-making models, a shift in priority from medicine (24.4%) to engineering (26.3%) occurred, and computer sciences had the third rank (21.8%).

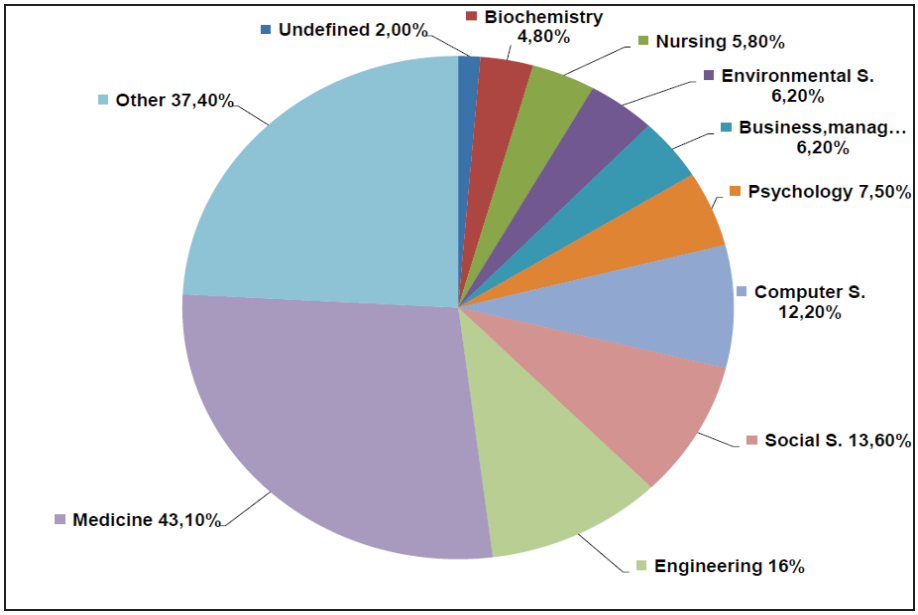

Figure 4.2. *The frequency of Publications about decision-making in the different scientific areas. Data sources: Scopus, 2016*

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The analyses of sources in the web of Scopus revealed that Plos One (2178), European operational Journal (2041) and Pharmaceutical Journal (1666) had the highest number of publications about decision-making respectively. Risk analysis, Safety Science Journal, and Ergonomics, which cover safety and human error, were among the lowest number of publications between 120 sources of the highest ranks of publications in decision-making. However, even this result indicated that there are many publications in the safety domain. The study was then narrowed down to Safety Science, and a primary statistical analysis revealed that there were 1,597 publications in Safety Science about decision-making until 2016. However, relying on this type of analysis is not acceptable, precisely because this analysis is based on the counting of the keywords in the text, while comprehensive analysis did not confirm these findings and the number of publication was fewer than this number. The following quotation demonstrates how an irrelevant document can be categorized as a decision-making topic and misleads researchers making simplistic statistical calculations. In one paper that was in the list of documents showing the decision-making models, the word decision was repeated three times and model twice; however, it was irrelevant to decision-making.

"*In the course of* ***modelling****, the* ***modell****er will make two major* ***decision****s. The first* ***decision*** *should be a balance between the number of explanatory variables and a reasonable goodness-of-fit. The second* ***decision*** *referred by Hauer and Bamfo (1997), the functional form used may affect the performance".*

This analysis reveals that sometimes reliance on the numbers and statistics can be confusing and unreliable. Therefore, the review of the literature in this field with these tools seems more time consuming and less accurate concerning missing proper references.

In the next step, two main criteria applied for the exclusion of studies. Although most studies about decision-making focus on driver decisions and influencing factors, these kinds of studies were excluded for two reasons. Firstly, they are mostly about individual decision-making and secondly, the context of decision-making is far removed from any organisational environment. Articles containing decision-aid or decision-support systems were excluded also, since the primary purpose of the study in this chapter is understanding the process of middle managers' decision-making.

In the next step, we focused on the common Multi-criteria decision-making (MCDM) models to examine whether and how they have been applied in safety management. Multi-Criteria Decision-making (MCDM) is a branch of Operations Research models which are concerned with decision problems under the presence of multiple and conflicting criteria. This major class of models is further divided into multi-objective decision-making (MODM) and multi-attribute decision-making (MADM). MODM are designed to deal with two or more conflicting objective planning problems, which can be solved by design of the optimal/ best

alternative. The predominant criteria for the judgment in multi-objective decision-making are objectives (what do we wish to achieve?), while criteria to test the acceptability of alternatives in MADM are attributes (what is the information that we regard as the most relevant for making the decision?). In other words, a set of objectives is optimized considering a set of constraints (Cristóbal, 2011) that lead to one possibly novel solution, while, MADM methods are adequate for making a choice of the best option amongst the predetermined finite number of alternatives (Mendoza & Martins, 2006).

As our intent is not an exhaustive review of the literature, but rather to highlight the key models for decision-making in safety, with special reference to middle management decision-making, we searched several databases that are shown in Table 4.1 to identify the common models of both MADM and MODM. They consist of Analytical Hierarchical Process (AHP), Fuzzy decision-making, Techniques for Order Preference by Similarity to an ideal Solution (TOPSIS), Best-Worst method, Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), and the VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) model of decision-making.

4.3 Results

Among the multi-attribute decision-making approaches that have been applied in the safety field, Fuzzy, AHP and Best-worst decision-making method were the most widely used decision-making models respectively. Although several scholars stated that the analytical hierarchy process (AHP) is the most widely used decision-making approach in risk assessment (Badri, Nadeau, & Gbodossou, 2012; Hahn, 2006), the statistical analysis revealed that fuzzy decision-making is actually the most common decision-making method studied and reported in the safety and human error domains.

Table 4.1 Frequency of mentioning different decision-making models in several databases, 2016.

Method	Scopus	Science direct	Google scholar	Mandalay
AHP	17,150	16,005	422,000	5,550
Fuzzy	19,333	52,680	805,000	8,590
TOPSIS	3,786	2,538	73,900	725
ELECTRE	866	1,837	25,900	1,210
Best-worst	531	311,830	6,070	14,900
VIKOR	562	593	11,600	110
PROMETHEE	875	1,352	24,000	10

The fuzzy MCDM model is the most popular technique for decision-making in safety, which has been developed to aggregate the decision maker's subjective assessment of the appropriateness of alternatives, criteria selection, and criteria weighting. This model is the most striking method in both safety and other domains, and the model is suitable when the decision maker is unable to judge as a result of vagueness and uncertainty of the data or where there are a large number of attributes to be considered in the evaluation (Wang, 2000). Fuzzy logic, which is based on possibility theory and fuzzy set analysis instead of probability theory (Markowski, Mannan, & Bigoszewska, 2009), is appropriate for the reduction of imprecision and approximation in safety analyses. When getting the precise information is hard, fuzzy methods form a good solution for capturing the system behaviour instead of mere simplification (Bowles & Peláez, 1995). Fuzzy models can manage the complexity of multi-dimensional entities properly and can integrate different kinds of information (Omero, D'Ambrosio, Pesenti, & Ukovich, 2005).

To our knowledge, Karwowski and Mital introduced fuzzy sets into industrial safety analysis in 1986. Fuzzy sets, which is based on possibility rather than probability theory, was originally introduced by Zadeh in 1965. Fuzzy decision analysis was later introduced to support decision-makers by playing a better role in decision-making in 1973 (Zadeh, 1973).

However, fuzzy approaches and their principles were only developed in the safety arena about two decades later.

The analyses revealed that Fuzzy models have been applied to overcome some limitations of conventional risk analysis techniques in process safety. For instance, Hazard and Operability Analysis (HAZOP), Qualitative Risk Analysis (QRA), Failure Mode and Effects Analysis Failures (FMEA), Fault Tree analysis (FTA), Event Tree Analysis and LOPA are techniques that all assume a single-value for risk which represents only one possible outcome. However, there are uncertainties and subjectivities in the analysis of information that can cause imprecision in the results. For instance, the collection of failure frequencies is difficult; in many cases failure rates or failure effects and causes data are not available, so they may have to be estimated by techniques such as expert judgements or extrapolation. If data are assumed by the expert knowledge, it can be influenced by a lack of knowledge and vagueness in interpretation. Also, if data are based on extrapolation, it is formed out of conditions that are not very similar.

Table 4.2 Frequency of researches on different models of decision-making in safety-related journals. Data sources: Science Direct, 2016

Journal	AHP	Fuzzy	TOPSIS	ELECTRE	Best-worst	PROMETHEE	VIKOR
Accident Analysis & Prevention	10	69	3	3	21	0	0
Safety Science	82	159	15	4	16	4	6
Journal of Loss Prevention in the Process Industry	33	113	2	5	4	1	1
Journal of Hazardous Materials	26	61	4	3	9	7	0
Journal of Chemical Health and Safety	0	1	0	0	3	0	0
Process Safety and Environmental Protection	24	51	2	1	0	0	0
Reliability Engineering & System Safety	51	259	8	9	46	5	0
Applied Ergonomics	12	43	3	0	18	0	0
International Journal of Industrial Ergonomics	38	68	3	0	20	1	0
Journal of Safety Research	4	9	0	0	5	0	0
Total	280	833	40	25	142	18	7
Percentage (%)	21.4	63.6	3.1	1.9	10.8	1.4	0.5

In addition, conventional methods of risk analysis or the application of the precautionary principle are based on the max-min principle in decision-making, which assumes that if the worst case can possibly happen, then it will happen. The max-min principle reflects excessive caution that is not always realistic and also requires a lot of resources (Markowski et al. 2009).

Fuzzy methods were used for risk assessment in a variety of industries such as the chemical process industry, construction, and transportation. The most application of fuzzy sets has been in process safety. However, it has been used in other fields as well, such as, for instance, the construction industry (Gürcanli and Müngen 2009; Gürcanli at al., 2005; Cho at al., 2001).

Fuzzy approaches have been applied in both qualitative and quantitative methods of risk analysis to improve the accuracy and precision of results. Some examples are the development of fuzzy fault analysis; fuzzy LOPA; fuzzy HAZOP for quantitative risk assessment; and qualitative methods of fuzzy in risk assessment of construction sites. The most application of fuzzy in risk assessment methods has been in combination with FTA and ETA which are quantitative risk analysis methods (Kimet al., 1996; Huanga at al., 2001) that was about 1/5 of researches on fuzzy methods identified in the safety management scope.

In addition, the fuzzy approach has been applied for the integration of health, safety, environment (HSE) and ergonomics or human factors (Azadeh et al., 2008) because it provides a useful tool to integrate human factors as well as environmental factors into risk assessments (Grassi et al., 2009; Azadeh et al., 2008; Huanga at al., 2001). Researchers have argued that fuzzy expert systems can reduce human error, create the expert knowledge, integrate a large amount of vague data, and improve day-to-day decisions of managers (Azadeh et al., 2008). Fuzzy methods have also been used for the prediction of accidents and occupational injuries (Jalali Naieni 2012; Lee, 2002). The strengths of the Fuzzy Set theory are various. For instances, it provides a framework for modelling imprecision, possibility, and vagueness.

It is not sensitive to small changes. It also captures the interactions among multiple dimensions of performance and allows for gradual transitions from one category of evaluation to another (Omero et al., 2005).

However, Table 4-3 shows clearly that fuzzy models have not been used in abnormal or emergency conditions that mostly occur in process industries and managers have to overcome these circumstances. Another issue is that they are merely academic research studies instead of being the methods applied by the actual decision makers in organisations; there was no study which examined whether practitioners are actually using these methods of decision-making in safety related problems or not. The studies identified in the literature were not, therefore, indicative of how decision-makers in industries such as the process industry go about making decisions in their daily practice; they are prescriptive rather than descriptive of the decision-making process.

The analytical hierarchy process (AHP), which was initially developed by Saaty (1973, 1980), has the second highest rate (21.4%) among multi-attribute decision-making approaches that have been applied in safety research. Table 4-3 presents the application of AHP approaches in safety management, noting where other techniques have also been implemented with AHP. AHP uses both qualitative and quantitative data and applies to decision situations involving subjective expert judgments (Henderson & Dutta, 1992). It decreases the inconsistency of expert judgments and provides a reliable method for comparing risk factors, evaluating risks, defining priorities, designating resources and measuring performance (Henderson & Dutta,

1992). AHP models human factors more clearly, simply and hence practically (Zhang, Zhan, & Tan 2009).

Table 4.3. Application of Fuzzy sets in safety management

Reference	Year	Qualitative/ quantitative	Scope	Normal/ Emergency	Method
G. Kou et al.	2014	Qualitative	Fast disaster assessment	N	Fuzzy logic& survey questionnaire& Delphi method
G. Cirovic et al.	2013	Qualitative& Quantitative	Prioritization of Railway level crossing	N	Neuro Fuzzy Inference System
A. Hatami-Marbini et al.	2013	Quantitative &Qualitative	Risk assessment in hazardous waste recycling facilities	N	Fuzzy group Electre
S.Gh.R. Jalali Naieni	2012	Qualitative	Accident forecast	N	Fuzzy logic
Pinto et al.	2010	Qualitative	Qualitative risk assessment in construction industry	N	Fuzzy logic
A. Pinto et al.	2010	Qualitative	Qualitative Model for Risk Assessment in construction Industry	N	Fuzzy Logic
A. S. Markowski, M.Mannan	2009	Qualitative	fLOPA in pipeline transportation of flammable substances	N	Fuzzy logic and LOPA (fLOPA)
A. Grassi et al.	2009	Qualitative	Integration of human behaviour and environment into classic risk evaluation	N	Fuzzy multi-attribute
G. Gürcanli, U.Müngen	2009	Qualitative	Occupational safety assessment at construction sites	N	Fuzzy rule-based system
J.Hu et al.	2009	Quantitative	Improvement of HAZOP for Gas turbine compressors	N	HAZOP & Fuzzy
A. S. Markowski et al.	2009	Qualitative	Application of fuzzy logic in process safety analysis	N	Fuzzy logic

Reference	Year	Qualitative/ quantitative	Scope	Normal/ Emergency	Method
A. Azadeh et al.	2008	Qualitative	Performance assessment of (HSE) and ergonomics in a gas refinery	N	Fuzzy expert system
A. S. Markowski and M.Mannan	2008	Qualitative	Development a fuzzy risk matrix in risk assessment	N	Fuzzy IF-THEN rules
M. Sallak et al.	2008	Quantitative	Evaluation of safety integrity level in safety instrumented system	N	Fuzzy probabilistic fault tree analysis
J. Zeng et al.	2007	Qualitative	Risk assessment in construction projects	N	AHP & Fuzzy logic
G. E.Gu¨ rcanli et al.	2006	Qualitative	Risk assessment in construction industry	N	Fuzzy base system
G. Gürcanli et al.	2005	Quantitative	Construction sites	N	Fuzzy sets
A.N. Paralikas et al.	2005	Quantitative	Rapid fire hazard assessment of chemical substances, units, and installations	N	AHP & Fuzzy logic
H.Cho et al.	2002	Qualitative	Risk assessment in construction projects	N	Fuzzy
M.R Lee	2002	Qualitative	Diagnosis of power plant accident	N	Fuzzy inference method
H.Sii et al.	2001	Qualitative	Risk assessment in marine and offshore systems	N	Fuzzy logic
D.Huang et al.	2001	Quantitative	Integrating human error into fault tree	N	Fuzzy logic in Event tree
H.N.Cho at al.	2001	Quantitative	Risk assessment in construction project	N	Fuzzy event tree analysis

Reference	Year	Qualitative/ quantitative	Scope	Normal/ Emergency	Method
A.Guimarees at al.	1999	Quantitative	Reliability analysis	N	Fuzzy FTA
C. Lin, M. Wang	1998	Quantitative	Hybrid of FTA with fuzzy set for evaluation of abnormal events in man-machine system	N	FTA & fuzzy
C. E. Kim et al.	1996	Quantitative	Introduction of fuzzy concepts to FTA	N	Fuzzy in fault tree analysis
A.Kraslawski at al.	1995	Quantitative	Evaluation of toxic hazard by Fuzzy hierarchy index	N	Fuzzy
J. Wang	1995	Qualitative	Safety analysis of system	N	Fuzzy sets and evidential reasoning
W.Karwowski and A.Mital	1986	Qualitative	Industrial safety engineering	N	Fuzzy sets

AHP was applied for the first time in safety and occupational health in a comparison of the NIOSH manual material handling with European manual material handling in 1987 (Freivold, 1987), at the same time that the Fuzzy method was developed in safety applications by Karwowski and Mital (1986) for industrial safety engineering.

AHP has several advantages such as the ability to use not only objective information but also expert knowledge and subjective preferences. Qualitative criteria can be included in the evaluation of alternatives since qualitatively expressed measures can be transferred into a ratio scale. However, AHP has some disadvantages. First, AHP itself does not provide tools for in-depth analyses of the comparisons, particularly when the uncertainty is inherent in the data. Second, the number of comparisons increases rapidly as the number of alternatives and criteria increases (Kanga and Kangas 2005). Third, inconsistency can occur in the AHP model because of data entry errors or missing information, poor concentration on criteria, and modelling problems (Badri, Nadeau, and Gbodossou, 2012). Fourth, as is evident in Table 4.4, this method cannot be applied either in abnormal or in emergency circumstances which is one essential segment of safety management to prevent accidents or control the situation to decrease the adverse outcomes as far as possible. In these situations decision makers are faced with neither predetermined alternatives nor clear criteria, nor do they have enough time to

perform in-depth analyses and pair-wise comparisons. Finally, similar to the Fuzzy method, studies on AHP in safety are academic studies instead of applying this model in practice.

Table 4.4. Application of AHP in safety management

Reference	Year	Qualitative/ quantitative	Scope	Normal/ Emergency	Method
An,et al.	2016	Qualitative	Railway risk assessment		FAHP
Akyuz and Celik	2014	Qualitative	Measuring the effectiveness of SMS implementation on board ships	N	A hybrid method of AHP and TOPSIS
Caputo et.al	2013	Quantitative	Choice of safety devices for industrial machinery	N	AHP
Aminbakhsh et al.	2013	Quantitative	Prioritisation of safety risks in construction projects	N	AHP& Cost of safety
Badri et al.	2012	Quantitative	Integration of occupational health and safety risk into projects assessment	N	AHP& expert choice software
Topuz et al.	2011	Quantitative	Integration of environmental and occupational health risk assessment for industries using hazardous materials	N	AHP& fuzzy Logic
Celik	2010	Qualitative, quantitative	Enhancement of the International Safety Management code in compliance with HSM in operation of chemical tankers	N	AHP& Fuzzy
Arslan	2009	Quantitative	Prioritizing precautions in carriage of the liquid chemicals (tankers)	N	AHP
Padma, Balasubramanie	2009	Quantitative	Quantifying the work-related risks on musculoskeletal disorder particularly shoulder and neck	N	AHP
Fera, Macchiaroli	2009, 2010	Qualitative, Quantitative	Integration of several methods to improve health and safety risk assessment	N	AHP, FMECA, SceBRA, and Italian standard UNI 7249:2007
Zhang et al.	2009	Quantitative	Analysing the marine accidents caused by human factors	N	AHP& questionnaire
Zeng et al.	2007	Quantitative	Risk assessment in construction projects	N	AHP& Fuzzy logic

Reference	Year	Qualitative/ quantitative	Scope	Normal/ Emergency	Method
Law and Chan	2006	Qualitative & quantitative	Prioritizing the safety in manufacturing enterprises	N	Interview& AHP
Paralikas et al.	2005		Rapid fire hazard assessment of chemical substances, units and installations	N	AHP& Fuzzy logic
Ha and Seong	2004	Qualitative & quantitative	Categorization of structures, systems, or component of a power plant according to safety significance	N	AHP& BBN
Cagno et al.	2000	Quantitative	Determining the priority distribution of gas pipeline failures	N	AHP& Bayesian inference
Freivalds	1987	Quantitative	Comparison of NIOSH manual material handling with European manual material handling	N	AHP
Henderson and Dutta	1992	Quantitative	Application of AHP in ergonomic evaluation	N	AHP

Applications of AHP can be observed either as a stand-alone technique or integrated with other suitable techniques mostly in combination with fuzzy method. Application of multiple methods, development of interactive decision support systems and application of fuzzy methods to tackle uncertainties in the data is also observed in the published literature; nonetheless validation of results have not yet been performed, particularly with multiple methods such as comparing the decision outcomes.

Decision-making methods can be divided into two groups. First, rational decision-making methods, which are mostly concerned with how a decision maker *should* decide. Expected Utility Theory is the most striking theory of individual decision-making developed originally by Von Neumann and Morgenstern in 1944 (Abrahamsen & Aven, 2008). This theory applied mathematics and statistical methods to behavioural science (Shubik, 1958) to form a foundation of rational decision-making. All the above-mentioned models are among rational or analytical methods that assume an ideal decision maker who is rational, fully informed, and able to compute perfectly (Reniers & Pavlova, 2013). They can be described as prescriptive in that they attempt to define exactly how a decision-maker can arrive at an optimal solution for any decision problem.

As there were problems associated with attaining optimal performance, such as lack of hard objective data or excessively large numbers of attributes or solutions, theorists moved to develop the satisficing theory or bounded rationality – basically moving from ‘perfect’ to

'good enough' choices. Therefore, Expected Utility Theory was developed into Subjective Expected Utility theory (SEU) of Savage (1954) and De Groot (1970) by changing objective probability to subjective probability (French & Insua, 2000). Extensive laboratory-based and practical studies have been done on human decision-making to evaluate how people take a risk. For instance, Tversky and Kahneman (1974,1979&1981) provided insight about biases and errors in the decision-making process that violate the principles of rational decision-making.

People do not behave consistently with axiomatic rules and they violate to optimize the decision due to ill-defined goals, imperfect information, uncertainty, and nature of the situations such as time-pressure or workload pressure. Therefore, descriptive theories emerged to describe how people actually decide in practice (e.g. Kahneman, 2011; Klein, 2008). Descriptive decision theories stem from organisation theories and experimental psychology (Peterson, 2009) that are often called Naturalistic Decision-making (NDM).

The proponents of descriptive methods argue that first of all the limited cognitive capability of humans conflicts with the concept of an ideal rational decision maker in a complex environment. Second, there were several definitions of expectation and variability of the expected value, which opposes the initial definition of maximization of expected value. Third, there was a difference between maximum expected value in theory and incorporating the psychological facts of monetary value. The expected monetary value is non-linear, which means in practice monetary value depends on the amount of money that a person already has. Fourth, typically outcome ranking is subjective therefore other objectives might have more value than monetary value. Fifth, decision-making in the real world involves multiple objectives without a common denominator, which makes it hard to optimize the decision (Gigerenzer & Selten, 2002). Finally, since gathering information progressively becomes more costly, time-consuming and difficult, decision makers do not necessarily evaluate all the information before making a decision.

The notion of bounded rationality proposed by Herbert Simon (1972) constructs a more realistic decision theory that can include considering the biases and heuristics. Models of bounded rationality describe the heuristic process of decision-making instead of specifying the outcome of a decision-making process. They focus on the environment within which judgements or decisions are reached. The knowledge limitation and computational capability could be used as a reliable instrument in bounded rationality. In fact, the first step in decision-making is information search about alternatives and cues that can be performed internally or externally. Both search methods cost time and attention and external search even demands more resources. To overcome these constraints, decision makers use simple heuristic tools, which can be simple but effective and as accurate as complex statistical models. They perform regularly in a given environment, and to some degree, they are dominant–specific (French &

Insua, 2000). Finally, human beings have limited cognitive capability which conflicts with the concept of having an ideal and rational decision maker, when operating in a complex environment, which may be limited by resources available such as information availability, the time required to gather information, and time to actually make the decision.

The simple search rules, simple stopping rules, and simple decision rules help us to specify the process of bounded rationality. Simple search rules refer to the step-by-step procedure of decision-making to acquire information or to make an adjustment, then to repeat the procedure until it stops. Simple stopping rules mean to terminate the search for information after selecting the first object satisfying a desirable level. Simple decision rules refer to choosing the alternative with the most important reasons instead of calculating the optimal weights for all reasons (Simon, 1972).

Normative decision-making methods, in contrast, are based on several principles: First there have to be clear, acceptable and explicit axioms, which represent the ideal decision behaviours (French & Insua, 2000). Second, there have to be feasible methodologies. It means that if the capacity of the decision maker is beyond their required computational power or they require numerous inputs, the normative methods will not be acceptable. Third, they must be robust and sensitive to input variations. Finally, they have to be compatible with the assumptions of the decision-making context (French & Insua, 2000).

Proponents of bounded rationality argue that these simple and fast rules can act as accurately as complex statistical models (Roth, 1999). Nevertheless, they make fewer demands on the finding of information and computational capacity. They also reason that simple strategies are more robust than complex models, since a large number of parameters in complex models increase the over-fitting risk.

Therefore, in bounded rationality, the decision maker integrates their decisions taking account of their available decision resources. They decide based on qualitative expectations and incompatible goals. The decision makers utilize recognition and ignorance to choose between two objects. They make decisions based on first cues by which they are able to categorize objects. It means applying heuristics for elimination following search to narrow down possible categories until one option remains. Consequently, decision makers overcome the constraints of mental or internal factors that are limited memory and information processing power as well as environmental or external factors that are time, money and energy.

Klein (1977) argued that rational methods have limitations. For instance, where it is crucial to react rapidly and efficiently, prescriptive methods might leave the decision maker incapable of mitigating outcomes, for instance it might take longer to make an optimal decision than is available. Also, in risk management, managers should be actively involved in decisions to shape events, not passively awaiting the outcomes (Klein, 2008). Naturalistic decision-making (NDM) research emerged in the 1980s to study how people actually make decisions in real

world circumstances (Lipshitz et al., 2001) which were taking place at the same time as the development of AHP model and fuzzy models in safety management. NDM models have developed from rejection of subjective expected utility (SEU) theory and decision research which has been primarily based on small problems in laboratory settings (Gore, 2006).

NDM models focus on the role of the decision maker's experience to rapidly recognise and categorize situations and make a decision. Even where other plausible alternatives exist, a good decision maker does not necessarily notice or compare them in practice. NDM approaches are knowledge-based approaches and differentiate the decision-making process into a preceding stage of perception and recognition of situations (Klein, 2008). These approaches emphasize the hazardous and complex nature of the environment in which time pressure, immediate feedback or other influencing factors mitigate the suitability of rational decision-making (Lintern, 2010), especially when the payoff is considerable, and the decision maker may be personally involved in the consequences. In total, naturalistic decision-making can be contrasted with rational decision-making in each of the processes of 1) identifying a set of alternatives, 2) evaluating those alternatives, 3) weighting criteria, 4) rating the options, and 5) selecting the final option with the highest score. Table 4.5 lists other decision-making models applied in safety management, which are mostly descriptive methods.

Nevertheless, the bounded rationality approach has following disadvantages: (1) since they are domain-specific they cannot be generalized. (2) A comprehensive, coherent theory of bounded rationality is not available. (3) This intuitive approach concerns on perceiving similarity of one situation to the other situations rather than understanding the task. (4) Heuristic processes can lead to the systematic error like intransitive preference (Gigerenzer & Selten, 2002).

The Recognition-primed decision-making (RPD) model (Klein, 1997) is an NDM model based on mental simulation and situation diagnosis (Lintern, 2010). Pattern recognition is fundamental to this model, in which there is the comparison of a situation with past experiences and recapturing of a potential course of action that has been successful in the past (Salas et al., 2009). The RPD model attempts to demonstrate how decision makers actually decide under significant time pressure, with ill-defined goals, vague information and changing conditions (Klein, 1997).

RPD differs from classical decision-making in several characteristics. First, it focuses on situation assessment instead of options judgment to contrast the strengths and weaknesses of different alternatives. Second, it relies on the recognition of a first good option by experienced decision makers rather than the generation of many alternatives. Third, it is based on satisfaction (Simon, 1959, 1972), using a heuristic called satisficing, rather than optimization. Optimization searches for the very best option, which may be impossible given the total set of constraints. Finally, RPD enables the decision maker continually to prepare to take immediate

action based on the current evaluation; in contrast, the optimal decision maker has to wait until finding out which option rated the highest (Klein, 1997). This requirement effectively means that every option has to be considered which may result in running out of time or other resources even when a decision has to be made before the optimal decision can be identified.

Arguably, some researchers demonstrated that in practice there is not sharp division between descriptive and normative approaches. Prescriptive and descriptive fields are closely bound with each other, so behavioural decision theory emerged. Behavioural decision theory has two facets, normative and descriptive, and they are interrelated.

Table 4.5. Other decision-making approaches that have been applied in safety

Reference	Qualitative/quantitative	Scope	Normal/ Emergency	Method	Type of decision method
Nunen et al. 2016	Qualitative	Decision analysis to choose between prevention and production investments under uncertainty and risks with major negative consequences	N	Survey	Descriptive
Yang, Haugen 2016	Qualitative	Offshore oil and gas industry	N	Propose a method to improve operational decision	Prescriptive
Michalski, Bearman 2016	Qualitative	Bush Pilots flying small commercial operations in Australia	-	Semi-structured interviews	Descriptive
Saffarian et al.2014		Identification and prioritization of risks in a gas power plant	N	Delphi, questionnaire, TOPSIS, AHP	Prescriptive
Wiggins et.al. 2014	Qualitative	Pilots' pre-flight and in-flight weather decision-making	Abnormal	Simulation	Descriptive
Hey 2012	Qualitative	Operational safety in air traffic control, nuclear power and chemical plants	N	Interview, observation, document analysis	Descriptive
Hopkins 2011	Qualitative	Evaluation of Risk-based and rule-based Decision-making	N/AN	Accident analysis, document analysis	Descriptive
Xhafa et al. 2011	Qualitative	Automate assignment of tasks and resource		Event-based method	Descriptive

Reference	Qualitative/quantitative	Scope	Normal/ Emergency	Method	Type of decision method
		allocation in disasters			
Ash et al. (2010)	Qualitative	Investigation of commander's decisions in emergency response	AN	Simulation of emergency rescue situations based on NDM	Descriptive
Brooker 2010	Qualitative	Examining the safety decision-making in the SESAR projects in European Air Traffic Management	N	Document analysis	Descriptive
Mojtahedi 2010		Project risk assessment in gas refinery constructions	N	TOPSIS in risk assessment	Prescriptive
Peng et al. 2010	Qualitative	An incident information management framework	N	Data integration, data mining, MCDM	Prescriptive
Reniers 2010	Quantitative	Improvement of cross-plant safety within chemical clusters	N	Game theory	Prescriptive
Keren et.al. 2009	Qualitative	Examining the relationship between safety climate and safety decision-making	N	Safety climate questionnaire, simulation	Descriptive
Rosness 2009	Qualitative	Conceptual	N	Propose a contingency model of decision-making	Descriptive
Chauvin, et.al. 2009	Qualitative	Evaluation of the impact of training on the decision-making process of trainees	AN	Ship-handling navigation simulator in experimental and control group	Descriptive
Johnson et.al. 2009	Qualitative	Evaluating the impact of Überlingen upon European Air Traffic Management	N	Accident causation analysis	Descriptive, RPD
Ginneken, Hale 2009	Qualitative	Describing a decision-making process in a maintenance department of an steel	N	A case-study	Descriptive

Reference	Qualitative/quantitative	Scope	Normal/ Emergency	Method	Type of decision method
		company			
Sachdeva et al. 2009	Quantitative	Industrial risks analysis	N	TOPSIS&FMEA	Prescriptive
Aven 2009	Qualitative	Review of perspectives on risk in a decision-making context	N	Propose a risk analysis method	Argument
Abrahamsen et al. 2008	Qualitative	Consistency assessment of risk acceptance criteria with normative decision-making theories	N	Expected utility theory	Prescriptive
Liou et al. 2007		New safety measurement model	N	Hybrid of a decision-making trial, evaluation laboratory and an analytic network process (ANP)	Prescriptive
Carvalho et al. 2005	Qualitative	Examine the cognitive process of operator decision-making during micro-incidents	AN	Cognitive task analysis	Descriptive
Aven et al 2003	Qualitative	Discuss strength and limitation of decision analysis approaches	N	Expected utility optimization, cost-effectiveness indices, cost/benefit calculations for decision analysis	Prescriptive
Frank 1995		Selection of safety development strategies	N	Intuition, cost-benefit, expected impact, AHP, decision trajectories	Prescriptive
Brito, de Almeida 2009	Quantitative	Risk ranking of natural gas pipelines	N	Multi- attribute utility theory	Prescriptive
Klein (1993)	Qualitative	Proposing RPD decision model	AN	RPD	Descriptive

4.4 Conclusion

Managing safety is a complex task within organisations and it involves numerous individual or group decisions. Understanding of the process of decision-making, of models of decision-making and of the circumstances which influence safety-related decisions are necessary. Having enough knowledge about available decision analysis techniques, their methodological and practical strengths and their limitations is required to help managers to take into account these issues in their decisions. This chapter addresses an initial identification and analysis of decision-making methods that have been used in safety management. This chapter leads to the following conclusions:

- It is evident that both rational and naturalistic methods have been used in safety. In fact what the analysis has shown is that no consistent approach has been applied. What is not clear from the scientific literature is whether there is an 'ideal' approach that can be recommended given the compound nature of the problem in safety as almost every method possible has been attempted with little critical evaluation and comparison.
- In our view, we have to acknowledge that there is no simple and mechanistic method or procedure for balancing different concerns. When it comes to their use, we have to adopt a pragmatic perspective. We have to acknowledge the limitations of the tools and to use them in a broader process.
- Comparison between analytical/prescriptive decision strategies and naturalistic (descriptive) decision-making approaches shows that rational decision-making models have been applied more frequently in safety management rather than the descriptive decision-making models; nevertheless, they have several pitfalls. For example, if they are used in conditions when time pressure is greater, when conditions are less stable, or when decision makers suffer from lack of experience or knowledge, they can leave the decision makers unable to react quickly and more efficiently (Klein and Klinger, 1991; Klein, 2008). Conversely, misapplying descriptive decision strategies have other dangers. For instance, in experience decision makers may be unable to simulate the first option mentally and to find pitfalls. Consequently, they may well fail to optimize their decisions or, when optimization is difficult, they may miss some of the better options or unwillingly select a dangerous option, such as skipping essential maintenance in order to maximise production.
- The studies we reviewed suggest that the context of a decision can affect the choice of analytical vs. naturalistic decision models. In abnormal conditions that are characterised by unstable options, high time or resource pressures, descriptive decision approaches are preferable. In normal conditions, when there is adequate time and where the data are more abstract, possibly being very complex and combinatorial, there is a dispute between different decision makers or the course of chosen actions

should be justified, the analytical decision-making methods may seem to be preferable (e.g., Hammond et al., 1987; Klein, 2008).

- Decision-making models have mostly been applied in the risk analysis stage to improve the risk assessment and to overcome the uncertainty of risk assessment. Among different methods of decision-making, applications of Fuzzy have been observed either as a standalone technique or integrated with other suitable techniques as the most popular technique, followed by AHP and NDM models in safety management. Application of multiple methods and development of interactive decision support systems were carried out; however, the validation particularly with multiple methods has not yet been performed. Counting which method is used as a way of evaluating the most frequent choice is probably meaningless, because the choice of method says more about the preferences of the researchers than of the safety managers.
- Attempts to demonstrate the process of decision-making and to find the patterns of decision-making in safety have not been given much attention. Rational decision-making models, which are concerned with finding the best decision from a set of potential courses of actions, have been applied in safety management rather than applying descriptive decision-making models, which demonstrate how a decision maker actually decides. It seems that, despite decision-making approaches having been developed in the area of industrial or societal safety, a stronger integration of both theory and practice is needed. What we might propose is that managers need to recognise the broad characteristics of the problem area within which they wish to make decisions and be trained to use the techniques that are appropriate to the problem rather than to their, or a researcher's, personal preference. Senior managers typically operate on longer timescales and with broader categories than do more junior middle managers. So, they are more likely to require a considered rational approach, unless there is a significant degree of uncertainty in a number of the dimensions under consideration. Middle managers, in contrast, have to take broad decisions and elaborate them, bringing in increasing levels of detail and, potentially, increasing uncertainty which will place constraints on the choice of the best decision-making methodology. Fuzzy-based approaches might provide a useful basis or adjunct for a 'reasonably rational' decision-making process. More junior middle managers and supervisory staff may well find themselves confronted with decisions that need to be made in less time than would be required by rational, optimal approaches, but that means that they need to possess the skill appropriate to making that type of decision, skills identified in the NDM field such as rapid option generation and recognition.

- In conclusion, we have identified a wide range of decision-making approaches that have been used in the field of safety management, but there is no evidence pointing strongly in one direction or the other with respect to which techniques are to be regarded as the best.

5. Underlying factors influencing safety objectives[7]

5.1 Introduction

Within an organisation not all objectives are equally important, they have varying degrees of importance. Within a production organisation, for example, there are a variety of objectives such as productivity, cost, reliability, and safety that are often not compatible and may even be detrimental to one another. Therefore, an organisation needs to prioritise between different goals, particularly because of the scarcity of the resources available. This diversity of objectives also occurs between an organisation and a wide range of external stakeholders such as contractors, clients, regulators and those living in the immediate vicinity.

Another element which can influence the priority setting of objectives is the fact that there are multiple layers of individuals forming an interconnected network that is acting to carry out all the aspects of operation (Chung, 2003). People interact with each other and interpret how the organisation's 'hard' process goals are to be prioritised and achieved in this personal context, so they will have both direct and indirect influence over the organisational goals.

Considering these influencing factors on safety objectives, we searched to identify the proper methods that have been applied for guiding and supporting the prioritisation of objectives. Analysis of decision-making methods revealed that Multi-Objective Decision-Making (MODM), which is a branch of Multi-Criteria Decision-Making (MCDM), being concerned with decision problems under the presence of multiple and conflicting criteria (Belton & Stewart, 2002; Mendoza & Martins, 2006), is appealing. MODM is made up of a collection of formal approaches that seek to take explicit account of multiple objectives in helping an individual or a group of decision makers to solve a decision problem. Mendoza and Martins (2006) stated that MODM has desirable features such as explicitly defined objectives, implicitly defined attributes, explicitly defined constraints, implicitly defined alternatives, infinite (or at least very large) number of alternatives, significant control of decision makers, relevance to design/search, and a process-oriented decision modelling paradigm.

Chapter 4 revealed that Fuzzy decision-making (Zadeh, 1973) and AHP (Saaty & Shih, 2009; Saaty & Shang, 2011) are the most popular methods that have been applied, not only as Multi-Attribute Decision-Making but also as Multi-Objective Decision-Making. Based on these rational decision-making models, decision makers either apply paired comparison of the importance of each of the objectives (AHP) or select the option that has the highest grade of membership (fuzzy decision-making). With these insights, this stage of the study was performed to test how decisions are made to rank the objectives in practice.

[7] This chapter is based on Rezvani Z, Hudson P, Rahimi E. (submitted article. 2017).

The hypothesis is that prioritisation in practice is more than just the ranking of objectives. It implies balancing an interlinked set of requirements so that resources can be allocated to satisfy the wide range of potential targets. Seen this way, there is a need for a fundamental understanding of the relationships between individuals at all the different levels with organisational objectives, not just a focus on a single group of decision-makers. This chapter answers research sub-questions # 3 and # 4 shown in Figure 5.1. *How are strategic objectives prioritised in practice?* and, *What are the underlying factors influencing safety objectives in an organisation?* In so doing, we address the following questions:

- How are strategic objectives prioritised in an industrial company?
- How do individuals at different levels, particularly middle managers, influence the organisational objectives?
- How do external stakeholders influence objectives?
- How do other components of an organisation affect the process of priority setting of objectives?

It is necessary to take into account the fact that many factors can influence the success or failure of safety targets such as the safety culture, the organisational structure, and training. In this study, we concentrate on exploring the components and their interrelations that can influence the priority settings of safety objectives using the lens of Activity Theory, consisting of various objectives, individuals, tools, rules, cooperation, and division of labour. They will be explained in more detail in subsequent sections.

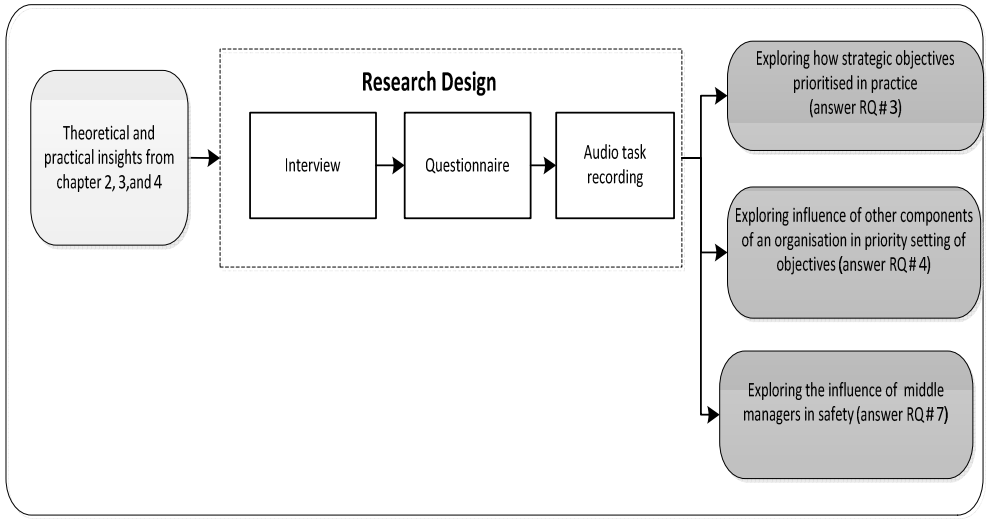

Figure 5.1. *The followed step in a case study to answer research sub-questions #3, #4, and #7*

5.2 Method

In the interest of clarity, the study was developed originally to build upon the middle manager's roles in safety management; however, the direction of data collection has evolved over the project. The following also explains the methods applied for investigating Multi-Objective Decision-Making in practice.

5.2.1 Interview

A number of semi-structured interviews, starting in January 2014, were carried out. The interviews covered several themes consisting of (1) the general roles of middle management in organisations, (2) middle managers' roles in safety, (3) the perception of middle managers in safety, and (4) decision-making (see Appendix B).

5.2.1.1 Sample

Middle managers from four different industries were approached. Potential participants were contacted. The response rate of participation was high (80%) but over a long period of time which was one year and five months. In total, eight middle managers participated in the interview, coming from the oil and gas industries, a chemical plant and an aerospace research centre. Data saturation in which new themes no longer emerge from further interviews was the main criteria for defining a purposive sample size (Guest, Bunce, & Johnson, 2006).

5.2.1.2 Data collection procedure

Except for one participant, all were contacted via email. We also sent them the participant information sheets including a brief description of the study (Appendix C). Interviews were conducted either by face-to-face interviews or by telephone according to the preferences of participants. Leeuw (1992) stated that there is a minimal difference in the quality of data between these two modes of data collection. Interviews were audio recorded with the permission of the interviewee, with the exception of one interview that was conducted at a conference; since it had not been arranged in advance, we could not record it. Therefore, shorthand notes were taken during the face-to-face interview with this interviewee and then a complete write-up was made following the interview to retain the data as much as possible. Interviews lasted between 30 and 60 minutes.

5.2.1.3 Data analysis

The interviews were either transcribed or translated to English by a researcher and then transcribed. The collected data were analysed by applying the qualitative data analysis & research software (ATLAS.ti Ink) version 8. After transcription (Ritchie, Lewis, Carol McNaughton, & Ormston, 2013), the thematic framework involving five stages were implemented to analyse the interview data, including familiarisation, identifying a thematic framework, indexing, charting, mapping and interpretation. It started with listening, reading

and reviewing the data to get a holistic sense of the content of the data. During this stage abstracting and conceptualization were carried out by finding the recurring issues, dropping non-essential facts, identifying particular patterns, or discovering emerging new themes. Coding and categorization of data were performed to label the data and organise clusters of units in a manageable way (Ritchie & Spencer, 1994). Finally, mapping and interpretation the data were carried out to detect and address the key objectives.

It was intended that the study was to be performed based only on in-depth interviews in different runs, starting from general questions and then going to more specific questions. So, the study was originally developed with the broad aim of working with a small sample to do an in-depth survey. This method supported researchers in identifying the general roles of middle managers in organisations and safety management. Additionally, it provided valuable information about priority settings of objectives in organisations that can influence safety management negatively. However, interviews stopped after the first run, as a result of international political issues, for a long time. It happened when interviews had been done with five middle managers and we had, fortunately, already arrived at saturation level for several questions about middle managers' roles and decisions about objective setting in organisations; while we could not find enough data about the processes and patterns of decision-making by middle managers. Consequently, the decision was taken to design an online questionnaire to get a larger sample.

5.2.2 Questionnaire

A structured online questionnaire with an introductory part was designed in NETQ Internet Surveys Professional Edition 6.0 (http://tbm.collector-survey.tudelft.nl/nq.cfm?q=E74C0A58-3CA8-40FD-B12F-E36536F9F66D). There was a similarity between questions in the questionnaire and the interviews since one purpose was to assess test-retest reliability (Lynam, Jong, Sheil, Kusumanto, & Evans, 2007). However, there were also complementary questions that were mostly related to decision-making that we had not been able to explore them comprehensively with the interviews.

The questionnaire consisted a total of 30 items including single choices (6), multiple choices (9), matrix questions (7), and open questions (8). Each questionnaire consisted of several parts including an introduction, general information about the participant, the roles of middle managers in an organisation, decision-making in an organisation, the involvement of middle managers in decision-making, and how decisions were made in previous accidents. To examine the content validity, the questionnaire was assessed by 7 experts who between them covered the three scopes of qualitative research methods, management and safety.

5.2.2.1 Data collection procedure

The questionnaire was sent to the email address of each middle manager. The questionnaire was sent to the middle managers with whom the interviews had also been performed to do the test-retest and convergent reliability. The questionnaires were also sent to middle managers who had agreed to fill in the questionnaire when the message was posted on Linked-In describing the purpose of the study. In total, questionnaires were sent to 41 middle managers, while the eventual response rate was 15%.

5.2.2.2 Data analysis

NETQ Internet Surveys Professional Edition 6.0 has the facility to enable researchers to do descriptive statistical analyses on this sort of survey.

5.2.3 Audio task recording (Real-time measurement) in a case-study

Since the response rate was low for the questionnaire and it could not provide enough information for answering the research sub-questions that were related to the decision-making process and safety-related decision-making, we implemented the third method for gathering data. Audio task recording was applied for the first time as a simple and easy-to-use tool for providing rich data in this research. For this purpose, a senior middle manager agreed to record his activities by using an MP3 player during a period of one month, excluding holidays, in an oil and gas process industry. In the following sections and Figure 5.2 you can find more information about the case where an audio task recording was done. The main purpose of audio task recording was to gain in-depth knowledge about the decision-making process and the underlying factors influencing decision-making in real conditions within a high-hazard process industry. In contrast to gaining understanding by analysing incidents, this approach covered a considerable period of day-to-day activity.

5.2.3.1 Sample

A middle manager, who had already been interviewed, was selected for this purpose. The advantage of choosing this individual was his unique position that bridges the higher macro and the lower micro levels in the company and allows us to gain an in-depth knowledge about activities and relations both between individuals at several levels and with the surrounding environment. Figures 5.2 and 5.4 show the position of this middle manager (head of operations of Gas and Liquid gas) in organograms. Less senior managers typically have less interaction with the external factors and executive management, whereas a manager at this level serves as a primary conduit integrating all the different, and often conflicting, demands on the work to be carried out.

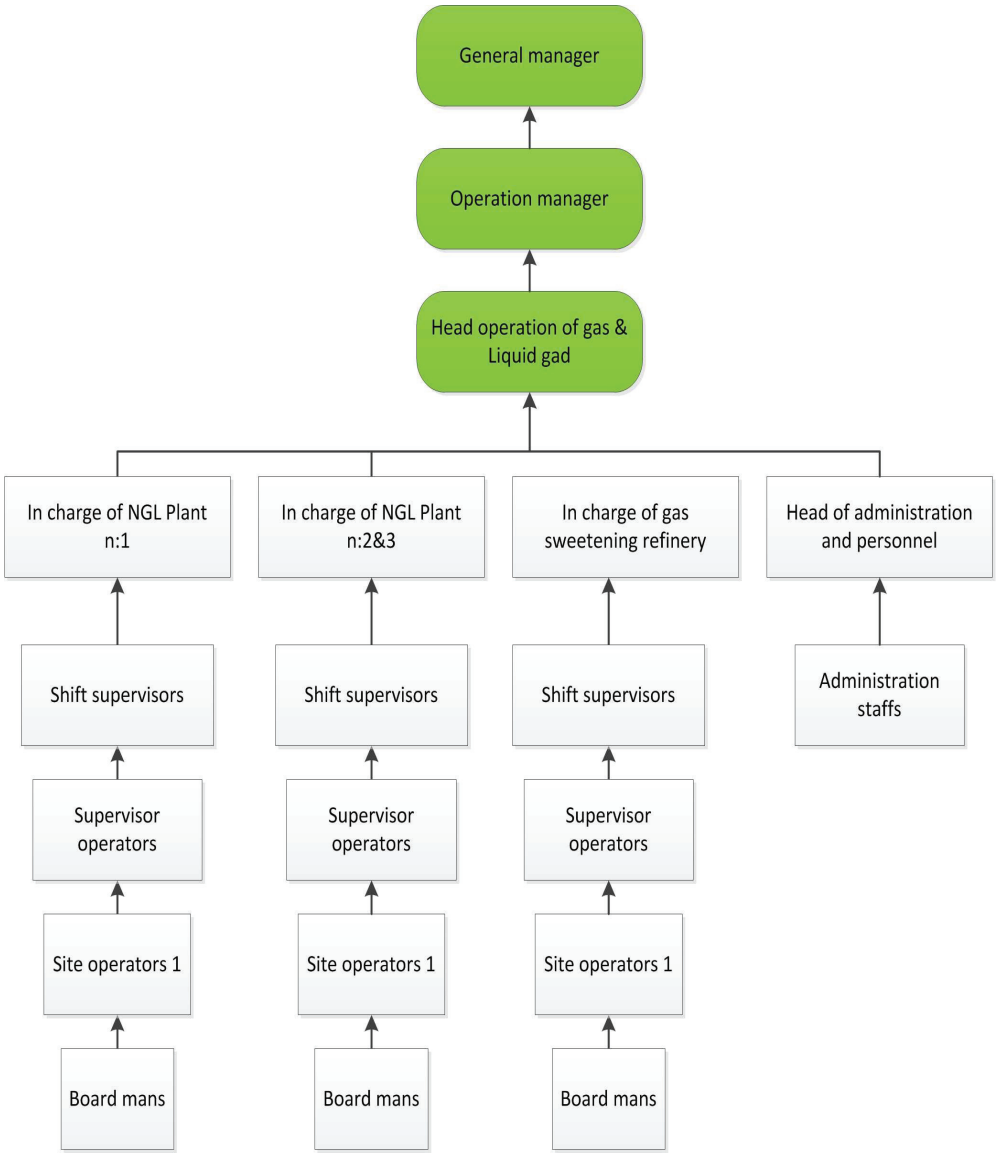

Figure 5.2. *The organogram of gas and liquid gas and direction of reports in NOC company*

Note: The middle manager being followed is presented in bold and black font. Two managers, who are executive managers, are higher than the subject. Other levels are direct reports and subordinates of the individual manager in this study. In total 130 personnel work in Gas and Liquid Gas Management.

5.2.3.2 Procedure

First of all permission to record the tasks was obtained by contacting the management of the Company and explaining the purpose of the study. A consent form was used in order to ensure that the ethical and confidentiality concerns (in particular anonymity) were adequately addressed. Then, a middle manager who managed four plants and one administrative department was requested to record his activities during all his working time for one month to capture what really happened in the company. The manager recorded all of his activities, such as meetings and other managerial businesses, on a daily basis.

"Diaries are records, reflections, personal experiences, behaviours and events" (Koopman-Boyden & Richardson, 2012) that provide a rich source of data. The diaries can provide more relevant information and they can capture the event spontaneously. In consequence, recalling the information is more accurate, and diaries are appropriate for events that can be overlooked or forgotten. However, conventional diaries can suffer from inaccuracy and incompleteness because participants do not have enough skill in recording or they omit some information. Audio recording, on the other hand, does not have these downsides because it takes place in real time as events unfold. Participants are not required to have significant literacy skills, and it is not time-consuming for them, while they can provide complete and accurate datasets (Crozier & Cassell, 2016). The method applied in this study even differs from other audio recording, since it is recording all the activities, behaviours and events without the influence of the perceptions and the reflections of the participants. The daily task recording method in this study seems like the observation of contemporary behaviours without interfering with the participants.

The middle manager selected forms a proper case for this study since this manager and other operational managers are called on to achieve an appropriate balance between production, safety and other objectives of their organisations and they are directly involved in the process. This manager also would be a suitable representative of other middle managers in the company, since the result of the interview with the manager and the organisational chart revealed that this manager has a high level of interaction with other actors at both higher and lower levels as well as at the same level. Therefore, applying the audio task recording method and selecting this case enabled researchers to capture a whole network of activities consisting of multiple actors and the links between them.

This approach can be justified for our purpose for the following reasons. First, we can consider a middle manager as an agent in the company who assesses the situations in the organisation, makes decisions, and interacts with others. By assessing one agent in this system, researchers are capable of capturing a broad picture of the company involving the current conditions of the company, the behaviour of middle managers, a network of interactions between middle managers and other entities in an organisation, and even the

relations with external organisations. Second, this microscopic technique is appropriate for exploring what is actually happening in the real world. It enables us to focus on middle managers, in dynamic and real-time conditions when they implement different tools to accomplish their firms' objectives. Consequently, the study of decision-making process and the influencing factors in organisation in real conditions are possible with a high degree of accuracy.

5.2.3.3 Data analysis

All audio data was transcribed and fully translated into English by the researcher. The collected data were analysed by applying the qualitative data analysis & research software (ATLAS.ti Ink) version 8. After transcription, the following steps were carried out in order to code the contents of the documents. First, whole documents were read completely. Next, the text was re-read line by line to determine meaningful fragments that would be relevant to the research topic. An appropriate code was assigned to that segment through the categories provided by Activity Theory (Flick, 2009). The pre-defined categorizations assist researchers in organizing the large amount of data into an explicit structure and it prevents miscoding and miss-linking, resulting in a focused and precise analysis (Miles & Huberman, 1994).

To understand the complex phenomenon under investigation, the extended version of Leont'ev's Activity Theory by Engeström, Miettinen, & Punamäki, (1999) was used. Activity Theory is a useful tool for this research because the focus of the study was rudimentary practices in the real world. This theory can also contribute to the identification and interpretation of units of analysis (Karwowski, 2006). Besides, the main core of this theory is objective-related goals produced as a result of the continuous process (Engeström et al., 1999); therefore, we can find how strategic goals are influenced not only by each other, but also by other elements of an organisation. It is useful to find the links between individuals that impact on the surrounding structure; consequently, it enables researchers to explore the process of decision-making and to identify influencing factors in those decisions. Figure 5.3 shows a model of Activity Theory that represents the core components and their interrelations within an activity system. The core units of this theory are subjects, objects, tools, rules, community, the division of labour, and outcomes (Wilson, 2009).

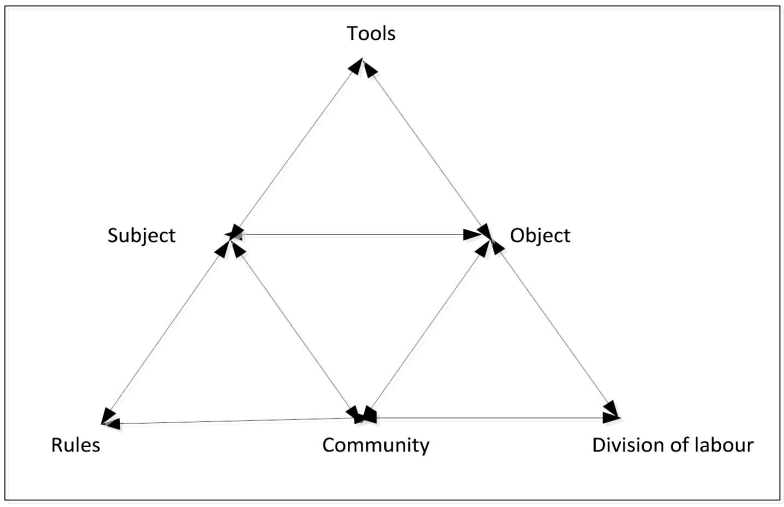

Figure 5.3. *Leont'ev's activity theory as represented by Engeström (1987).*

Then, coding, grouping codes, merging similar codes and establishing network diagrams were carried out to develop the links between codes and to find the patterns. We used the same techniques that are used to ensure trustworthiness of the qualitative analysis (Ritchie et al., 2013). Table 5.1 represents the techniques implemented.

Table 5.1. Techniques applied to ensure the reliability of qualitative analysis.

Reliability criteria	ID	Technique
Credibility	Internal validity	Saturated data, double-check, member check, direct observation
Transferability	External validity	Tick description, purposive sampling
Dependability	Reliability	Detailed documentation, double coding
Confirmability	Objectivity	Participant review

5.2.4 Industrial case description

The audio task recording was carried out in an oil and gas production company that is a part of a country's national oil and gas industry managed primarily by the government. The name and the profile of this company remain confidential, and it is just called NOC hereafter. The structure of the oil ministry spans three levels: macro (national), meso (regional) and micro (local). In this study, the case is a company at the micro level that is nevertheless substantial. It has seven operational units, four distillation plants, ten gas compressor stations, three liquefied gas plants, one gas refinery, and one water treatment plant that produces more than one million barrels of crude oil, 500M ft^3 gas, and 6500 barrels of liquefied natural gas per day.

The company consists of production plants with its customers in the downstream oil and gas sector. The NOC consists of several production plants, each with their unique process and productions that range depending on the geographical locations and the production characteristics. However, they are closely interconnected, meaning that the output of one plant forms the input of another plant. Therefore, cooperation between different plants is essential for accomplishing the company's overall goals. The final products of the company are crude oil, gas, and liquefied gas. The overall aim of the company is divided into four strategic objectives that are production, quality, safety and environment as they have implemented HSEQ management system in this company since 2003.

The company itself has its hierarchical levels in three layers that can again be described as the macro, meso, and micro levels: The entire company (macro) that is coordinated by executives (senior management) is divided into some departments organised by senior middle managers, the meso level. Finally each department then involves several work groups or plants, each managed by middle managers and supervisors, the micro level of description. Figure 5-4 shows a schematic of hierarchical structure in the NOC Company in more detail.

There are many external stakeholders including the central organisation, consumers in downstream, vendors, service providers, the regulatory organisations such as the health centre, the labour centre, the environmental centre, and non-government organisations (NGOs). All of these play roles in the determination of the company's requirements; at the same time, they may also influence the company's objectives. External bodies, therefore, play a role in determining both what goals have to be achieved and how those goals are to be met.

Different managers, such as operational managers, maintenance managers, financial managers, storage managers, security manager, and HSE manager, all perform their allocated activities in order to complete the objective's company efficiently. At the same time, they each have their specific functions and objectives.

The next section presents the results of analysis of the empirical evidence, reflecting the success and the failure of objectives and influencing factors as well as their complex relations in the NOC Company. It also compares the results of the interview with audio task recording in priority setting of objectives.

5.3 Results

5.3.1 Components of the organisation

The primary result of audio task recording study was a set of 17 audio files ranging from 1:14: 00 (hours: Minutes: Seconds) to 9:16:51(hours: Minutes: Seconds) with a mean value of 3:49:28 (hours: Minutes: Seconds). This was a total of approximately 65 hours of recording in the month. The 17 transcribed documents were in the range of 148-940 lines of text each. Every document involved daily activities that were coded and categorised into different

groups mainly based on the elements of activity theory. Table 5.2 shows the identified components of the organisation based on the principle of activity theory.

It is essential to remember that all of these sub-components are actual components that were identified from the audio task recordings; they are not based on a priori assumptions of the researchers. Besides, the actions were a long list and the rules were mentioned in the text; therefore, these core elements are not mentioned in Table 5.2.

The first component is *subject* that consisted of all individuals within the industry and outside of the company, which in this study were divided into management and operators/staff. Managers then divided into three managerial levels namely senior, middle and lower management. The primary reason for this type of grouping was the objective of the study that concerned middle managers who link the upper and the lower levels of an organisation. The second reason was the hierarchical structure of the organisation under study.

Another element was *objective* which are the results those individuals, at different levels, try to achieve. The strategic objectives of the organisation were divided into four main groups based on the HSEQ management system used in this company, consisting of production, quality, safety and environment.

To achieve organisational targets, another core element is *action*. Actions are not only individual actions, they but also depend on social interactions (Engeström et al., 1999). Therefore, all the actions and reactions that people made, were categorised as actions. We identified actions such as argument, complain, control, confirm, cooperation, decision, doubt

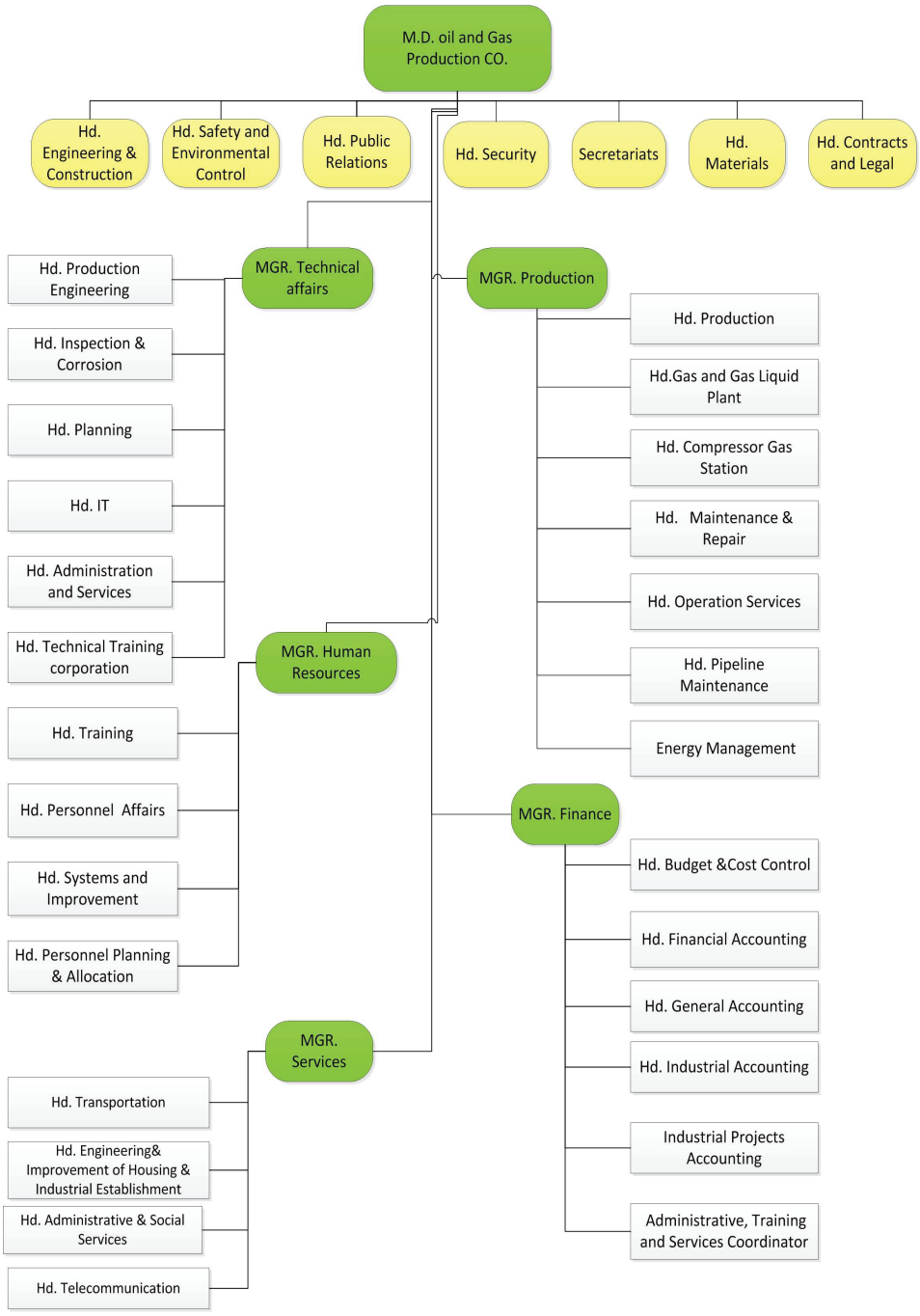

Figure 5.4. *The schematic of the hierarchical chart in the NOC Company. Data sources: nisoc,URL:http://kogpc.nisoc.ir/HomePage.aspx?TabID=3648&Site=kogpc.nisoc&Lang=fa-IR. last seen on 05-07-2016*

gossiping, farewell, kidding, meeting, report, inform, pursue, meeting, wondering, report negotiating, and staffing. We explain actions in more detail in Chapter 6 as they are useful for understanding the roles of middle managers in the NOC.

Table 5.2. Several components of the organisation identified according to Activity Theory

Subject	**Objective**	**Tool**	**Cooperation**	**Positive outcome**	**Negative outcome**
Senior management	Production	Committee	Department-department	Lower cost	Accident
Middle management	Quality	Contact	Central organisation-NOC	No flare	Complain
Supervisors	Environment	Contract	Stakeholders-NOC	No leakage	Cost
Operators	Safety	Equipment	Middle manager-middle manager within a department	Cooperation	Delay
Staffs	Security	Guideline	Supervisor-middle manager	Shorter than expected time	Shutdown
		Meeting	Operator–manager	Decision	Trip
		Method		Employee satisfaction	Failure
		Permission		Permission	Flare
		Planning		Repair	High workload
		Procedure		Problem resolved	Leakage
		Training		Solving conflicts	No permission
		Work order		Solution for sanction's problem	Not decide
				Meeting	Conflict
				Accepting responsibility	

Different *tools* were applied by subjects to deliberately maintain or modify the course of actions for achieving objectives (Engeström et al., 1999). We found 12 various groups of tools that individuals applied in this organisation which are shown in Table 5.2. Another core element in this organisation, which influenced the objectives, were *rules* that were rules behind the roles, procedural rules with a variable degree of generality, standards, guidelines and regulations.

Communication, cooperation, and collaboration are essential elements for effectively running an organisation. An essential aspect of the whole organisation is cooperation and collaboration between various systems both within and outside an organisation. Frequency of cooperation, and collaboration codes in the documents was 41. Lack of cooperation was the main element that resulted in adverse outcomes in this organisation such as conflict, cost, delay, and leakage. The *outcome*, another core element, was not necessarily positive expected outcomes; outcomes, instead, included both positive and negative or outcomes that evolved when individuals in organisations were performing corrective actions. Table 5.2. represents the outcomes of an individual's actions/reactions both positive and negative in that period.

5.3.2 Multi-objective decision-making (MODM)

In this section, the empirical results are used to explain in detail how multi-objective decisions were made in real conditions in the case of the NOC Company.

The core targets of the company were the four strategic objectives including production, quality, safety and environment. The analysis revealed that strategic objectives are not independent, they are mostly integrated and interrelated objectives, and sometimes they are incompatible with each other. It means that achieving the improvement of one objective, production, for example, does not necessarily result in the improvement of achievement of the safety objectives. In total, it was observed that production and environmental goals were dominant objectives, while safety objectives were non-dominant. This difference resulted from the difference in the reference point of the objectives; the reference point for production objectives was an aspiration level or a desirable level in this company, while the reference point for safety objectives and environmental objectives was a reservation point that is a legal minimal necessary level of achievement (Ustun & Demirtas, 2008) determined by regulations. The evidence for this statement is production reports in operational meetings that were performed every other day, consisting of senior managers and middle managers. Every meeting started with the forecasted and the actual levels of production, in which the actual levels of production were more than the forecast levels in 98% of meetings. While in safety and environmental targets they only mentioned the regulations. For instance, they discussed the number of emergency eye washes that were fewer than the number of emergency eye washes required by the regulations, or the amount of water in water tanks for fire-fighting based on the HSE regulations, while they discussed samples with less water than a minimal

acceptable level (the reservation point). This makes for a great difference between various strategic objectives and the motivation of individuals to prioritise one objective over others.

Since organisational objectives govern the motivation of employees (Rahimi, 2015) to achieve those objectives, the improvements in safety performance depend on changing the view of the company which starts from senior management and can be spread to other parts of the organisation by changing the organisation's reference point for safety objectives. (The advice here is that instead of holding the safety objectives in the reservation point, it is always better to move to the aspiration level that builds in a natural tendency to improve). The company should also take into account the fact that although the company may have managed safety for several decades properly, environmental objectives had not previously been one of the strategic concerns of management in the company. Currently there is a clear gap between what occurs in the organisation with a desirable level for environmental objectives even with the minimal reservation level. The management of the company should take into account the requirement that improvements in environmental objectives would not be at the cost of compromising the safety objectives.

The results showed that national and international trends impacted the objectives of the company too. The US had embargoed oil producers in this country, which had both direct and indirect effects on their achievement of the company's objectives. Although the impact appeared not to be statistically significant in the target country (Sterling, 2009)[8], the priority of objectives shifted from production to the maintenance of the current system, so the company was under the pressure of sanctions which resulted in both less production and more limitations on the provision of equipment; as a result the sanctions increased the number of failures in equipment and the time intervals for repair, as well as increasing conflicts between individuals.

The results also revealed that transformation, which is changing the objectives, has also happened in this organisation in another way. External organisations with their own objectives that have regulatory or social powers changed the internal perception about environmental objectives. The comprehensive legal framework, which served as a trigger for environmental governance and management, was introduced in this country from 1990 (Ahmadvand et al., 2009), while an integrated management system had been established in this company since 2003, integrating the quality, safety, and environmental management systems. The environmental objectives have essentially been shifted in this company; consequently, alteration of the focus of individuals in the company towards environmental goals may have resulted in new and different trade-offs against safety. Perversely that may have, in practice, actually increased the likelihood of catastrophic outcomes, both in safety and also, unfortunately, environmental.

[8] Impact means earning not the amount of production

Man 1: "…You made us disappointed these days?
Stakeholder's Manager: You use this opportunity to flare as much as you like (kidding)
Man 1: The environmental protection organisation is photographing us now.

Environmental regulation had an essential impact on the strategic objectives of the company. As the quote illustrates, trade-offs occurred between oil production, safety goals and environmental preservation. Therefore, one of the major focuses of managers from senior to the lowest level has become the achievement of environmental goals. One of the main questions posed of managers, either in daily meetings of middle managers or in operational meetings, technical meetings, and CEO's meetings, was about the amount of flaring. It occurred in every operational meeting (100%) when middle managers reported to senior management. This came immediately after the production reports, which indicates the relative levels of priority to be given to the objectives; this can be taken as meaning that production still has the first priority, but environmental objectives clearly come next in importance.

On the one hand, this transformation is a desirable outcome of implementing an integrated management system intended to give greater weight to environmental and safety objectives. On the other hand, an obvious deviation from predicted outcomes observed in giving a greater weight to environmental goals compared to safety objectives may result in less investment in safety, resulting in an increase in the number of incidents.

One important emerging issue in this study was personal conflict, a factor that can prevent people from achieving their objectives. In this study, we refer to the conflict definition by Thomas' (1992) as 'the process which begins when one party perceives that another has frustrated, or is about to frustrate, some concern of his.' Conflict can occur as a result of conflicting values (Eisenhardt, Kahwajy, & Bourgeois, 1997; Fasihi Harandi, 2016), ambiguity, uncertainty or in high-stakes decisions (Eisenhardt et al., 1997), which is normal in the management of a large production company like this one; however, it can influence safety objectives and prevent appropriate management of safety. It seems that on-going conflicts in this organisation, particularly between the organisation and the third parties, unfolded in slow motion, and therefore management failed to take appropriate courses of action.

As Table 5.3 shows conflicts happened between various subjects on three levels - interpersonal, intergroup, and intragroup. Interpersonal conflict is disagreement and incompatibility between two or more individuals within a group, on the same or different levels (Rahim, 2002). Interpersonal conflicts observed in the NOC were conflicts between middle manager-middle manager, supervisor-middle manager, operator-supervisor, and senior middle manager-middle manager. Intragroup conflict refers to conflicts between the groups, units, or divisions within an organisation (Rahim, 2002). The most frequent intragroup conflict in this company was between production departments and the maintenance

department as a result of a great number of failures in instruments that were exacerbated by the embargo. These conflicts, then, extended to conflicts between the maintenance managers and both the financial manager and the manager of supply department. Nevertheless, there was no evidence that sanctions influenced the priority of safety objectives directly. However, frequent failures in equipment and longer required time for repairs as a result of this condition, still had the effect of influencing safety process negatively.

Intergroup conflicts occur between two or several parties because they are interdependent in their functions (Rahim, 2002). Intergroup conflicts that were identified in this case were conflicts between NOC company and service providers, particularly the overhaul company that has its own contractors and between the central organisation and the NOC, as well as among the NOC Company and suppliers.

The results revealed that conflict between actors were brought about as a result of the conflict in motivation, incompatibility of objectives, different perceptions, an ambiguity of responsibility, lack of cooperation, ambiguity in the division of labour, improper or ambiguous procedures, improper methods, an imbalance in cost-quality, improper information communication, and failures of instruments. Failures in equipment (technical tools) triggered the above-mentioned conflicts.

5.3.2.1 The interconnection between internal components of the NOC and their impacts on strategic objectives

Figures 5.5 to 5.8 not only illustrate the impact of other components of the organisation on safety objectives but also show their interrelations. Figure 5.5 illustrates the impact of the failures in instruments (the trigger event) and organisational objectives. The instruments and equipment are the primary tools for maintaining production within an industry; they are also essential for achieving other organisational objectives. Figure 5.5 shows how failures in essential instruments, such as compressors, valves, turbines and vessels, as a result of mechanical, electronic or instrumentation failures in equipment gave rise to adverse outcomes on various objectives. These negative impacts include leakage (production, safety, and environment), flaring (production and environment), shutdown and trip (production) in that period. Consequently, these adverse outcomes negatively impacted on the strategic goals of the company. The right side of the figure shows the compatibility or incompatibility of objectives. For instance, flaring can improve safety objectives, by reducing pressure with the release to the flare, while it can decrease production and environmental objectives as a result of wasting and burning the oil and gas being released. Leakage is an example of compatibility of objectives because it decreases *all* strategic objectives, even security ones, because maintaining and repairing such a wide-spread network of pipelines requires considerable efforts by operations, plant management, adequate financing and more efforts of the security department (Rezvani et al., 2011).

Table 5.3. Several conflicts which happened in the NOC.

Type of conflict	Level of conflict	Cause
Transportation of operators with contractors and other staff	Intragroup	Rule
Safety objectives with production and environmental objectives	Interpersonal	Priority of production and environmental objectives to safety objectives
Training of operators	Interpersonal	High workload
Lack of cooperation between the NOC and a stakeholder during the overhaul	Intergroup	Conflicting values
Conflict between an operation manager and maintenance manager	Intragroup	Long-time maintenance
Conflict between an operation manager and a maintenance manager	Intragroup	Repeatedly equipment failure
Lack of cooperation between the NOC and a stakeholder for decreasing the input gas during the overhaul	Intergroup	Conflicting values
Transferring the equipment out of factory by maintenance without permission of operation unit	Intragroup	Conflicting values
Conflict between operators and middle managers	Interpersonal	Conflicting values
Conflict between the NOC's middle manager and a stakeholder's middle manager	Intergroup	Stakeholder could not provide an essential valve (as a result of sanction)
Conflict between the NOC's middle managers and a stakeholder's middle manager	Intergroup	Stakeholder did not repair vessels and equipment on-time

We found the same results in interviews, when middle managers mentioned to compatibility or incompatibility of objectives.

MM 2: "…every time that we do something we do it with safety. If you ask me can I ask you to separate safety from the design, I cannot separate safety from design. In everything that we do, every drawing which we make, the base is always safety. Even operability has direct relation with safety. Because if you cannot operate a plant, your plant will be unsafe. If I draw a line which represents a pipe, the pipe has to be according to standards. So, that's the safety issue. If I am designing a draw, so for the high velocity, it is safety issue, if it is for low velocity, it is a safety issue, so everything which I do has direct effect on safety. If I design something which is so complex that nobody understands it, I have safety issue. If I design

something which cannot commission because it will go up, then I left a safety issue. So, everything which I do one way or another has to do with safety.

Figure 5.6 indicates the outcomes of equipment failure on subjects/individuals. Although in conventional methods of incident analysis, we focus on errors that caused incidents, Figure 5.6 shows that deviation in the processes and failures in instruments triggered the actions to overcome the abnormal conditions. Sometimes communication needed to solve such problems triggered conflicts between individuals. The unresolved conflicts that take more time in an intragroup than an interpersonal conflict can result in an incident. The applied methodology and analysis allowed us to determine the conflicts at the interpersonal and intragroup level as well as intergroup that can cause incidents. In a systematic view to prevent accidents, it is essential to take into account both communication and conflict as underlying factors that can lead to accidents. Figure 5.6. shows that the causes of conflicts led to improper cooperation in the intragroup and intergroup level that, in turn, influenced the strategic objectives in the NOC context.

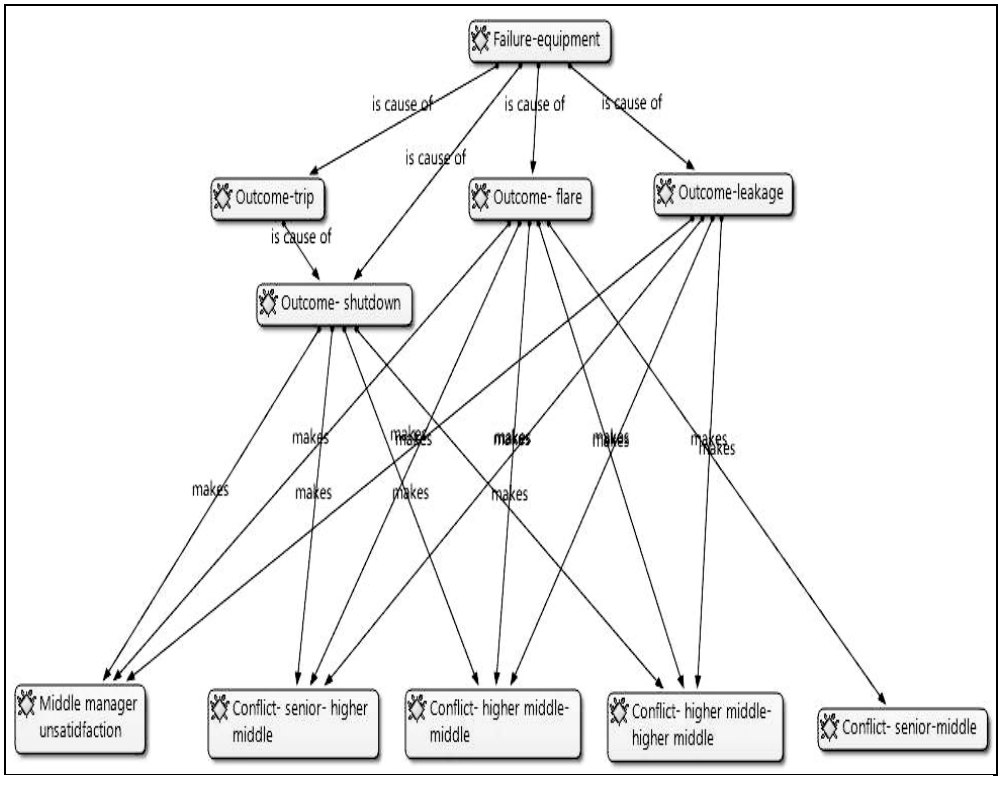

Figure 5.5. The relationship between failures, outcome, and individuals in the NOC Company

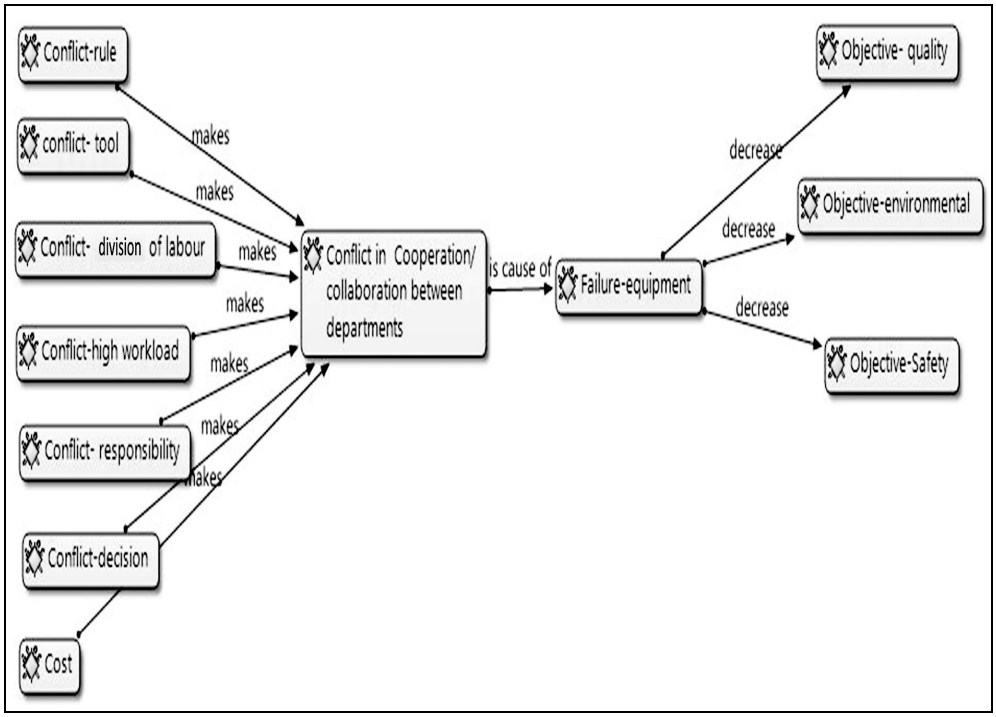

Figure 5.6. *The causes of conflicts led to improper cooperation in the intragroup and intergroup level that in turn influenced strategic objectives in the NOC context.*

Figure 5.6. illustrates how the influencing factors that caused conflicts in cooperation on an intragroup level occurred between departments, which in turn triggered failures in instruments that ultimately influenced strategic objectives negatively. It is essential to take into account the fact that the most frequent conflict was between production departments and the maintenance department as a result of the high number of instrumentation failures. The underlying causes of these conflicts that were detected are mentioned on the left side of Figure 5.6. This evidence proves that these causes and consequences act in a loop. It means conflicts in cooperation give rise to failure in instruments, and then in turn failures in instrumentation produce conflicts between departments.

5.3.2.2 Impact of external organisations on company's objectives

Not only did managers in different departments have different desired goals and different criteria, but also other organisations that were affected by operations, decisions or the policy of the company (TrimisiuTunji, 2015), with their own visions and defined goals, influence companies' strategies, plans, actions and even the way of communication (Aven, 2007). Contractors had the most negative impacts in achieving the safety objectives of the company.

Task analysis revealed that neither safety performances of contractors were approved by the HSE management and other operational managers, nor did contractors actively integrate safety and environmental goals into their management system. Although contractors have been legally required to provide a safe environment for their workers, contractors did not take a proper approach to providing and implementing an effective management system which has to cover more than just the personal well-being of their own personnel. Implementing the project was the first priority of contractors, while contractor companies suffered from the lack of an effective means for either providing safety equipment or monitoring and controlling the system. This condition was escalated by contractors, like the overhaul contractor, that in turn have their own contractors. Following is presented evidence for our arguments:

…Man 6: "…(from overhaul company): Overhaul of a storage vessel was finished but in-charge did not approve it. If you confirm it, we can use our scaffolds for other parts.
Senior manager: Around the storage polluted by oil, we are waiting for cleaning then we approve.
Man 6 (from overhaul company):If you confirm, the contractor will be free for other duties.
Senior manager: If they want to be free, clean it as soon as possible.

Another example

…Technical engineering manager: "…. The contractors leave their waste materials in our units.

Next

The guys are busy with repairing the storage. The work going very slowly because of conflicts between contractor and security officer.

Another example

…Man 6: "…(from overhaul company): We wrote that HSE of the overhaul company confirms it and then HSE of the NOC approves it. In guideline (procedure) there is one item that explains HSE controls the Contractors that they have HSE training or not, noting more. Confirming scaffolding or finding other safety issues have not defined in this guideline.

Finally

…Man7: "…The contract depends on 5+1 contract also. Since the price changes so much and the contractor has to buy more expensive equipment than what he wrote in contract, He has to change the quality. There is one way for solving this problem. You should write a correction in your contract.

Figure 5.7. illustrates the influence of one contractor that, in turn, has its own contractors, on its organisational objectives. The overhaul company with its specific elements and its particular objectives, while has continues interaction with this company and other companies on the meso level. The company are doing the overhaul based on a pre-planned agenda. As presented in Figure 5.7, both the NOC Company and the Overhaul Company announced that they did not have enough personnel to overcome the high workload brought about by safety issues; consequently, they did not take the responsibility for safety monitoring and

supervision. Therefore, conflicts in the division of labour, on cooperation between the two companies and on the perception of regulations occurred at the intergroup level, which resulted in conflicts between two companies which could have the effect of preventing the proper management of the HSEQ management system. This ambiguity of responsibilities was mainly about safety supervision and safety permitting. In a safety management system, control is a critical element, for which both companies failed to take responsibility, and which could cause disastrous outcomes.

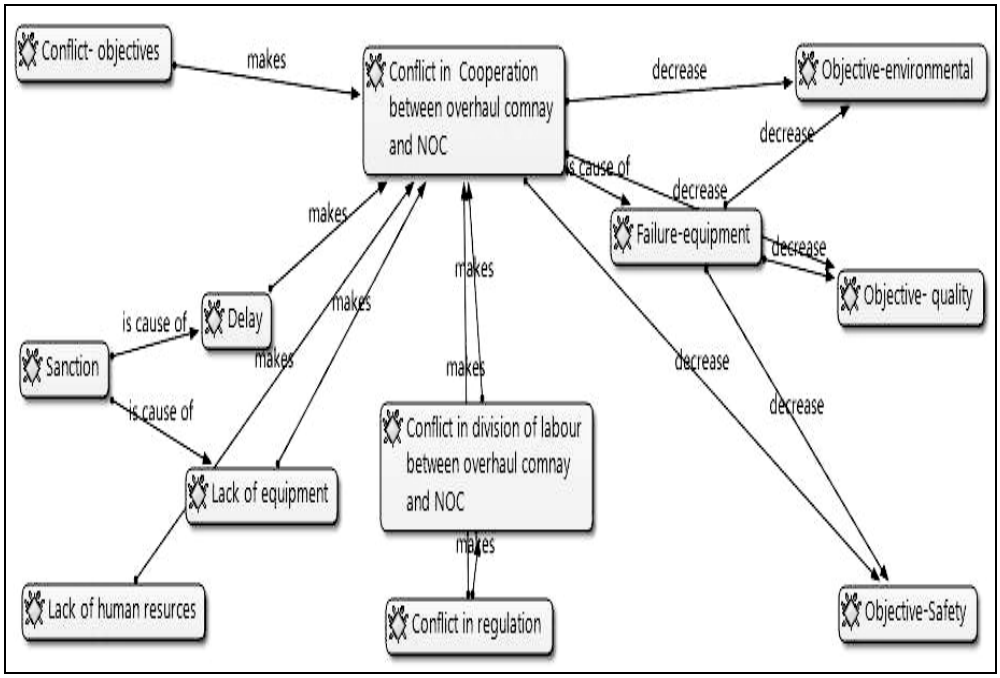

Figure 5.7. How an overhaul company impacts strategic objectives of the NOC Company

Another stakeholder with a great impact on the objectives and other components of the NOC company is the central organisation (COR). Since the structure of the oil ministry is hierarchical, this company on the micro level is governed indirectly by decisions taken at the wider meso and macro levels. The causes of conflicts that happened between the company and the central organisation, which in turn impact organisational objectives, are shown in Figure 5.7.

Other stakeholders that also influence the strategic objectives of the NOC Company are consumer companies. The products of the company form inputs to other downstream companies; for instance, products of NGLs are sent to gas compressor stations, a refinery, National gas company and a petrochemical complex. Therefore, cooperation between the NOC company and consumer companies is essential for accomplishing the company's overall goals. During this research, several operational plants were overhauled in this company that

made the cooperation even more critical. Data analysis showed that there was not enough collaboration between these companies, which caused more flaring and therefore influenced all strategic objectives negatively.

In this period the number of failures increased and some vessels failed to work properly, affecting all strategic targets. Also, the quality of the gas decreased for a short period, while the NOC company did not notice it as a result of equipment failure. Consequently, although downstream companies promised to cooperate with the NOC, they got even less gas than under normal conditions, which exacerbated the adverse effects of the overhaul on achieving the organisational objectives. It was heightened by the complete failure of one critical valve, and sanctions which caused a delay in delivery by the overhaul company to the NOC and low capacity of the NGL to separate the gas from oil in an optimal capacity, as a result of which flaring and shutdowns again occurred more frequently.

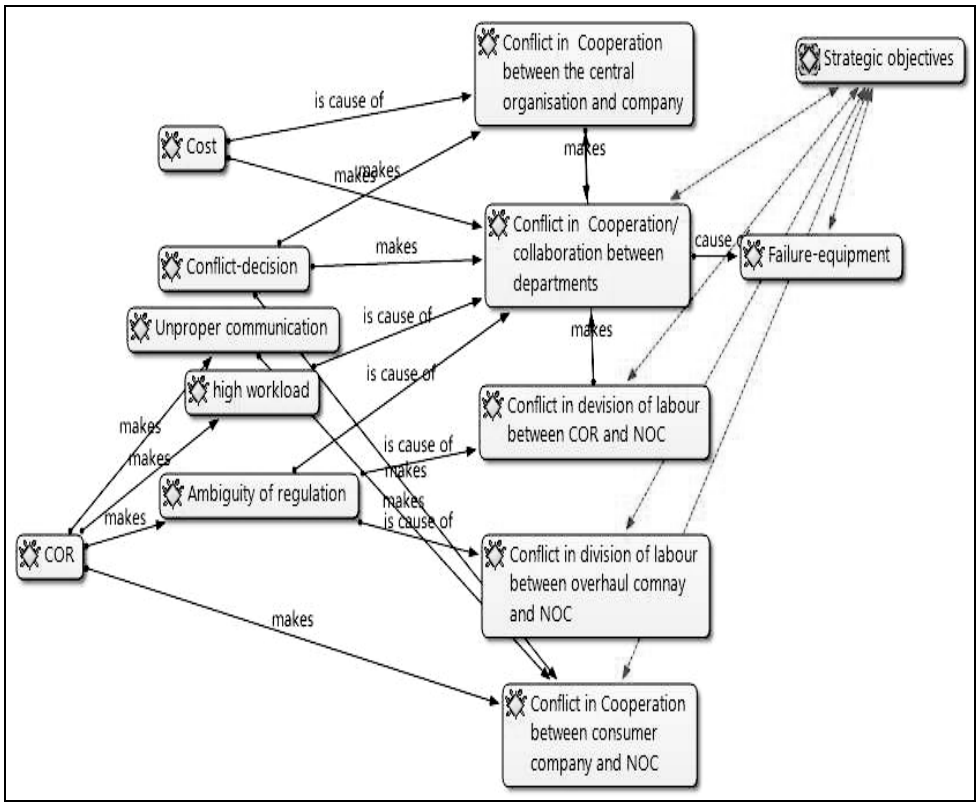

Figure 5.8. *The influence of the central organisation on the objectives and other components of the NOC company*

5.4 Conclusions

In this chapter, section 1 of the research design has been presented and then it focused to explore and scrutinize multi-objective decision-making in an industrial setting in order to answer the sub-research question: What underlying factors influence safety objectives in organisations? This chapter leads to the following conclusions:

- It is necessary to implement new techniques to uncover the quite complex phenomena under study in the safety domain, instead of only using traditional research methods. Audio task recording is a simple and easy-to-use tool for providing rich data and more precise information in a safety and human factors analysis. Task recording appears to provide a proper method in qualitative research where the researcher does not interfere with participants during the data gathering, which happens in the working context, and still permits some observation. Furthermore, it mitigates the contamination due to the social desirability response bias that means participants may try to answer what a researcher is wanting to hear instead of what is actually the case (Khayatzadeh-Mahani, 2012). Social desirability forms a significant source of bias influencing the validity of many social science research studies (King and Bruner 2000; Nederhof, 1985; Peltier & Walsh, 1990).
- Applying Activity Theory also enabled the researchers to clarify the understanding of how tasks are performed, as well as helping to understand the manners of interactions and communications between individuals, both internally and externally within a system. Activity Theory supported the researchers in identifying an emergent issue – personal conflict - between different actors. Conflict can occur on three levels and would be intensified by any failure in other components of the system consisting of tools, rules, communication and collaboration. This study confirms that Activity Theory provides a useful analytical technique to find hidden and underlying causes of failures in safety management system simultaneously which can give rise to accidents. Other methods of risk analysis are mostly concerned with only one or a few elements. For instance, HAZOP and FMEA are concerned with the technical causes of accidents while Activity Theory enables researchers to find more complex and interconnected causes and to go through them in detail. Besides, several methods are based on the assumption held by investigators or experts, while Activity Theory and audio task recording are tools to capture the realities.
- The combination of the task recording method with the activity analysis approach seems to provide a systematic and structured methodology for conditions where the data are complex and often combinatorial due to its contribution to identifying, interpreting and analysing data. The main advantage of this method is exploring the

relations between the individuals with other elements in an organisation in real conditions.

- Political issues do not just influence sectors such as the market, they also affect the practice of science; it can stop the research for a period costing human, financial and even emotional (psychological) resources; however, in this case, this challenge enhanced the quality of the research more than expected as the stresses that were created by sanctions enabled issues such as conflict to come into sharper focus.
- One disadvantage of pre-defined coding is that the researcher is not able to think outside of the established question structure; if one or more categories had become evident once analysis had started then it would be too late to incorporate them. On the other hand this would only be critical if the missing classes were clearly both vital and of sufficiently high frequency to make a substantial difference. This was not the case in this study. If there were distinct and significant missing categories it would, of course, be necessary to start over again, but the extra work this would involve should not normally be too extensive as most assignments would nevertheless still remain the same. Since the volume of documents was large, applying this method sharpened the focus, consequently raising the level of the precision, even at the cost of missing some categories that can result in some minor added uncertainty.
- This method is also quite time-consuming at the point of transcription; usually an interview takes time between 30 and 90 minutes, while task recording took 8 hours per day. Therefore, it requires more time for transcription and analysis but gives a considerably better picture of what happens in practice. On the other hand the data is not filtered through the lens of a short interview, the constraints of predetermined interview questions in the case of structured and semi-structured interviews and the restrictions on memory of the interviewee determined by biases such as availability and representativeness (Kahneman, 2013).
- It is widely accepted and confirmed by this study that an organisation can be considered as an interconnected network that is commonly divided into levels with differing authorities, accountabilities, and responsibilities that can influence the achievement of the strategic objectives. The results show that a rigid hierarchical pyramid structure which depends on a single central power is not a correct concept in safety management, neither as a description nor as an approach to managing. In the NOC Company everybody is engaged in safety activities. The study revealed that other managers such as operational managers and maintenance managers were actually *more* involved in safety activities than the HSE department's manager. This latter realisation casts some doubt on studies that have concentrated on the activities of

the HSE department and its members, as their role can only be properly understood in the wider inter-related personal context that characterises day-to-day operations.

- This study revealed that safety objectives can be impacted by all other components of an organisation. Safety goals can be influenced by other objectives with differing degrees and ways of influence. It can also be affected by divisions of labour, tools, rules or cooperation. An organisation is not an isolated island. It has interconnections with other stakeholders, with their own intra-connected networks and special goals which may mostly be similar to the company's goals but differ in priority setting, influencing strategies, plans, actions and even the manner of communication in an organisation. In this case, contractors affected the strategic objectives of the company negatively, particularly the safety objectives. More specifically, we concluded that in practice, it is not possible to make an optimal decision. Managers struggle to find a balance between various and incompatible objectives, while they do not necessarily make optimal decisions.
- The safety objective was influenced by other objectives because of a culture in which revenue generation and environmental objectives commanded the top most and second priority. The trade-off effects between safety and other objectives suggest that a power associated with an objective corresponds to its position in a hierarchical structure. Production has the highest level, quality and environment are placed on the next levels and finally safety, with the lowest influence is located at the bottom among these four objectives. These hierarchical levels of objectives resulted from an organisational culture in which senior management graded varying degrees of importance to objectives, allocating the highest grade to production that was spread in middle managers and supervisors and finally to front level workers. It is also influenced by external factors like regulation. Environmental regulation has more power than safety regulation. Besides, people are now more aware of environmental effects of industrial activities than safety results.
- One approach that can improve the chance of achieving all the strategic objectives together, which is presumably the primary purpose of an integrated management system, is to change the baseline reference points of safety and environmental objectives. It means moving from (minimal) reservation points determined by regulation to setting aspiration as the desirable level. Finding the differences and similarities between the reference points of various strategic objectives can be considered as an interesting topic for future research. We could also suggest studying how factors such as aspiration, aggregation, communication, pre- and re-distribution, and risk and loss aversion can influence the settings of the reference points in safety decision-making.

6. Breaking the clay layer: The role of middle management in safety management[9]

6.1 Introduction

Through the results of the previous Chapter, we obtained an insight into the underlying factors in safety objectives. One essential component in an organisation that influences safety is individuals at different levels with various degrees of authority and responsibility. Generally, in organisations, we are confronted, on the one hand, with CEOs and other executives who prefer to stay within their narrow disciplinary boundaries to explain and address safety issues. In Isaiah Berlin's terms, they are '*hedgehogs who know one big thing*'[10]. On the other hand, frontline staff who have a narrow vision within their own segments are hedgehogs too. Their jobs are relatively straightforward; they do not require them to consider a wide range of issues in order to be successful. However, for complex issues that are typically non-linear, subject to unexpected and unintended consequences and require more breadth of knowledge and experience, middle management, the foxes in organisations, *who know many things*, are crucial.

Achieving safety objectives closely links middle managers with various and vital tasks in organisations. It is essential to understand the under-estimated role of middle management in safety within the organisational context. A literature review in Chapter 3 revealed that there are few if any articles in the safety domain highlighting the role of middle managers specifically which was also stated by (Bhattacharya & Tang, 2012). Instead, there is a tendency to study senior management, assuming that senior management has the highest responsibility in safety management (Roger, Flin, Mearns, & Hetherington, 2009; Roger, 2013). Or they focused on the operational level, those who are directly involved in fieldwork. For instance, human reliability methods like PHEA HEIST, CREAM, and SPAR-H (Embrey, 2014; Hollnagel, 1998; Kariuki et al., 2007; Shorrock & Kirwan, 2002).

Accident causation analyses in Chapter 2 also revealed that although middle management plays a crucial role in organisations, middle management's roles were not given attention in accident investigations. Adverse events are likely to occur as a result of systemic and organisational factors such as inadequate strategic decision making, weak management, insufficient training, poor communications, and improper procedures which closely links with

[9] This chapter is based on Rezvani Z, Hudson P. (2016).

[10] This has been attributed to the ancient Greek poets Homer and Archilocus (See C. M. Bowra, ' The Fox and the Hedgehog', Classical Quarterly 34 (1940), 26–9 . We thank Tim Hudson for making this distinction originally.

middle managers who are located in pivotal positions and perform crucial multiple roles in an organisation.

Given the limited number of studies on middle management in the safety domain, further studies are needed to examine the role and influence of middle managers in safety management specifically in safety-related decision-making. Therefore, we hypothesise that middle managers have a crucial and distinctive role to play in safety management. In order to examine this hypothesis, in this Chapter two fundamental sub-questions will be addressed:

- *What are the roles of middle managers in an organisation?*
- *How do middle managers influence safety management?*

6.2 Research design

The study presented in this Chapter is in the same context as the previous Chapter. Figure 6.1 represents what has done in this part of the study.

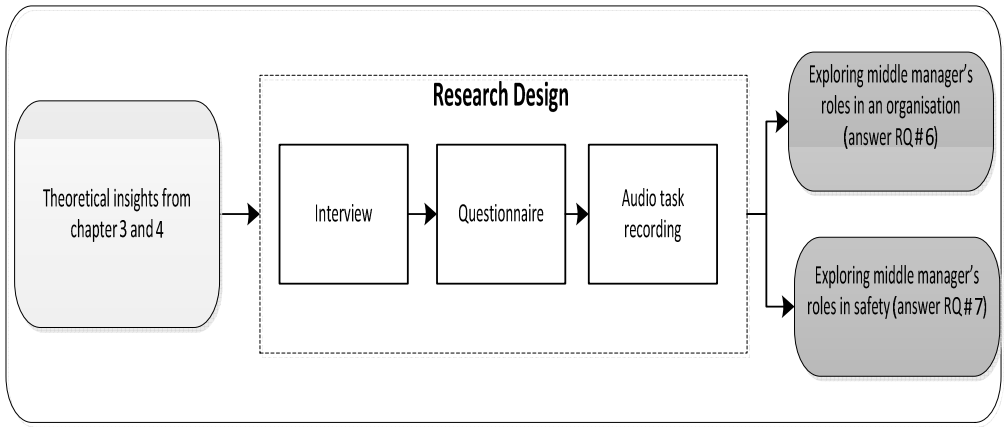

Figure 6.1 *The followed design steps to answer sub-questions# 6 and 7 in this Chapter.*

The interview method described in Chapter 5 provided good insights about the roles of middle managers; however, the task recording method equipped us with rich data about roles of middle managers as a complementary method as well as a method for capturing the data about the process of decision-making. The case where task recording was done and the procedure of task recording were already explained in details in Chapter 5, so we avoid duplication in this section. Nevertheless, the data analysis in this section had some differences with what was done in Chapter 5. In this part of the study, the researchers focused on actions that middle managers had taken in order to identify the role of middle managers and their influences on both the whole of company and the safety management system. Therefore, all of the coded actions were grouped and analysed under headings, which were selected to be the elements of the managerial roles defined by Mintzberg (1973) as shown in Figure 6.2 and described in

Table 6.1. They are all middle managers' actions that were grouped under the headings of the management's roles. Mintzberg defined 10 roles for all managers that were categorised into three categories of interpersonal, informational, and decisional.

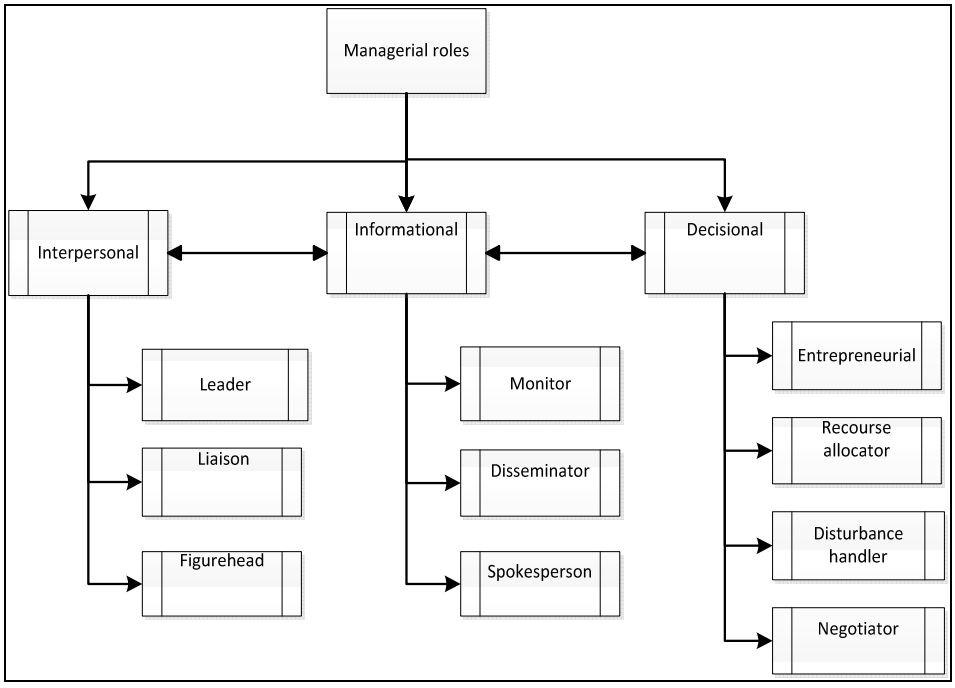

Figure 6.2 *Managerial roles defined by Mintzberg (1973)*

6.3 Results

In the audio task recording, we recorded the functions of one manager; nevertheless, the actions or reactions of at least 32 other actors were tracked by this method at the same time. These actors included senior managers (executive directors), middle managers at the same level, middle managers at a lower level who were in charge of the plants, or maintenance units, operators, staffs, peer middle managers, representatives of contractor companies, and representatives of central organisations. These representatives are those whom we can also classify as middle managers.

Table 6.1. Mintzberg's Managerial Roles. Adapted from (Mintzberg, 1971)

Role	Description	Examples
Interpersonal		
Figurehead	Performs some duties of a ceremonial nature	Greeting visitors; attending the wedding of a subordinate
Leader	Responsible for motivation of subordinates and staffing and training	Most activities involving subordinates
Liaison	Establishes his/her web of external relationships	Attending conferences
Informational		
Monitor	Seeks and receives information to understand organisation and environment	Reading periodicals and reports
Disseminator	Transmits information to other organisation members	Forwarding reports and memos; making phone calls to relay information; holding informational meetings
Spokesman	Involves the communication of information or Speaking to the board of directors ideas and top management	
Decisional		
Entrepreneur	Acts as initiator and designer of much of the controlled change in his/her organisation	Developing an improvement project
Disturbance handler	Responsible for corrective action when the organisation faces unexpected crises	settling disagreements between subordinates
Resource allocator	Responsible for allocation of human, financial, material, and other resources	Working on budget; deploying staff
Negotiator	Responsible for representing the organisation in negotiations	Negotiating a new stock issue with the financial community

The middle manager interacted with four lower level managers, still in the middle managers group, on a daily basis. They included individuals in charge of NGL plants, in charge of gas sweetening refinery and the head of administration and personnel. Those managers

themselves had the direct interaction with head supervisors and shift supervisors but not to this extent with operators, board men, shift operators and site operators. The results also revealed that they had considerable communication and cooperation with contractors. It is essential to know, since the task recording overlapped coincidentally with the annual maintenance that was carried out in two sites under the authority of the case manager, the frequency of the communication with a particular contractor company might be more than normal. However, this is evidence that confirms the high amount of the relations with contractors which is usual in a process industry with so many contractors. The manager also interacted with seven other managers at the same level and one manager at the senior level by attending the scheduled operational meetings once per week. Additionally, he attended other planned meetings consisted of CEO meetings, technical meetings, maintenance progress meetings, a meeting between NOC and the maintenance company for annual maintenance, and two meetings arranged by the central organisation. The interval times for these meetings were different for various meetings, ranging for continual meetings from once a week for CEO meetings to once a month for technical meetings. It is important to take into account that the number of middle managers as well as senior executives in those meetings was greater than the operational meetings. During the study, the case manager also had four scheduled meetings with managers outside of the company. Finally, the middle manager interacted with frontline employees such as head supervisors, shift supervisors, operators, and staff in site visits or scheduled meetings in his office.

The actions and interactions evaluated were not limited to the meetings or only the middle manager; rather all the actions and interactions, which happened between different actors in this task recording, were evaluated. In this way, the whole picture of the company was depicted, which formed a network of agents containing managers, operators, and staff who all cooperated with one another to achieve the organisational goals, despite the many conflicts and disruptions to the system that they had to deal with. The audio task recording enabled us to extend the study from focusing only on middle managers to finding a network of connections in an organisation, with greater clarity in the centre that is the middle manager, while being more blurred as the distance from the centre increases.

The interview analyses had revealed that middle managers are involved in various activities. Data analysis of audio task recording also provided real evidence that confirms middle managers' involvement in different activities and their interaction with other actors both inside and outside of the organisation covering many subjects such as production, technical, legal, economic, safety, environmental, and security. In the next step, to address middle management activities and their roles in a process industry, all the middle manager's actions

were grouped under the headings shown in Table 6.1 and Figure 6.2, which are the elements of the management roles defined by Mintzberg (1973). Table 6.2 indicates that the most of the codes match with the Mintzberg managerial roles correctly, except emotional actions that were not mentioned explicitly in the role definitions by Mintzberg (1973), while they are vital in some roles such as, spokesman, disseminator, leader, and figurehead.

Table 6.2. The roles and the frequencies of the middle manager's actions.

Category	Role	Action	Action freq.	Role freq.	Role Perc.	Freq. of roles in a cate.	Perc. of roles in a cate.
Interpersonal	Figurehead	Looking for information	5	8	0.26	885	28.59
		Arranging a ceremony for a retired manager	1				
		Attend a ceremony for a retired manager	1				
		Kidding	1				
	Leader	Support	44	727	23.49		
		Control	95				
		Wondering	240				
		Cooperation	41				
		Emphasise	93				
		Order	73				
		Respect	66				
		Confirm hiring new employees	3				
		Cooperate with other departments to exchange their positions	2				
		Cooperate with other similar factories to exchange the positions	5				

Category	Role	Action	Action freq.	Role freq.	Role Perc.	Freq. of roles in a cate.	Perc. of roles in a cate.
		Passing information to subordinates	3				
		Confirm or report attending employees in training courses	15				
		Kidding	47				
	Liaison	Wondering		150	4.85		
		Arranging with other departments/ central organisation	134				
		Surprise	3				
Informational	Monitor	Control	121	370	11.95	1740	56.22
		Wondering	240				
		Surprise	9				
	Disseminator	Transferring information	68	110	3.55		
		Adding more or new information	42				
	Spokesperson	Introduce a problem	161	1260	40.71		
		Complain	292				
		Disappoint	61				
		Report	191				
		Defending	195				
		Argument	360				
Decisional	Entrepreneurial	Arrange with another company for repair of a critical valve	1	17	0.55	470	28.59

Category	Role	Action	Action freq.	Role freq.	Role Perc.	Freq. of roles in a cate.	Perc. of roles in a cate.
		Arrange with another company to find the causes of leakage	1				
		Looking for other options	15				
	Disturbance handler	Arrange with other factories /central organisation/consumer firms/overhaul company	10	331	10.69		
		Clarifying	256				
		Postponing discussion	1				
		Calming down	2				
		Giving a deadline	1				
		Arrange with another company to find the cause of leakage	1				
		Arrange with other departments	60				
	Allocator	Decision	114	114	3.68		
	Negotiator	Negotiate with central organisation	5	8	0.25		
		Negotiate with consumer companies	1				
		Negotiate with reactor company	1				
		Negotiate with another firm for repairing	1				

6.4 Discussion

The purpose of this study was to investigate the role of middle management in safety management. Middle managers in this company perform multiple roles within the set of

different actions, as summarised in Table 6.1. However, the particular importance of several managerial roles is highlighted by a higher frequency of actions in these roles.

The Informational category was the most frequent role in middle managers (56.2%) that was mentioned by previous researchers (Brubakk & Wilkinson, 1996; Floyd, Wooldridge, & Wiley, 2011; Wooldridge, Schmid, & Floyd, 2008). This category of roles incorporates activities such as wondering, looking for other options, transferring information, adding new/more information, introducing a problem, making suggestions, arranging with and reporting to other departments in the company, to the central organisation, and to the external stakeholders. Middle managers also employed emotional actions to transfer their messages to lower, higher and their peer levels. For instance, they applied complaining, and disappointing tone for transferring any disruptions or conflicts in their systems to highlight and emphasise problems. This is an alarm system that equates to humans (managers), comparable with technical (process) alarms. 'Hard', technical alarms have been applied widely in the safety domain while we have often ignored these 'soft' alarm systems in safety management. Integrating these systems can improve the management of safety, enhancing the identification of safety risks and covering the gaps in the safety management system.

Mintzberg (1971) and Pavett & Lau (1983) pointed out that there is a relation between the hierarchical level of management and their roles. So, lower managers tend to perform more internal roles, like disturbance handler, negotiator, and leader, than upper-level managers who focus on strategies and planning performing external roles (e.g. liaison, monitor, figurehead). The analysis revealed that in the NOC context, middle managers roles incorporate spokesman (40.7%), leader (23.5%), monitor (12.0%) and disturbance handler (10.7%) having the highest rates respectively, which cover both internal and external roles.

The spokesman role (40.7%) had the highest percentage among different roles in middle managers by which managers extend the communication of information outside the department to other areas of the organisation (Grover et al., 1993), as well as the board of directors and top management (Mintzberg, 1971). Managers receive and collect information to perform their monitoring role (Balogun, 2003). The higher middle managers, the manager in this case, for instance, collected information not only just from attending different meetings, but also from dialogues with peer groups, greetings with the various employees on different levels, phone calls, site visits, even attending an informal farewell party and gossiping. Middle managers who are the subordinates of this higher middle manager collected their information primarily from their plants. Therefore, they have more direct information from the operational level, as compared to higher middle managers who get their first-line information mostly indirectly. Senior management does this with the longest interval time, being the most distant from the frontline; they cannot monitor their system without the help of middle managers.

The difference between the disseminator role and the spokesperson role lies in the direction that the transfer of information takes place. While in disseminator role middle managers forward information inside the organisation or their units, in spokesperson role the information is transferred to the outside of the unit, department, or plant. The primary role here is conducting information into two different directions (Wooldridge et al., 2008). Scholars such as Dutton et al., (2001) and Wooldridge et al., (2008) applied different typologies for these roles, in synthesiser and championing roles the direction of information is upward to the top management, while in facilitator and implementer roles, information is transferred downward. The degree of these roles may be various in different middle managers based on their functions and their relations with external stakeholders that require more examination. Nevertheless, the evidence demonstrated that middle managers transmitted information from contractors, the maintenance company, consumers, and the central organisation to senior executives, peer-middle managers, and other middle managers who are their direct subordinates. They mostly transfer information to other groups indirectly.

Another example of the informational role of middle managers is that they can easily notice any threat, disruption, and conflict in their system. The results show that the contractor's reactions to safety issues formed one of the big problems in this company since contractors were not aligned with the company's safety management system. Middle managers transferred these shortcomings to higher levels. In the other direction, middle managers also disseminate the organisational focus on safety objectives to the contractors.

The second role is the leadership role that is the second most frequent role for middle managers. This role describes the relationships between the manager and employees when middle managers control the various parts of their plants/departments on a daily basis in order to direct different activities in the sites easily and precisely. Alongside these activities they cooperate by providing training programs, that in this case were mostly safety, environmental or organisational courses, instead of just technical training, enabling employees to improve their knowledge in the HSEQ management system. In this way, they also contribute to identifying developmental requirements and achieving the strategic objectives of the company.

By performing this leadership role, they supervise, hire, train, and motivate their personnel (Grover et al., 1993). They also commit to improving their services and their products by performing actions such as control, order, cooperation, wondering, and confirming employee's attendance in training programs, applying various strategies to provide and maintain enough human resources for their departments. They committed to improving and maintaining their services as well as their production. For instance, the middle manager resisted a new decision by the central organisation, involving omitting colorimetric instruments in LNG plants, that would have decreased the quality of the products. Middle

managers also motivated and confirmed the attendance of their subordinates in training programs regarding HSEQ objectives. It was observed that most courses for employees were about safety or environmental issues. Therefore, middle managers contributed to others gaining knowledge of safety management. Training was the second tool among various tools that were applied to achieve the strategic goals of the company.

The leadership role is important in safety management too (Dea & Flin, 2001; Flin, 2004; Martínez-Córcoles, Gracia, Tomás, & Peiró, 2011; Sun & Anderson, 2011). As asserted by Flin & Yule (2004), leadership means a manager implements skills such as selection, training, and competence assessment to influencing a group to attain particular organisational goals. We found in Chapter 5 that senior managers prioritised productive and environmental objectives to safety objectives that was transferred to managers at lower levels, while for safety leadership it is essential to emphasise safety over productivity (Flin & Yule, 2004). Another example of the failure of the top level in safety leadership in the NOC and the maintenance company was not allocating human resources to HSE, which caused conflict between the NOC and maintenance company on various managerial levels. It seems that senior managers in the NOC case failed to perform their safety leadership roles. In contrast, in the middle level there is evidence that middle managers *do* perform safety leadership. For instance, a middle manager emphasised the priority of safety over production when his subordinate (a middle manager) worked with a smaller safety margin in an abnormal condition. Middle managers also asserted themselves in HSE training. When employees did not do the periodical examination, they punished them. And finally, the HSE manager assigned the carrying out of safety inspections to two fire officers to resolve the lack of resources for a short time.

Middle managers control many different activities in their sites and therefore they can notice any disruption in their system that can cause incidents. Most of these potential failures had been solved and prevented before the HSE department, that is mainly responsible for safety issues, even knew about them. Therefore, middle managers can contribute to process safety actively since they have access to information on a daily basis. They have more information about process parameters and failures in equipment, so they can more easily notice any deviation from normal conditions; consequently, they can react to them before losing control of the system.

Access to information, the effective nerve centre of organisations or units, places middle managers in a unique position where they can use information as an input to play major decisional roles (Brubakk & Wilkinson, 1996). Middle managers can make decisions as they have formal authority to choose and take a course of actions in their units (Reynolds et al., 2003). They also have indirect influence on other decisions by transmitting, filtering, and adding information, as well as negotiating and cooperating with other departments. The

results showed that the frequency of decisions, in the period of study, made by middle managers (114) was more than senior management decisions (3). It might be due to a difference between their decisions. Senior management make strategic and long-term decisions while middle managers make more tactical and short-term decisions. Our methodology can capture information with high resolution in the centre, but has a lower resolution at the edges, such as senior management. Nevertheless, the high frequency of decisions highlights the crucial role played by middle managers. It also shows that middle managers still are involved in internal roles, which are related to a lower level management.

Production managers are a group of middle management who mainly perform decisional roles because they focus on efficient work-flow (Reynolds et al., 2003). To do so, they perform a different kind of activities in diverse aspects such as production, quality, safety, maintenance, and environment. Therefore, this group has a crucial role in the safety management system since they decide between different objectives and have to strike a balance between them. Prioritising safety in organisations is not possible without the active engagement of this group in safety management and changing the perception of this group about the safety objectives compared to other objectives, such as production. Middle managers allocate resources for operation, safety, training, and equipment. They hire, fire or reward their staff. They are regularly called on to strike a balance between different objectives of their organisations such as operations or safety. They take advantage of a variety of courses of actions to achieve their goals. For instance, the middle managers were faced with a lack of applicants for operational units, while at the same time they were being put under pressure to hire, as the result of a decision made by the central organisation about filling the vacant positions, with the threat that they would lose those positions. They used a range of different alternatives to achieve their goals. They changed their vacant positions within and between the plants. They also cooperated with other plants outside of their plants to avoid loss of human resources within the company.

One of the essential middle manager's roles was dealing with disruptions, either upsets or conflicts. The disruptive upsets were brought about mainly by failures of equipment. Another issue was personal conflict between different actors, such as a middle manager with senior management or of a supervisor with middle or between middle managers. Disruption can also be the result of conflicts in cooperation between departments or between the central organisation with the company, or stakeholder with the company. Conflict as a result of disagreements in a division of labour, taking responsibility, methods and procedures were other causes of threat to this organisation.

The following example provides evidence that can clarify the role of middle managers when they resolve the conflicts that can arise between different objectives, tools, and even

individuals. The middle manager worked with a tighter safety margin to prevent flaring (the burning of excess gasses), when consumers would not get the gas, at the same time the operation plant was faced with disruption in a vessel. So, the manager of the operation plant decided to send the excess gas to an LNG plant, even while some units of the LNG plant were in overhaul. This manager dealt with this condition successfully by making this decision.

In the disturbance handler role, the manager deals with threats to the organisation as mentioned earlier by taking corrective actions. The actions involved a wide range of functions including argument, ignoring what was said, pretending to misunderstand, acceptance of decisions, accepting orders, adding new information, arranging with other departments, clarifying, cooperating, defending, postponing discussion, overt displays of anger, calming down, making decisions, imposing a deadline, negotiation, and proposing solutions.

Negotiation formed a useful tool for dealing with the disturbance in this case. One scenario was a failure of a crucial valve during maintenance. It was rated off while the maintenance contractor could not provide a replacement valve. Although it was the responsibility of the maintenance company to provide this valve, this failure led to flaring and a shutdown that influenced three of the primary objectives of the company: production, safety and environment. Middle managers took these actions to play their negotiation roles. First, the middle manager negotiated with consumer companies to take more gas. Second, the middle manager communicated with other gas plants to take gas. Third, middle managers requested other plants to procure the valve in question. Fourth, a more senior middle manager negotiated with one consumer to find an option to provide this valve in another way to overcome the sanctions limitation. Fifth, the senior middle manager had requested from the central organisation and the senior executive of the national gas company that they convince the consumer companies to take more gas. Finally, the middle managers found another valve in their storage and negotiated with a company to repair the valve in a short time.

Although the entrepreneur role is not scalable with other decisional roles in middle managers, there was evidence that confirms that middle managers also play this role. Middle managers tried to get their subordinates to adopt an integrated management system. In another case, middle managers accepted the new proposal to initiate a new performance assessment method for their employees.

Mintzberg's classic managerial role model assisted in explaining the middle management roles. Nevertheless, it is necessary to take into account that these roles and the actions are inseparable. For instance, control and wondering can be acts for performing the leadership role; at the same time, they are being implemented as monitoring roles or middle managers clarified the topics or problems for both supporting the decision making and handling the

disturbance. The transferring of information can be done for the disseminator, spokesperson as well as the disturbance handler roles. In our study, that started by finding the actions and then grouping them into various roles, these overlaps created confusion in the analysis.

Another limitation of this study was the inability of the methodology to explore the extent to which the managerial roles differ from those of senior managers, or the extent to which middle managers differ regarding managerial roles from lower-level managers and the extent to which middle managers roles change at the same level with different functions. This problem can be solved by applying task recording for various cases or interviews with proper cases. Nevertheless, it is out of the scope of this study.

As mentioned before, some functions such as disappointment, kidding, wondering, surprise cannot be categorised into managerial roles that encompass the activities that must be performed as part of the roles. They are rather abilities or skills of the holders that enable middle managers to share a common overall goal or purpose (Dierdorff & Morgeson, 2007; Dierdorff, Rubin, & Morgeson, 2009).

6.5 Conclusion

In this chapter, we have focused on middle managers' roles both in the organisation and in safety management. The results led us to conclude that middle managers play multiple roles in their organisations. They can acquire information by various methods; they can get frequent feedback, over a daily or weekly period; and they have enough knowledge about potential alternative causes of a problem so that they can make use of a range of different types of information. This frequent feedback and extensive breadth of experience help them to make both more accurate and less ambiguous decisions that reduce the 'hedgehog' tendency. While senior management has a longer interval time to receive feedback, they are also more prone to interpretation and hedgehog tendencies. Middle management do not make their decisions based on a single principle; in contrast, they use several pieces of information to make better decisions. While senior management and lower level management are more likely to favour having one big objective, with a large confidence in their opinions, middle management must try to employ a diverse array of strategies to fix a problem rather than applying more rigid and fixed procedures to get better results. They are flexible and adjust the techniques according to the context (Keil, 2010). They integrate several sources of information as much as possible, so they are inclined toward fox-like styles. There are two problems that this disparity in styles brings up. How do we move junior middle managers from junior hedgehogs to middle-management foxes and, then, how do we select potential senior executives, hedgehogs, from successful middle management foxes?

To sum up, middle managers are involved in various stages of safety management by playing multiple roles. They are actively involved in risk assessment because they can access to information in short time intervals and they have more information about process parameters and failures in equipment. Also, they can get information from various sources and combine several pieces of information to enhance the identification of safety risks. Consequently, they can make more financial decisions in safety issues as well. They are internal and mostly informal auditors in safety management. Besides, they form 'soft' alarm systems in safety management. Finally, they are actively involved in the control of the safety risks, since they can notice any disruption which may have a potential for occurring incidents and they have sufficient authority to control these situations.

7. How do middle managers take decisions in real life? [11]

7.1 Introduction

The theoretical constructs in Chapter 2 and the empirical results reported in Chapter 6 led us to the conclusion that middle management, who are a management group between top level/central management and the lower level/outer edge management, performs critical and multiple roles in organisations. Among the various roles that they perform in organisations, decision-making (28.6%) plays a crucial role in safety, encompassing being entrepreneurial as well as performing the disturbance handler, allocator, and negotiator roles (Chapter 6; Rezvani & Hudson, 2016). Middle management is continually faced with conflicts that typically arise from deviations in normal conditions. Conflicts can be created as a result of technical disturbances or disagreements between individuals at different levels or can even occur between people within an organisation with individuals in other organisations that have a relationship with the leading organisation. Because of middle managers' positions which are in the middle part of the organisation between the operating core, strategic apex, support staff and techno structures (Mintzberg, 1980), they face more disturbances and have to resolve conflicts with good decisions. Nevertheless, it is still necessary to take into account the fact that middle managers have limited authority to allocate resources; their span of authority might be influenced by the context of the organisation. Yet, they have authority to prioritize one objective that can be production to other objectives, safety for instance, which can cause catastrophic outcomes.

As discussed in Chapter 4, there are two main methods of decision-making, namely rational (prescriptive) and naturalistic (descriptive). In rational decision-making the information presented to a decision-maker is expected to be complete and organized. So a decision-maker ought to make a decision by comparison of a limited number of options based on various predetermined criteria (Aminbakhsh et al., 2013; Chan et al., 2004; Guimarees & Ebecken, 1999; Huang, et al., 2001; Mahdevari et al., 2014; Markowski et al., 2009; Markowski et al., 2009; Paralikas & Lygeros, 2005; Saaty, 1990; Topacan et al., 2009; Vaidya & Kumar, 2006). The primary disadvantage of these methods is their inability to support management decisions and their judgments under real conditions. In organisations the influencing factors go beyond the straightforward framework of rational decision-making; including only alternatives and criteria makes it hard to establish an utility function reflecting middle managers' preferences or their probability assignments for all types of decisions (Abrahamsen & Aven, 2008). Descriptive (Naturalistic) decision-making methods which describe the process of decision-making (Benjamin & Budescu, 2015; Klein, 1984; Klein & Calderwood, 1989; Keller &

[11] This chapter is based on Rezvani Z, Hudson P. (submitted articles. 2017).

Cokely, 2010; Lejarraga, et al., 2016; Ross et al., 2004), are either studied under controlled conditions, like simulation, or they focus on individual decisions. However, there is a clear knowledge gap about the decisions of middle managers who are working in an organisation and are interconnected with other elements of that organisation.

In this chapter we show the steps in Figure 7.1 that were carried out to investigate the actual decision-making process in process industries in order to better understand the reality of middle managers' decisions in both normal and in abnormal situations when the conditions deviate from the usual conditions. We have also investigated the decision-making process under emergency conditions. To address this complex phenomenon under study, the following questions are examined:

- *Which managerial decisions are middle managers made or involved in?*
- *How are decisions made under various scenarios by middle managers?*
- *What factors influence managerial decisions?*

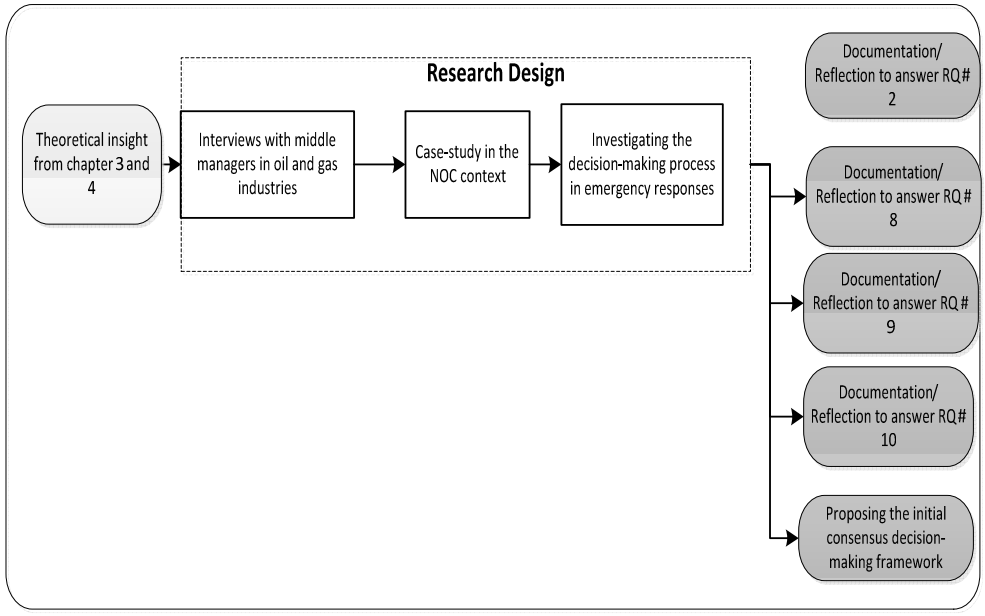

Figure 7.1. *The followed design steps to answer sub-questions# 2, 8, 9 and 10 in this chapter*

Details of the research design, results, and discussions are presented below.

7.2 Research design

7.2.1 Accident analysis: A comparison of the accident scenarios in the NOC company with accident scenarios in the World

Review of the literature led us to the conclusion that to examine the safety-related decision-making process by middle managers the first step taken should be to find the decision-making scenarios. There is no firm consensus for scenario definition and its application, because the range of topics covered is so wide and the concept does not provide much in the way of theoretical focus as a result of a variety of disciplinary backgrounds and various perspectives (retrospective versus predictive). However, for the purpose of this study we refer to Go & Carroll (2004) and First (2010) who give definitions of safety scenarios. A scenario is a generalized description of the actors, their goals, sequences of actions and events, and background information, in other words the dynamics of an accident (Go & Carroll (2004). First (2010) stated that an accident scenario forms unplanned event sequences that can result in the unwanted consequences. He argued that one or more conditions are also necessary for an accident scenario, besides the sequence of events.

Our purpose in this study is investigating three broad decision-making scenarios that middle managers have made or they have been involved in. First, decisions in regular and routine activities that middle managers take to stay within those stable conditions. Second, abnormal conditions when some parameters of the process deviate from the normal conditions and middle managers may be faced with some situations such as uncertainty, lack of resources, lack of time to allocate the activities or resources, or other influencing factors. Finally, in emergency conditions when something wrong happens which results in incidents, so middle managers, as well as other managers, try to overcome and control the conditions with reduced losses, while being faced with considerable pressure, both in time and other resources (Rezvani & Hudson, 2015).

To identify the decision-making process in abnormal and emergency conditions, one technique could be accident analysis, allowing us to uncover the actual common accident scenarios based on historical data about what happened in a specific environment, rather than very general and abstract considerations of what might be an appropriate scenario (Rezvani & Hudson, 2015). For this purpose, first a documentary analysis was carried out on published incident reports to identify accident scenarios in the NOC company. Accident scenarios were categorized into 16 broad scenario types (First, 2010). Then, we compared them with accident scenarios at the same sector in the World (Sam 2005).

As Figure 7.2 shows accident scenarios in the NOC company are quite similar to the accident scenarios in the wider world, not surprisingly as a result of using the same basic equipment

(pumps, tanks, vessels columns, etc.) and similar processes. Fire was the major accident in terms of consequence and loss of containment was the most frequent scenario type in this case. The frequency of incidents in Pipelines was the highest (Ghazinoory & Kheirkhah, 2008) as a result of a wide-spread network of pipelines that needs considerable efforts by operations, plant management and adequate financing (Rezvani & Hudson, 2015). Finally, the accident scenario analysis revealed repetitive patterns of accidents and root causes of events all over the world in this sector.

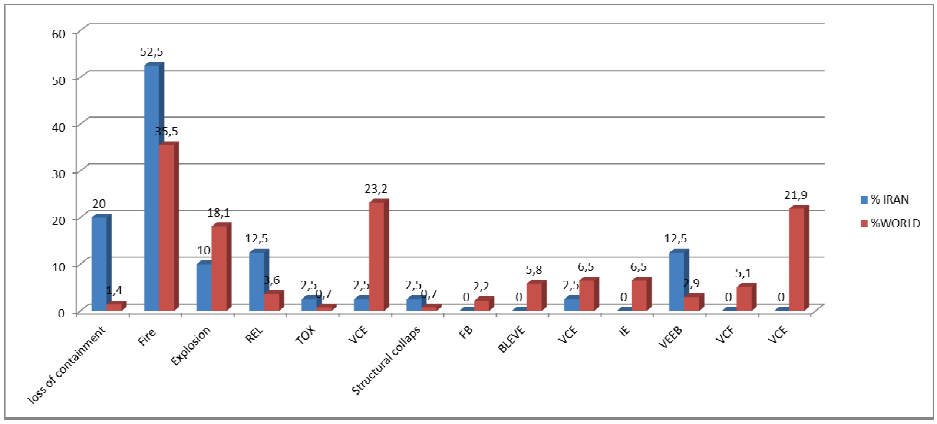

Figure 7.2. *Comparison of major accidents in Middle Eastern case (blue) with world accidents (red) in the oil and gas industry for different scenarios.*[12]

Accident scenario analysis revealed two other main results. First, we had originally expected that document analysis would provide sufficient information to enable us to systematically explore a combination of the heterogeneous factors simultaneously (Wack, 1985) that describes how accidents happened in this way; consequently, we could find decision scenarios. In practice however, the accident investigation reports focused primarily on the technical failure causes or blaming an individual who was directly involved in the accident, while failing to capture the overall structure of causal conditions and sequences that led to incidents or even catastrophes. Second, one contributing factor for repeating accidents is confidentiality about public reporting. Failure to learn occurs even though there is a ”depressing sameness” in the scenarios that might be reduced if more openness was exercised. It is more unfortunate that this failure continues to happen, even in developed industries which documented and published their earlier failures which has also been pointed out by Hopkins (2008). It is necessary to take into account the fact that accidents in one country,

[12] LOCA: Loss of containment; F: Fire; EX: Explosion; BLEVE: boiling liquid expanding vapor explosion; IE :internal explosion; TOX :toxic release; VCE: vapor cloud explosion ;VCF: vapor cloud fire; VEEB: vapor escape into, and explosion in, building; B:blowout

where the scenarios are very similar, can and should serve as lessons to prevent the same scenario being actualized in other countries. For more details, we refer the reader to Rezvani & Hudson (2015).

To sum up, the document analysis failed to provide the data related to decision-making and the influential factors in the making of decisions. It did not have any information about the involvement of middle management in these accidents. Therefore, the challenge for finding the appropriate technique to operationalize and investigate decision-making in real conditions remained unsolved in the first empirical study of this project.

7.2.2 Interview

In the next step of the study, it was decided to interview, which is a proper method for exploration of a complex phenomenon under study (Creswell, 2013). To explore how safety decisions are made in an organisation, instead of applying predictive scenarios which are pre-determined by the assumption of the researchers, we now referred middle managers to the last major incident that they had experienced, or they were involved in personally. Although, in this method, recall bias can occur, it still closer to actual conditions that middle managers make a decision rather than using an imaginary scenario. Detailed information about the interviews has been mentioned earlier in Chapter 5.

7.2.3 Audio task recording

In the next step of the study, we carried out a new and straightforward method, audio task recording that enabled us to gain insight into the complex process of decision-making in an organisation with many influencing factors. The methodology was explained in Chapter 5, and in the following sections, we present the results of both interviews and audio task recordings.

7.2.4 Mapping accident scenarios in different parts of the World

After preparing the interview questions for the first run of the interview, we were faced with sanctions, which severely limited the development of the study both in the Middle-East and in the western nations. Consequently, the study again concentrated on accident scenarios to map accident scenarios in various regions of the World, assuming that we can identify decision-making scenarios or information about middle management involvement in accidents in other cases. So, the span of the study was extended to collect data in various regions of the World, to identify the decision-making concept and middle management roles. We also assumed that by providing big data, the information could be shared and reused so that the data will be dynamic through liquidity. However, this step of the study failed to uncover any proper data related to decision-making and middle managers, so we ignored the presentation of the data analysis, and their documentation in this part. Essentially it turned out that while it may be

commonly agreed that middle managers and the decisions that they make are probably crucial in the management of safety in high-hazard industries, this sort of information is signally lacking; in short there is nothing to report despite the agreed importance of the information.

7.2.5 Analysis of accident investigation reports in oil and gas industries reported by CSB

After exploring and scrutinizing the decision-making process in normal and abnormal conditions in the process industry setting, the last stage of the empirical research was carried out. The purpose was to scrutinize the decision-making process in emergencies in order to identify the similarities and differences between decision-making in normal, abnormal, and emergency conditions. Therefore, we evaluated the completed accident investigation analysis reported by the US Chemical Safety Board (CSB). These accident investigation reports in oil and gas industries were assessed to find whether there is any data about decision-making process in emergency, if so, what are they?

In the final step of the study a qualitative case study approach was applied to analyse activities in emergency response cases so as to investigate the process of decision-making under emergency conditions. However, instead of focusing on the poor decisions that *caused* those incidents, that had been our concern in Chapter 2, we focused on probing information about the patterns of decision-making in emergency conditions within the context of oil and gas industries. The study started by analysing the major accident investigations reported by the CSB in oil and gas refineries between 2000 to 2016. This purposive sampling enhanced the transferability of the findings. It also allows us to investigate the phenomenon in depth and embed in the context (Miles & Huberman, 1994; Patton, 2002). The CSB documents are proper for this research since the information for incident investigation gathered from interviews, records, and security camera videos which enable the confirmation or corroboration of each other (Miles & Huberman, 1994); consequently, promote a great understanding of the case (Baxter & Jack, 2008).

To date, ten major accidents have been documented completely by the CSB in a period from 2000 to 2016 in oil and gas refineries in the USA. All of these reports were assessed to find data about the emergency response decisions. Among them, two cases had information about the abnormal conditions as well as the emergency responses that enabled us to depict the decision-making process and to test the research hypothesis.

The information was extracted by analysing the activities in these incidents, mostly from accident timelines that show how deviation/s in a system occurred. They also show actors' reactions to those disasters as well as the reaction of emergency response groups which

resulted in either a successful response, a failure to the disaster, or even resulted in intensifying the outcomes for the worse.

7.2.5.1 Context (cases description)

The first case is an incident that occurred in the McKee Refinery of Valero Energy in Sunray, Texas on Friday, February 16, 2007. Propane escaped from the extractor tower and formed a vapour cloud that travelled downwind towards the boiler house, where it most likely ignited. The flames flashed back to the leak source. Then, a steel support column that was not fireproofed, located on the east/west pipe rack, was impacted by a high-pressure propane jet fire giving rise to multiple pipe failures. The discharged liquid petroleum produced; subsequently, damaged pipes, contributing to the rapid spread of the fire and the damage to the surrounding equipment (CSB, 2007).

The incident caused a complete shutdown of the refinery for nearly two months. The rebuilding of the PDA unit took one year, then the refinery restored to full production capacity. Two Valero employees and one contractor were seriously burned in the initial flash fire. A member of the fire brigade received minor burn injuries, and ten Valero employees and contractors were treated for minor injuries and released (for more details on the accident see the CSB report 2007).

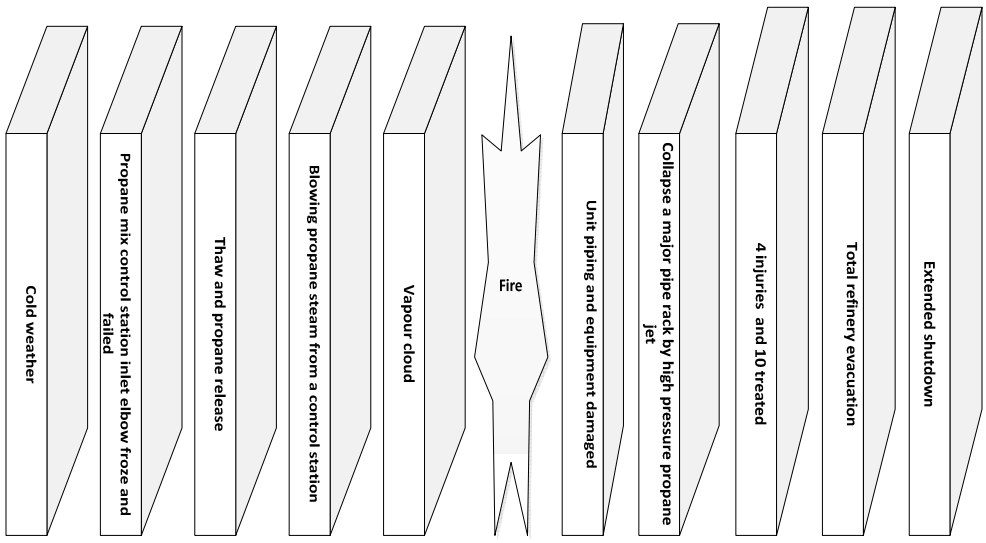

Figure 7.3. *The sequence of events in LPG fire at Valero-McKee refinery accident (2007)*

The second case is an incident that occurred in the Tosco Avon oil refinery in Contra Costa County, California, on February 10th, and 23rd 1999. A pinhole leak was discovered in the naphtha piping attached to the fractionator. The emergency response centre reacted to control the condition immediately and successfully. Then a decision was made to replace the naphtha piping because of the extensive corrosion of the naphtha piping (CSB, 2001).

Over the period of 13 days, several unsuccessful attempts were made to isolate and drain the naphtha piping to replace the line. Besides, leakages repeated three times that were controlled by retightening the isolation valves and finally the leak was controlled by opening the naphtha control valve through the pump to storage. Although attempts to isolate and drain the naphtha piping failed, the Tosco supervisors proceeded with the line replacement while the unit was still in operation (CSB, 2001).

In 23rd February, maintenance employees attempted to drain and to remove the piping, but they failed, then the maintenance supervisor ordered maintenance workers to cut the line in two spots. The line was drained by opening a flange in the second cut. However, suddenly, pressurised naphtha as a result of running the unit through a leaking isolation valve, was released from the open end of the piping. The naphtha ignited, most likely from contacting the nearby hot surfaces of the fractionator, and quickly engulfed the tower structure and personnel. Four workers died and a worker who jumped away from the flames at an elevated location was injured seriously (CSB, 2001).

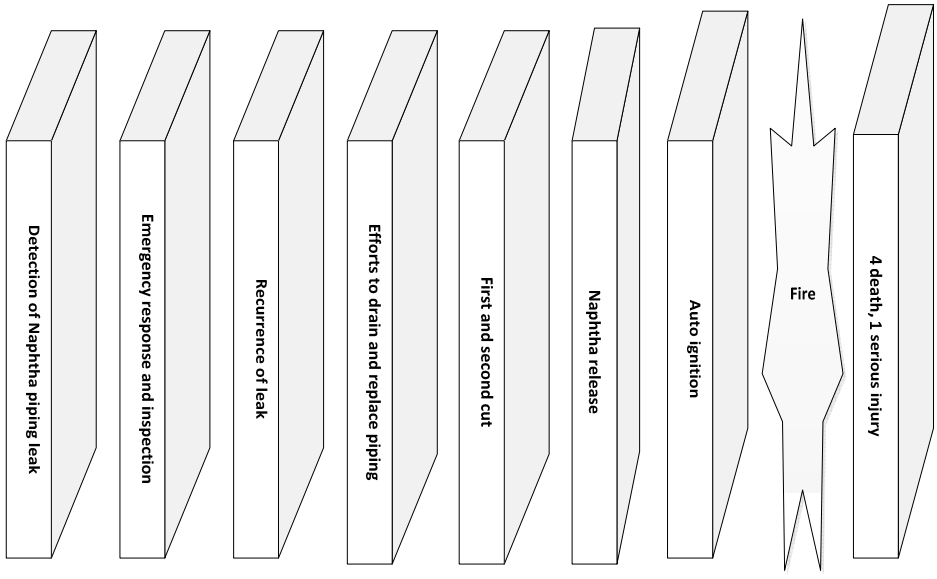

Figure 7.4. *The sequence of events in the Tosco Avon Refinery fire incident (1999)*

7.2.5.2 Data analysis

The analysis of data started with time series analysis of incidents. The steps of decision-process and influencing factors were clarified in this way. The whole process of decision-making was depicted for each case in Microsoft Visio 2010 to visualise the decision-making process. Then further evaluation of the results of the pattern-matching and linking data to prepositions were carried out (Baxter & Jack, 2008).

7.3 Results

In this section, we present the decision-making process in various situations arising out of the interviews, audio task recording, and document analysis.

7.3.1 Decision-making processes in normal and abnormal operations

Audio task recording, which has been explained in detail in Chapter 5, revealed that decision-making was allocated the high frequency among the various actions of middle managers. The results showed that the frequency of decisions made by middle managers (114) were more than senior management's decisions (3). It might have resulted from differences in the type of decisions because senior management make more strategic and long-term decisions, while middle managers make more tactical and short-term decisions. Besides, although task recording enables researchers to find the link between different actors, the extent of clarity that this method can explore is different. In other words, the central actors can be depicted with high resolution, while the resolution decreases depending on the distance from the focused actor (the senior middle manager in this case). Nevertheless, the high frequency of decisions highlights the crucial role of middle managers in decision-making.

Middle managers made decisions under many scenarios such as economic, technical, legal, safety, environment, and security. Figures 7.3 to Figure 7.10 and Tables 7.1 to 7.8 present different decision scenarios that middle managers made or were involved with in the NOC company during this period. It is essential to take into account the fact that the figures contain different types of nodes: the ecliptics represent decision problems, the rectangular boxes represent criteria, the diamonds represent alternatives and the rounded rectangles show objectives. Decisions were not made only once at a time. Instead, decisions were made progressively in several meetings and information was presented to each meeting which sometimes caused the changes in the final decision that was taken. As the figures show, decisions themselves consist of different decisions with a variety of degrees of complexity and uncertainty; furthermore, the results show that safety decisions have a high level of complexity and uncertainty.

Table 7.1. The decision about how the organisation can improve safety management in relation with contractors

What is the decision problem?	Contractors did not take into account safety issues in their jobs
Which alternatives were considered?	Allocate 5% of the budget to the HSE in contracts or nothing
Which criteria were considered?	Improve safety objectives
Which alternative was selected?	Allocate 5%of the budget to the HSE in contracts
Who took the decision?	A group of decision makers including middle managers from production and technical affairs, 3 senior managers from the NOC company as well as two middle managers and one senior manager from a maintenance contractor company
Why was this alternative selected?	Contractors did not take into account safety issues in their jobs
Why were alternatives rejected?	Other managers did not suggest any other alternatives
Conclusion	In this case, the decision goes to selecting the first option. (RPD Model) There are not so many options that compete with each other This decision brings about three other alternatives for decision about how they can invest this money. The outcome of the decision was performing several options in parallel at the same time instead of a sequential alternative. These alternatives are shown in Figure 7.5 Suboptimal choice (consensus cost) for the NOC since the NOC should pay this money

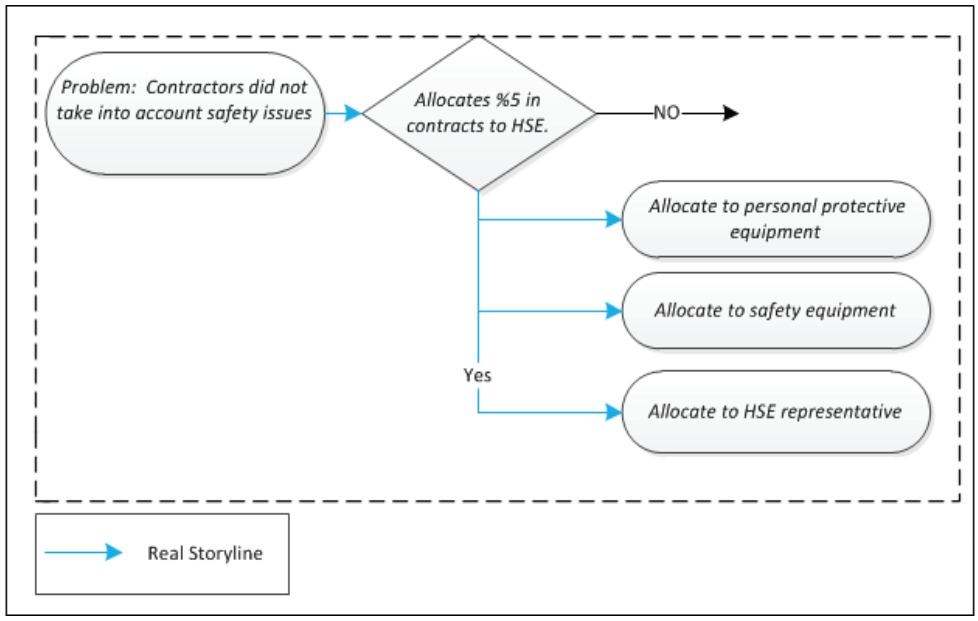

Figure 7.5. *The decision for investment in HSE*

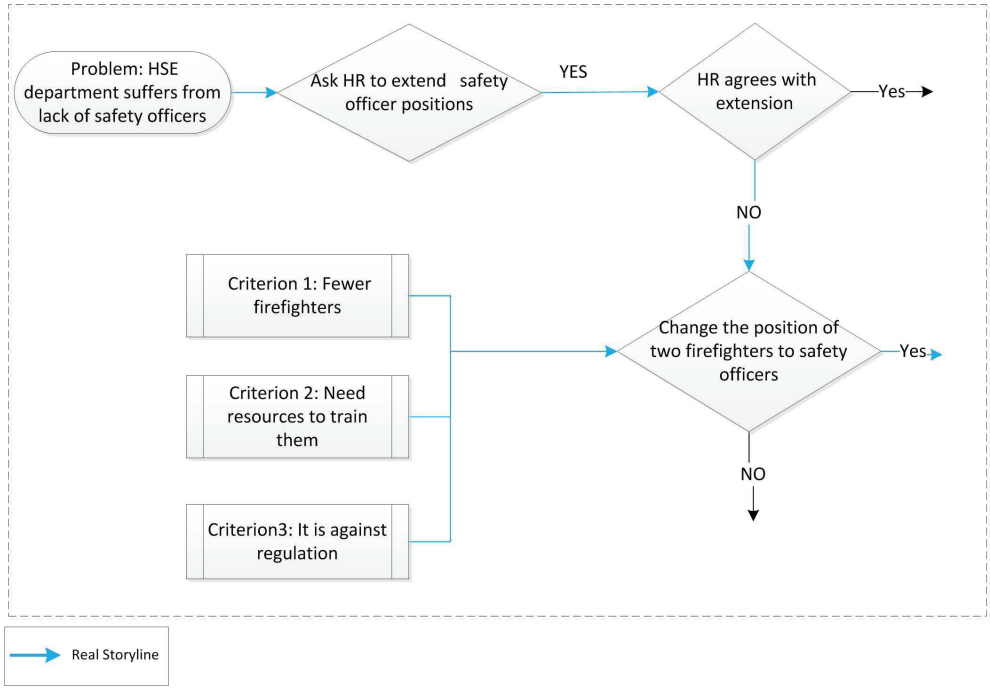

Figure 7.6. The *decision about the lack of safety officers in the HSE department*

Table 7.2. Decision about solving the lack of human resources in the HSE department

What is the decision problem?	Lack of human resources (safety officers) in the HSE department
Which alternatives were considered?	Ask HR to extend the positions for HSE department or Change the position of two fire-fighters to safety officers
Which criteria were considered?	HR did not accept to extend the position Fewer fire-fighters It is against the regulations Require resources to train them
Which alternative was selected?	Change the position of two fire-fighters to safety officers which resulted in the assigned activities
Who took the decision?	Manager of the HSE department (a middle manager)
Why was this alternative selected (criteria)	HR did not wish to extend the position
Why were other alternatives rejected (criteria)?	HR did not wish to extend the position
Conclusion	Although the HSE manager argued about the disadvantages of one option against another option; he took this option after he was faced with an obstacle. Suboptimal decision (consensus cost). He accepted a lower level of safety instead of noting for safety management Decision was made sequentially. First (best) option did not work; then he tried another option (RPD Model)

Table 7.3. The decision about the promotion of four volunteers for the same position at the same time in NGL plants

What is the decision problem?	There are four volunteers for the same position at the same time
Which alternatives were considered?	Volunteers 1 to 4
Which criteria were considered?	Lack of positions for four employees
	Type of position
	Competency
	Retirement time
Which alternative was selected?	Volunteer 1 and Volunteer 4
Who took the decision?	Higher middle manager
Why was this alternative selected (criteria)	They had competency
	One will be retired
Why were other alternatives rejected (criteria)?	There was not any position
	They have less competency than two others
	They will be retired later
Conclusion	This example clarifies how new information can change the final decision (prevention of confirmation bias)
	New information provided by lower manager improved the final decision
	Sequential decision
	Limited number of criteria and alternatives
	Less consensus cost as a result of new information (two promotion and two flooding positions)

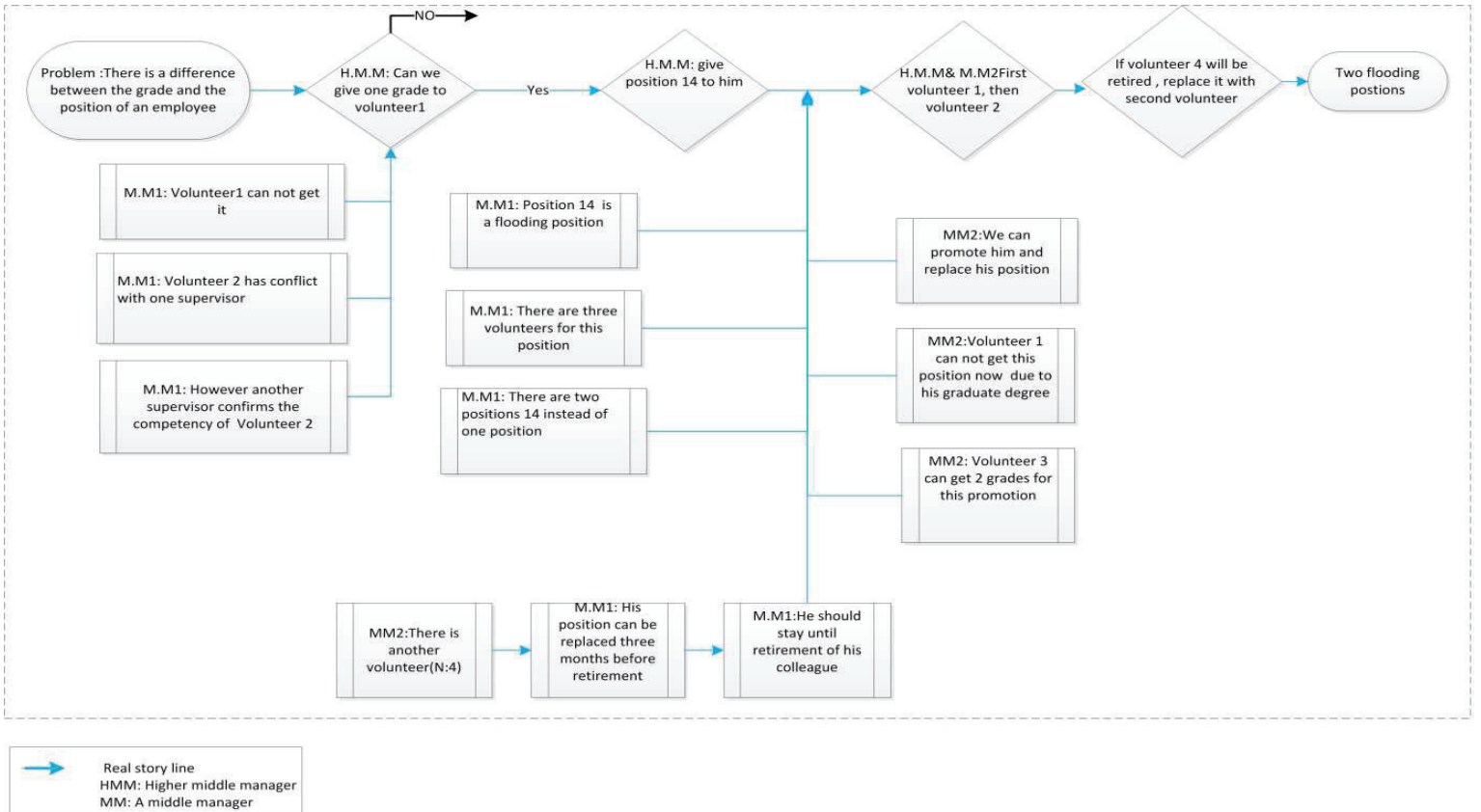

Figure 7.7. *The decision for promotion of 4 volunteers at the same time*

Table 7.4. The decision about confirmation of finalizing the contractor's jobs

What is the decision problem?	The NOC did not approve the finalizing of the contractor's jobs
Which alternatives were considered?	Approve or Not approve
Which criteria were considered?	Performing the housekeeping
Which alternative was selected?	Not approval
Who took the decision?	Operational manager (senior manager)
Why was this alternative selected	The contractors did not do housekeeping.
Why were other alternatives rejected?	The contractors did not do housekeeping.
Conclusion	Again limited numbers of alternatives and criteria Gaining for the NOC company and loss for C.C Consensus cost)

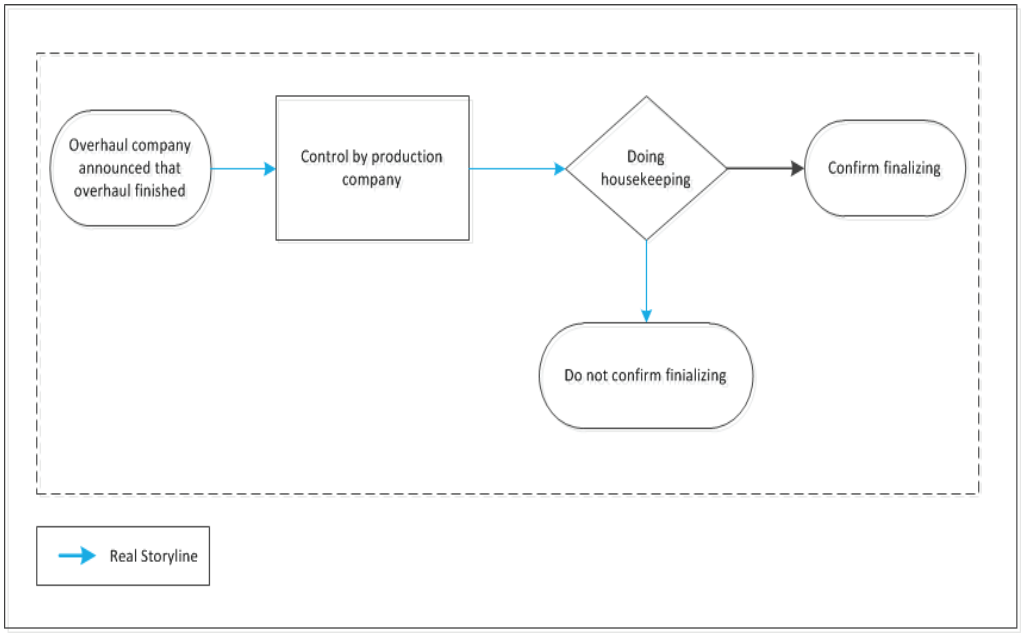

Figure 7.8. *The decision for approving the finalizing the contractor's jobs*

Table 7.5. The decision about confirming the scaffolding.

What is the decision problem?	Confirm use of scaffolding
Which alternatives were considered?	Yes/No
Which criteria were considered?	Safety
Which alternative was selected?	No
Who took the decision?	HSE manager(middle manager)
Why was this alternative selected?(criteria)	The contractor company did not perform scaffolding safely
Conclusion	Again two options

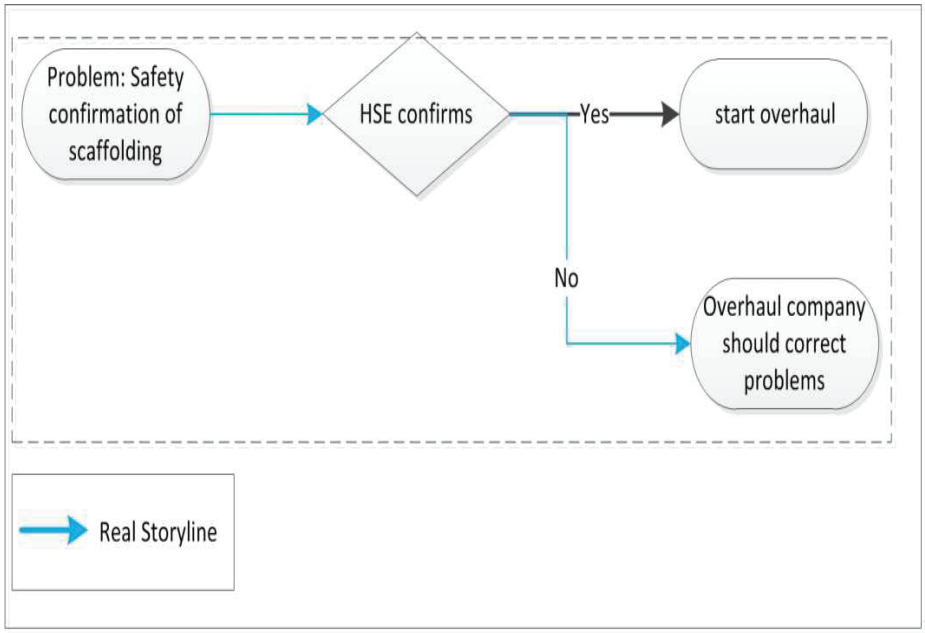

Figure 7.9. *The decision for approving the scaffolding*.

Table 7.6. The decision about who is responsible for issuing and confirmation of safety permit.

What is the decision problem?	Who is responsible for getting a safety permit
Which alternatives were considered?	Contractors are responsible for issuing safety permits
	Production company is responsible for confirmation of safety permits
Which criteria were considered?	High workload
	Lack of safety knowledge
	Conflict in division of labour
Which alternative was selected?	Issue and confirm the permit without controlling the situations
Who took the decision?	Supervisors in both companies
Why was this alternative selected (criteria)?	Contractor company does not have enough safety officers
	Production company does not have enough personnel to control and then confirm a permit
	There are misperception regarding assigning activities
	High number of permits per units at the same time
	Supervisors does not have enough safety knowledge to differentiate between safe and unsafe conditions
Why were other alternatives rejected (criteria)?	Same with the previous column
Conclusion	Again two options with several criteria (not more than 5)
	Priority of production objectives against safety objectives
	Saving time (efficiency)
	Consensus cost (lower level of safety)
	Although lower level managers made these decisions, the underlying causes are related to higher level management

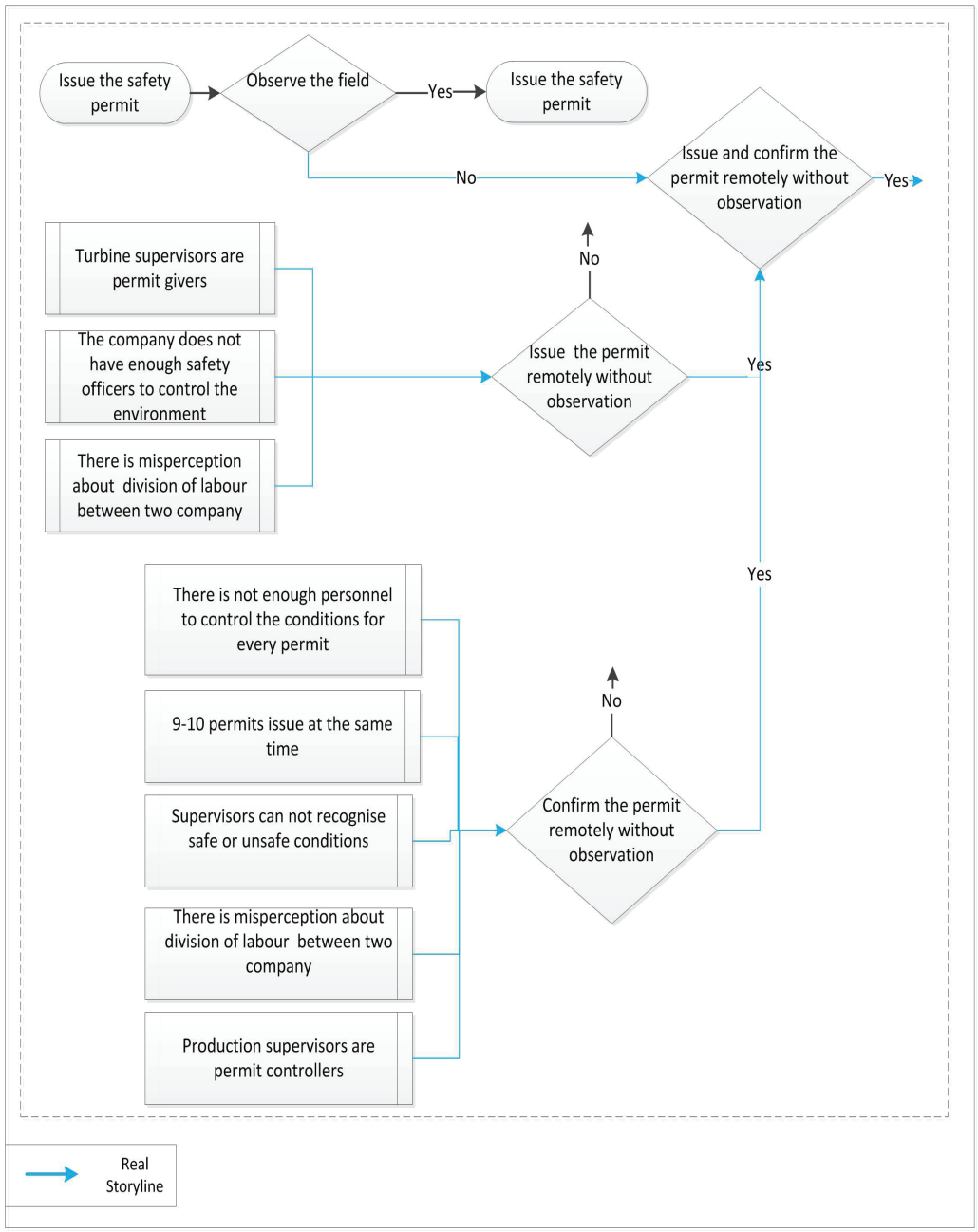

Figure 7.10. *How conflict between the production company and the maintenance in issuing a permit* caused a dangerous decision

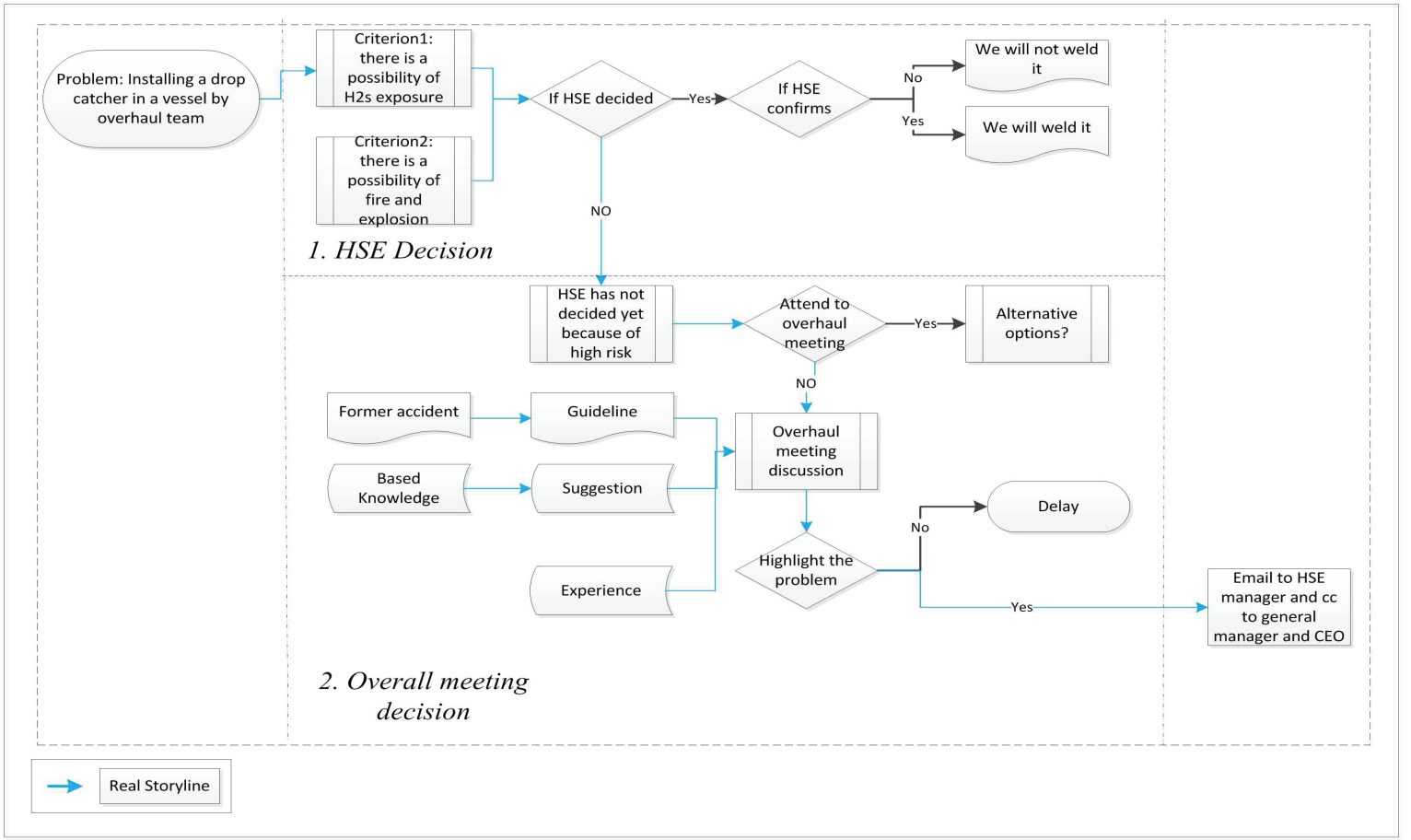

Figure 7.11. *A decision for installing a drop catcher in a vessel by the overhaul company*

Table 7.7. A decision about a safety permit for welding.in a vessel.

What is the decision problem?	Decision about a safety permit for welding.in a vessel
Which alternatives were considered?	Yes/No
Which criteria were considered?	Possibility of existing H_2S in the vessel
	High risk of fire and toxicity
	HSE department did not take the responsibility
	Uncertainty
Which alternative was selected?	HSE manager should decide
Who took the decision?	Operational manager
Why was this alternative selected (criteria)?	There is a possibility of H2s in the vessel (hazardous conditions, both fire, and exposure)
	High uncertainty
	HSE department did not decide
Why were other alternatives rejected (criteria)?	Three options (a limited number of options)
	When a decision consists of high adverse outcomes with high uncertainty, managers do not take responsibility.
Conclusion	Decision about a safety permit for welding.in a vessel

Table 7.8. A decision about how the NOC can improve the safety management regarding contractors that have fewer workers than 25.

What is the decision problem?	Do contractors with employee less than 25 should have an HSE representative?
Which alternatives were considered?	Yes/No
Which criteria were considered?	Improving safety
Which alternative was selected?	Conditional. If the number of workers is more than three persons then yes
Who took the decision?	A group of middle managers and senior managers
Why was this alternative selected (criteria)?	To improve the safety management Contractors are the main weakness point which have influenced the safety management
Conclusion	Limited number of alternatives

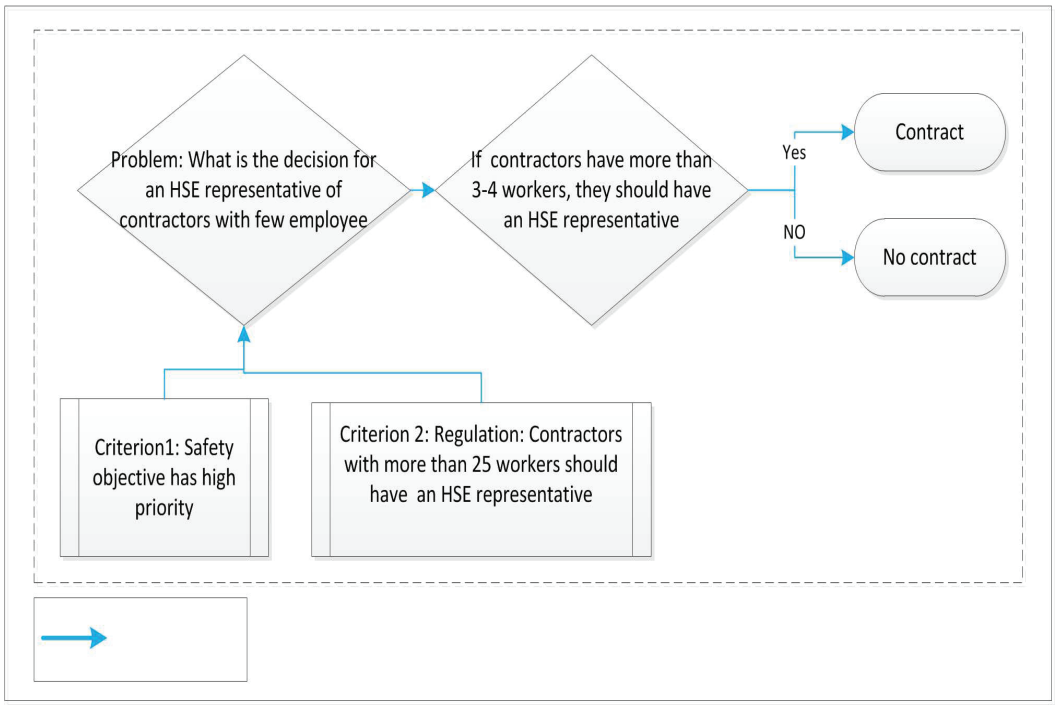

Figure 7.12. *The decision for a contract with contractors who have fewer workers than 25, while according to regulation they do not need to have an HSE representative.*

Table 7.9. A decision about eating lunch at a factory.

What is the decision problem?	Central organisation decided two different options for two diverse groups of employees
Which alternatives were considered?	Eating in a factory Paying the money
Which criteria were considered?	Working in factory or not
Which alternative was selected?	Conditional option
Who took the decision?	Central organisation
Why was this alternative selected? (criteria)	May be health related issue
Conclusion	Evidence of if rule decision Limited numbers of alternatives and options

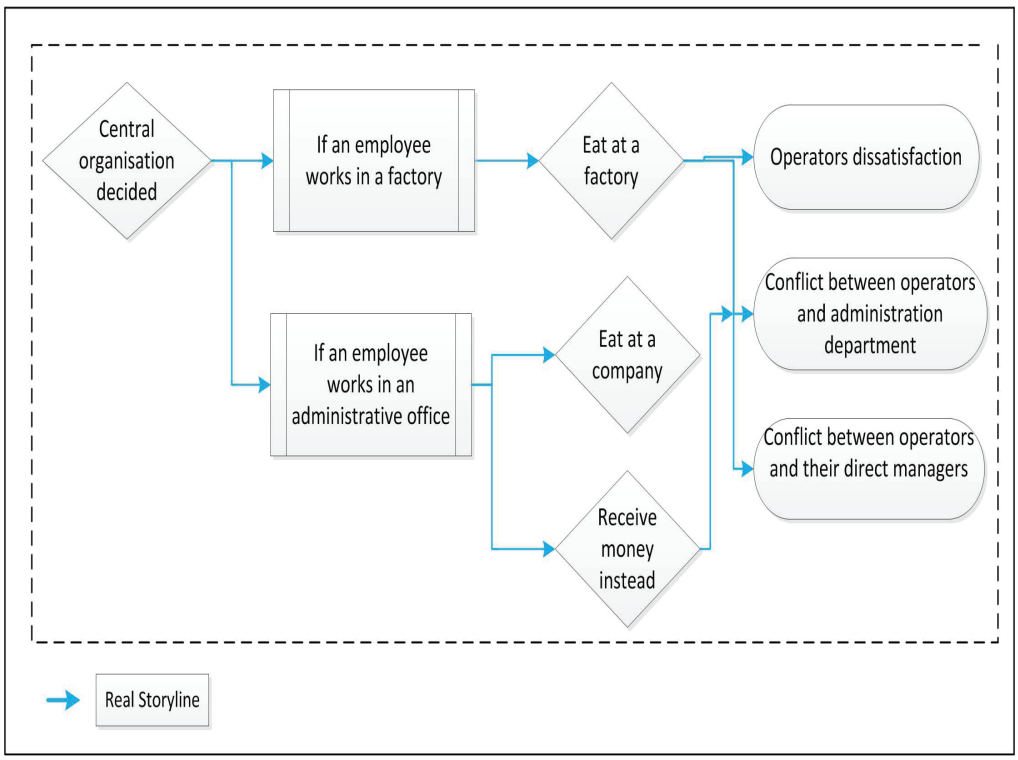

Figure 7.13. *A decision about eating lunch at a factory*

7.3.2 Decision-making process in emergency response

Among ten major accidents that have been documented completely by the CSB in the period between 2000 to 2016 in oil and gas refineries, two cases had information about the emergency response and the actions taken that enabled us to depict the decision-making process in these conditions. Figures 7.14, 7.15 and Tables 7.10 and 7.11 depict the process of decision-making in these two cases.

Table7.10. Decisions in McKee Refinery of Valero Energy incident (2007).

What is the decision problem?	Ignition of propane vapour cloud; consequently, multiple fireballs/ruptures
Which alternatives were considered?	Activation of fire alarms Emergency response reactions including shutdown, isolation, fire extinguishing, and joint entry
Which alternative was selected?	Shutdown Isolation Fire extinguishing Joint fire-distinguish
Who took the decision?	Emergency response team and maybe the supervisor
Why was this alternative selected? (criteria)	To control and decrease the outcomes of the incident
Why were other alternatives rejected (criteria)?	Entry joint was rejected because fire distinguish could take less time with this option, however, it may endanger more people from emergency response group (limit the outcome of incident)
Conclusion	This case shows that decision-makers chose several options at the same time to limit the consequences of the incident. More precisely, decisions consist both parallel and sequential decisions. Shutdown, isolation, and fire distinguish were parallel decisions; while joint entry was made later because there were several fireballs and ruptures.

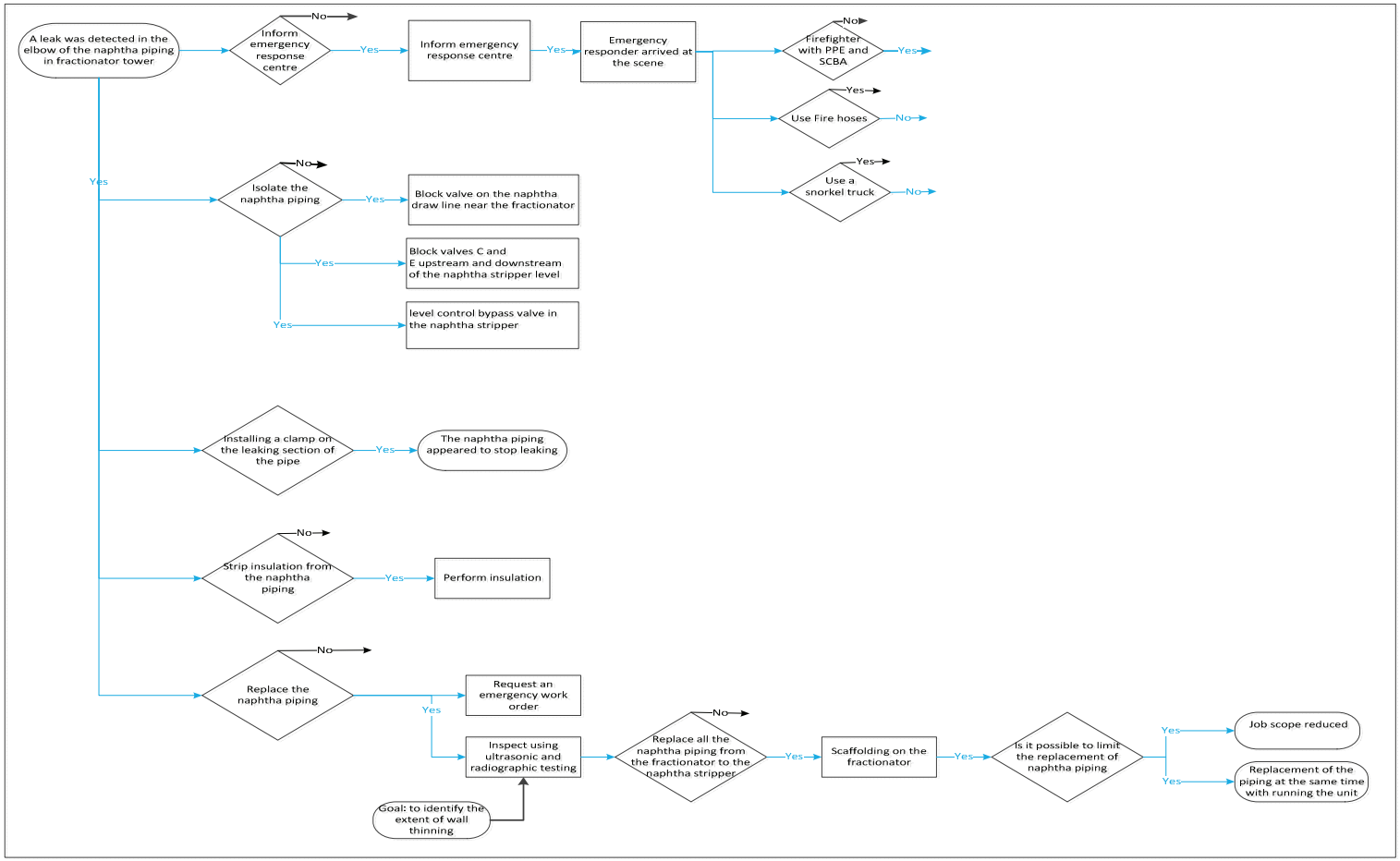

Figure 7.14. *Decision analysis based on the incident timeline in Tosco Avon oil refinery, on 10th February 1999*

Table7.11. Decisions in emergency response in Tosco Avon Oil Refinery, on 10th February 1999.

What is the decision problem?	A leakage in the elbow of the naphtha piping in fractionator tower
Which alternatives were considered?	Inform emergency response centre Isolate the naphtha piping Installing a clamp on the leaking section of the pipe Strip insulation from the naphtha piping Replace the naphtha piping
Which alternative was selected?	All of them
Who took the decision?	Emergency response centre
Why was this alternative selected (criteria)?	To decrease the outcome of incident
Why were other alternatives rejected (criteria)?	-
Conclusion	This case shows various kinds of decisions. First several options for decision-making that were chosen in parallel for decreasing the outcome. Another example is fire-fighting reactions that they selected the first option, which is applying Personal protective equipment with Self-contained breathing apparatus because it was only the leakage without big fire. This case clarifies that decision can be either selection of the first option or choosing several options at the same time. This case also revealed that how safety objectives were traded off against the production objective when the supervisor of the refinery asked technical inspection for more assessment for limiting the scope of replacement for running the refinery at the same time with replacement which caused catastrophic outcome on 23rd February 1999

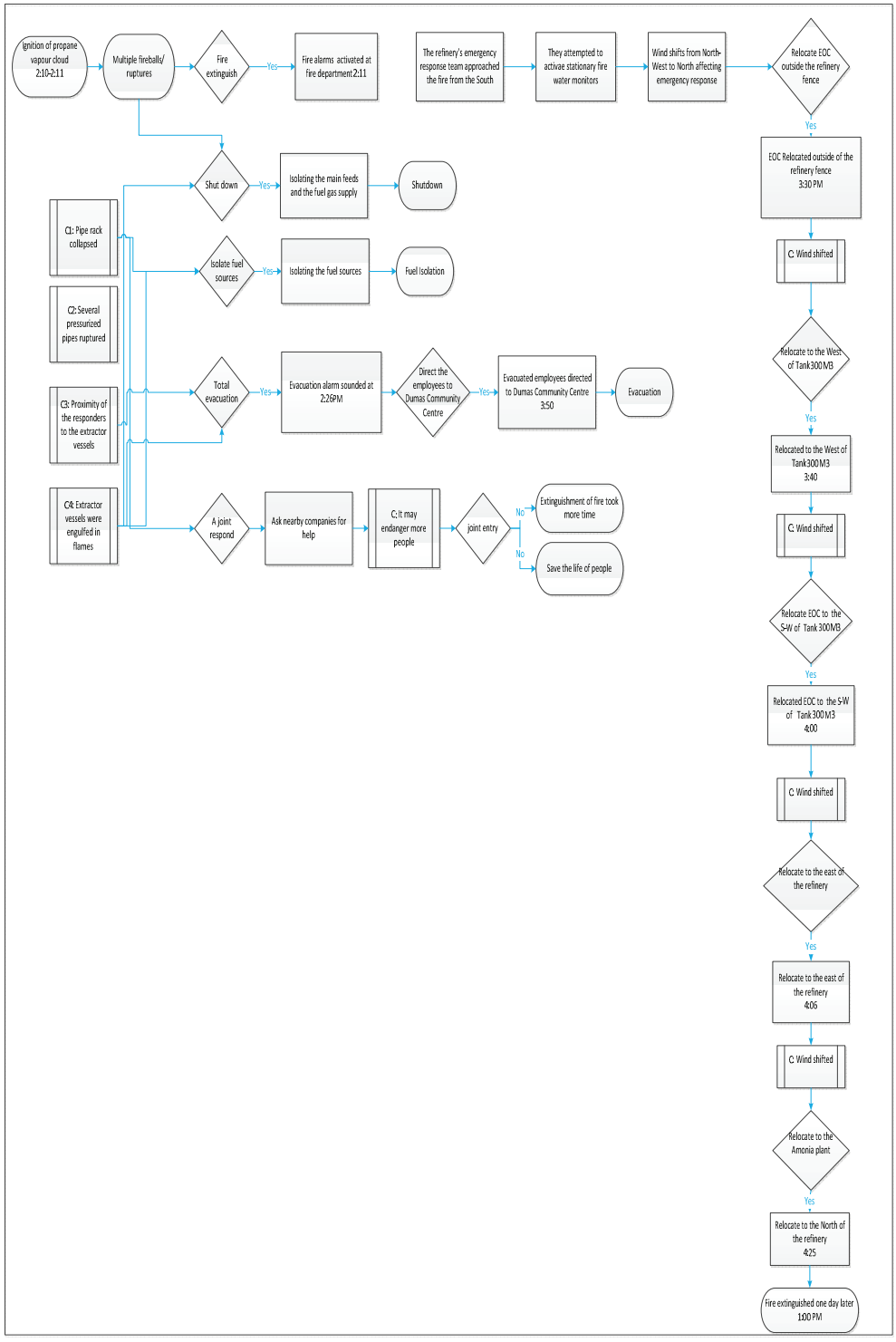

Figure 7.15. *Decision analysis in the McKee Refinery of Valero Energy incident*

7.4 Discussion

7.4.1 Some patterns in middle management decisions

Both the interviews and the audio task recording confirmed that managers decided under many different scenarios or they were involved in various decisions in organisations that indicates both the variety of decisions as well as the complexity of decisions that middle managers are involved in. Compared to senior managers and lower managers, middle managers are involved in not only strategic but also in tactical and operational decisions for which they employ a diverse array of strategies to fix problems rather than applying more rigid and fixed procedures in order to get better results. Middle managers are flexible and adjust the techniques they use according to the context and they integrate several sources of information as much as possible because they are in the best position to perform information-based roles resulting in better decision-making roles. Furthermore, middle managers decided either to prevent the occurrence of losses, such as inventory, quality, safety, security, and environmental losses, or to provide corrective actions to restore an operation before losses go beyond their control (Littauer et al., 1976). In other words, they perform continuous corrective adjustments by making different decisions to handle a variety of disturbances in process industries.

The analysis indicated that middle managers did not apply the common scientific rational decision-making techniques such as AHP and Fuzzy decision-making. They were not even familiar with those decision-making techniques that can be used to support and to improve decisions; they had not been trained in them neither did they use those types of techniques intuitively. There was not any difference between the western cases that have more cooperation with scientific centres that might have influenced them in the ways they went about making decisions by having greater opportunities to access the developments in the decision-making domain, as opposed to the middle managers in developing countries. Therefore, there is an apparent knowledge gap between scientific improvements in decision-making and application of these methods in practice across the industry in general.

Table 7.12 provides a summary of our findings from analyses of decisions that will be discussed in more detail below. The middle managers considered fewer than three options in their decisions rather than considering a greater number of alternatives, while they included multiple criteria in their decisions they still limited numbers, which were fewer than three criteria in 80% of decisions. In other words, in practice, middle managers considered limited numbers of options and criteria, possibly to prevent considerable computational efforts (Xu, 2012; Hammond et al. 1998; Simon,1972). These results provide strong evidence supporting the notion of bounded rationality that is based on the use of simple search rules, simple

Table 7.12. A summary of findings from the decision-making analysis

Decision	Criteria ≤ 3	Alternatives ≤ 3	Involve consensus cost	Evidence of RPD	Sequential	Parallel	If rule	Safety related
Improvement of safety management regarding contractors	Yes	Yes	Yes (money)	No	Yes	No	No	Yes
Contract with contractors who have fewer workers than 25	Yes	Yes	No	No	Yes	No	Yes	Yes
Installing a drop catcher in a vessel	Yes	Yes	Yes (time and production)	No	Yes	No	Yes	Yes
Responsibility for issuing and confirmation of safety permit	No	Yes	Yes (Safety)	No	Yes	No	No	Yes
Approving the scaffolding	Yes	Yes	Yes	No	Yes	No	Yes	Yes
Finalizing the contractor's jobs	Yes	Yes	Yes	No	Yes	No	Yes	Yes
Promotion of 4 volunteers at the same time	No	Yes	Yes	No	Yes	Yes	Yes	No
Lack of human resources in HSE department	Yes	Yes	Yes (Safety, quality)	Yes	Yes	No	No	Yes
Eating lunch at a factory	Yes	Yes	Yes	No	Yes	No	Yes	No
Failure of an important valve	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Total	8	10	9	2	10	2	6	8
Percentage	80	100	90	20	100	20	60	80

stopping rules, and simple decision rules. By applying heuristics for the elimination of sequential search to narrow down possible categories, middle managers overcome the

constraints of mental or internal factors. These factors include limited (internal) memory and information processing power as well as environmental (external) factors such as time, money and energy (Gigerenzer & Selten, 2002; Hutchinson & Gigerenzer, 2005).

This limited number of options and criteria also confirms the expertise-based intuition about middle managers when they make decisions without expending considerable efforts to search for various options and criteria; they rather make decisions based on their extensive experience. The main difference between middle managers and other subject-matter experts is the extent of their experiences across a *variety* of disciplines that are unique and overlapping. They have enough experience in at least one technical domain and management scope, but their experience will usually extend beyond the single discipline. In addition, middle managers are usually faced with operational problems that have repetitive patterns, that are subject to influence by internal causes and that have predictable outcomes (Littauer et al., 1976). Furthermore, decisions are taken based on feedback that requires less sophistication and less knowledge of the environment which is a proper method for in abnormal conditions when the environment is changing within a short time (Selten, Pittnauer, & Hohnisch, 2012). Consequently, equipped with knowledge, experience, and feedback, middle managers are competent enough to distinguish patterns and use them in their decisions which ultimately cause quasi-automated decision processes (Salas, Rosen, & DiazGranados, 2009) resulting in more efficient and qualified decisions.

Middle managers strive to work with an accurate representation of the conditions. Nevertheless, instead of acquiring large samples of options and criteria, as would be common in financial decisions, they work with smaller samples, and their searches are less extensive. The results of both the interviews and the audio task recording illustrate that in safety decisions, middle managers are primarily interested in the *magnitude* of outcomes or consequences (87.5% of interviews) rather than the *probability* of those outcomes. This result is similar to what has been found in the medical decision-making area (Lejarraga, Pachur, Frey, & Hertwig, 2016; Pachur & Galesic, 2013; Waters, Weinstein, Colditz, & Emmons, 2007). The middle managers appear to be inclined to minimize or to avoid the worst possible loss when there are not a significant amount of data that represents conditions and when decisions are for rare events, high uncertainty, and less knowledge about the environment. Therefore, similar to the medical domain, in safety-related decisions, middle managers rely on small samples, and they have a tendency to avoid the worst case (Lejarraga, Pachur, Frey, & Hertwig, 2016; Pachur & Galesic, 2013; Waters, Weinstein, Colditz, & Emmons, 2007).

Despite the pattern of behaviour that was discovered by Hayes (2012), middle managers balance safety against other objectives as a result of weighting to other goals such as production, deadline or environmental targets more than just the safety target. Both interview

analysis and assessment of the audio task recording revealed that a trade-off between safety and other objectives happened. Task recording revealed that production and environmental preservation were given greater priority than safety objectives as a result of highlighting the environmental issues within the organisation. In meetings the senior managers asked about the amount of flaring immediately after discussing the production report which indicates the relative levels of priority to be given to the objectives; this can be taken as meaning that production still has the priority, but environmental goals clearly come next in importance; safety came lower down the list. For example, a middle manager decided to recycle the glycol with the tighter safety margin in order to prevent flaring in an abnormal condition when the annual maintenance was performed in an NGL factory at the same time as another plant. The outcome of this decision was normal production, less flaring and a lower level of safety.

In contrast, this next example clearly demonstrates how middle managers make a balance between safety and production properly by monitoring the system continuously in the control room and adding another safety barrier (an operation in the site) simultaneously to control the condition. The middle manager brought personal experience into his decision as he argued with a higher manager that he had performed the same actions several times before. This example also shows that how middle managers apply their own rules to overcome the uncertainties based on their experiences (Hopkins, 2011).

Additionally, in the NOC context, middle managers took not only risk-based decisions but also rule-based decisions; however, managers did not weight options based on a mathematical framework. Instead, they have their judgments, and the method of weighting was influenced by the organisational context such as the culture of the organisation, regulation, and stakeholders, which affect the process of priority setting of objectives.

Rule-based decisions were more frequent (60%) than risk-based decisions in the NOC company. Rule-based decision-making as implemented by the middle-managers contains a set of if–then rules including simple if–then rules or logic connectives of and/or, else with the if–then rules. As asserted by (Rezaei & Dowlatshahi, 2010), it assisted middle managers to show interdependencies and non-linear relationships which exist between different criteria as well as the uncertainty of outcomes. In line with arguments of Hopkins (2011), the higher frequency of rule-based decisions in safety demonstrates its appropriateness in the safety domain since it is a deterministic approach that decision makers do not leave without having clear criteria to make decisions. In this way, middle managers overcome one limitation of conventional risk assessment methods in which decisions cannot be taken without carrying out a comprehensive numerical risk assessment (Hopkins, 2011) that requires much effort or is mostly impossible. For example, in current risk assessments, decision makers are not able to decide with high accuracy about the acceptability of the current risks as a result of the

ambiguity associated with a wide range of possible outcomes or the uncertainties associated with estimates of the probabilities associated with outcomes in the risk computations.

Middle managers applied and shared rules with others for both representing and reasoning about situations. These rules may have been established by regulation, by company procedures or by personal experience (self-organising rules). This rule-based method forms a simple and practical tool to deal with the uncertainties caused by incomplete, vague, or imprecise information in these multi-criteria decisions. It is also a valuable method for an accurate and reliable judgment. However, evidence shows that decision-makers did not determine a referential set for each antecedent attribute and their consequences; In other words, those "if–then" rules were incomplete and composed of a selective collection of if–then rules, while other rules were ignored. The managers might use a particular collection of if–then rules to show the relative importance of each antecedent attribute as well as setting the relative importance of a rule (Yang et al., 2006) that may result from the experiences of managers.

Another important emerging issue in this study is the *type* of decision-making. We found in some cases (20%) that decisions are not only sequential decisions but rather decisions are made in both parallel and serial modes. It means that decision-makers choose the final decision by either eliminating other alternatives until only one alternative remains, or the final decision is made by applying two or multiple options at the same time. In the NOC context, middle managers then took actions to implement options until they were certainly sure that one option was working better or faster than any of the other alternatives; otherwise, they continued to pursue several options in parallel, simultaneously. It is a useful strategy both to overcome the uncertainty and to limit the decision costs. This kind of decision is proper in abnormal and emergency conditions when the probabilities of alternative outcomes are roughly equally attractive and the alternatives are middle-truth-value. This result confirms by the study of McKinstry et al. (2008) who identified a parallel competition when a decision maker pulls from multiple options at the same time. However, to our knowledge, we could not find evidence that other scholars take into account this type of decision-making, one that is a proper solution to overcome the uncertainty and to decrease the likelihood of making suboptimal decisions.

7.4.2 Consensus decision making is predominant in the NOC

Audio task recording revealed a striking result that middle managers are mainly involved in consensus decisions, in taking combined decisions, and then making individual decisions respectively. In consensus decision-making "members of the group reach an agreement to choose a mutually exclusive option between two or more several options," while in combined

decision-making "members of the group make the decision individually, but dependent on the behaviour of other members of the group" (Conradt & Roper, 2005).

Consensus decision-making has two fundamental components. First, a complex cooperation of information pooling is substantial. We found in Chapter 6 that the most common roles of middle managers are informational roles, in line with the results of other researchers (i.e. Brubakk & Wilkinson, 1996; Wooldridge et al. 2008; Floyd, et al. 2011; Rezvani& Hudson 2016). Accessibility to information in short time intervals and more informational sources (Brubakk & Wilkinson, 1996) enhance the cooperation of information pooling and improve the efficiency of decisions (Rezvani & Hudson, 2016). Second, a consensus cost is inevitable for all involved individuals. Consensus cost is a cost like a suboptimal decision or timing activity that makes compromises with other group members (Conradt & Roper, 2005). Table 7.12 shows that 90% of these decisions include some consensus cost, the only exception is the decision about a contract with contractors who have fewer workers than twenty-five. We did not consider it as consensus decision since contractors were not involved in this decision, while it still creates costs for contractors for allocating human resources.

Hopkins (2012) argued that consensus decision-making is not proper for making important technical or safety decisions because of cases in which everybody is comfortable but nobody really assumed the responsibility. Sumpter, Krause, James, Couzin, & Ward (2008) contended that it occasionally may lead to cascades of incorrect decisions, resulting in suboptimal decisions; however, consensus decision in organisations may still be necessary for four reasons. First, it prevents creating a split in the group. Second, it increases the efficiency, where a decision involves significant conflict of interest and unbalanced information is communicated between individuals. For instance, as a result of the different spatial positions of individuals in an organisation, which is often inevitable when they are at distinct sites, the functioning of the group is dictated by the majority of the group; so, a group achieves agreement in early stages of their decision-making process which improves the efficiency of the decision-making process (Dyer et al., 2008). Third, the members of the group do not require to directly compare the available alternatives, they integrate complex information effectively and intuitively (Sumpter et al., 2008) or by pattern recognition (Rezvani & Hudson, 2017, *in press*). Finally consensus decision-making may be more accurate because individuals can make use of the diverse information from various sources of information (Sumpter et al., 2008); consequently, the probability that a group settles on the wrong option decreases (Conradt & Roper, 2005; Dyer et al., 2008; Sumpter et al., 2008). In the context of the NOC, a small proportion of informed middle managers were enough to guide others. They stayed in an argument position at the front of the group for a longer time when the group polarised, to approach others to their targets; they spent more time in a defensive position in the zone containing their targets when others were leaning in the same direction. This

approach prevents wasting time by giving the direction instead of leaving the members circling around the decision space.

Figure 7.16 proposes a systematic framework for consensus decision-making in a process industry based on our results. The consensus decision-making framework was developed based on theoretical concepts and the results of this research to specify the primary factors that must be reflected in the model to describe the structure and operation (process) of decision-making. To our knowledge, three main elements of decision-making, which are alternatives, criteria, and decision-makers, have been considered in proposed models of decision-making while they failed to consider the context in which decisions are made (e.g. AHP, Fuzzy, best-worst). In other models such as the decision ladder model and RPD, although they mentioned the situational factors in decision-making, they focused on decisions made by an individual rather than a group. What happens in an organisation is a complex relation between different decision-makers who are influenced by situational factors, so decision-making seems a process with various elements that are interconnected. This part of the study illustrates these main units of decision-making in an organisation and their interrelations in a framework. The solid components in this structure consist of the conflict of interest, communication, the type of decision, function, the underlying mechanism and the outcome.

A core emerging issue from the analysis was the conflict between decision makers that can influence the decisions both positively and negatively. Conflict is something that has not been given so much attention by previous researchers on decision-making. Conflict can occur as a result of conflicting values (Fasihi Harandi, 2016), ambiguity, uncertainty (Eisenhardt et al., 1997), or variety of functions. The data analysis revealed that conflict happened in the NOC between various subjects that we divided them into three levels, which are interpersonal, intergroup, and intragroup.

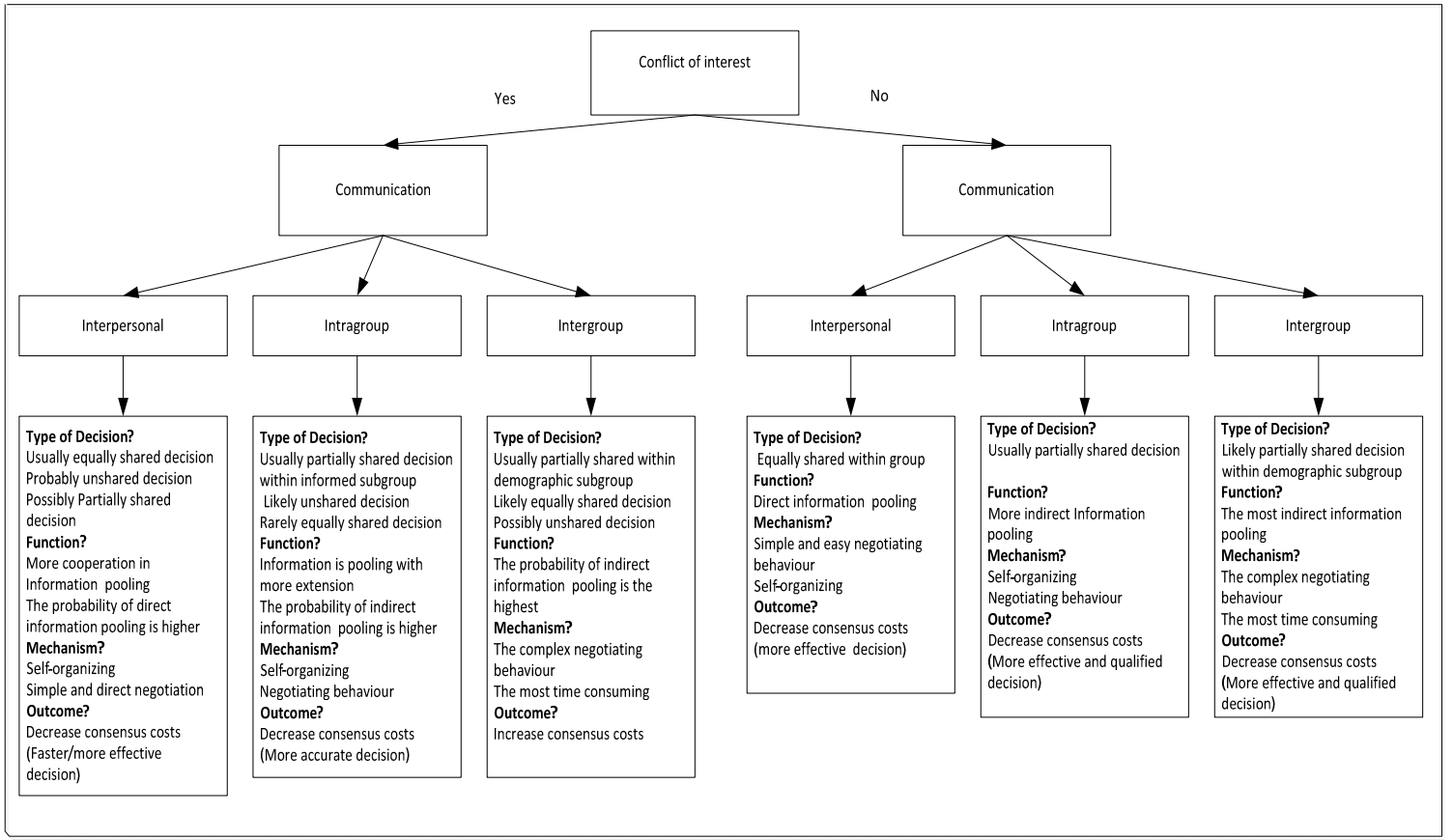

Figure 7.16. *A conceptual framework for consensus decision-making in a process industry*

The interpersonal conflict is disagreement and incompatibility between two or more individuals within a group, at the same level or different levels (Rahim, 2002). We observed conflicts at this level such as operator-staff, operator-supervisor, supervisor-middle manager, and middle manager-middle manager. Intragroup conflict refers to a conflict between the groups, units, or divisions within an organisation (Rahim, 2002). The most frequent intragroup conflict in this company was between production departments and the maintenance department, mainly as a result of the significant number of failures in instrumentation, which had been exacerbated by the sanctions embargo. Intergroup conflicts happens between two or several parties because they are interdependent in their functions (Rahim, 2002). However, in the consensus decision-making framework, we focused on the existence of conflict. So, in the consensus decision-making framework decisions consist of two kinds of conflicts, one with no conflict and another with a significant conflict of interest.

In consensus decision-making, there are usually three types of decisions according to decision makers. (1) unshared decisions where "a decision maker is a single dominant individual who decides on behalf of others and all members of the group have to obey". (2) partially-shared decisions when particular subsets of group members contribute to decisions. (3) equally shared decision when all team members contribute equally to a decision (Conradt & Roper, 2005). The results revealed that of these three, partially shared decision-making is the most common manner of decision-making in this organisation (62.5%), which were taken on the intragroup level mostly.

The partially shared decision approach is an effective way of making decisions in an organisation. Because, compared to an unshared decision, the combined errors of several group members are fewer than the errors of any particular member of the group in the unshared decision case (Surowiecki, 2004), the accuracy of partially shared decision-making is higher than with an unshared decision. Besides, there is a greater sharing of information and more collaborative and cooperative behaviour in a group instead of competitive behaviours in an unshared decision, resulting in focusing on group goals and more satisfaction (Flood et al., 2000). It also more effective than an equally shared decision since members of the decision-making group reach a final decision in a shorter time. According to Makoul and Clayman (2006), it is unlikely that decisions are taken equally in the medical domain as a result of the imbalance of medical knowledge and social power between doctors and patients. It is inevitable in the NOC context too, because members of the decision-making groups had a variety of knowledge and a range of social power. Considering only these two criteria, the probability of equally shared decisions occurring is rare in most organisations.

While an unshared decision in which the CEO or another dominant individual makes a decision has several disadvantages, the results revealed that unshared decisions were made in twenty-five per cent of decisions. An unshared decision manner was a proper solution when

the conflict was significant by "forcing team members to resort to covert coalition" (Flood et al., 2000) or when the members of the group could not make decisions in situations such as high-stakes decisions and under high uncertainty. Table 7.7 and Figure 7.11 explain an example of an unshared decision when the members of the group could not make decisions for welding inside of the vessel as a result of high risk. In these conditions by making an unshared decision, the group maintained a cohesion and accomplished its purposes.

The third component in this framework is communication. Since conflict occurs between individuals, similarly to consensus, we considered three levels of communication in an organisation the first of which is interpersonal, where individuals within a group communicate with each other on the same level or different levels. Intragroup communication refers to the communication between the groups, units, or divisions within an organisation and intergroup communication occurs between two or several parties (organisations) because they are interdependent in their functions.

Accordingly, on an interpersonal level, the communication and the probability of direct information pooling is higher than other levels as a result of less spatial distance and interaction in shorter time. Less conflict can also occur at this level as a result of similarities in values, functions, and objectives. Less conflict, fewer decision makers, and more cooperation of information pooling at this level lead to a more equally shared decision, and more efficient decisions in consensus decision-making. However, information pooling is mostly limited within the group, so the amount or the extent of shared information is less than intragroup cooperation that may lead to suboptimal decisions compared to the intragroup level. The results also demonstrated that numbers of unshared decisions at this level were greater than at the intragroup level. This might happen due, first, to the differences in authority because in an interpersonal level most of the individuals have less authority to make decisions and the authority increases up to a middle manager who is the manager of each unit or each department and he is empowered to make decisions. Second, the applied methodology that zooms on a middle manager may fail to provide more detailed information about the lower levels. In total, our results revealed that in at this level, decisions were equally shared-decision (50%), unshared (40%), then partially shared-decision (10%) respectively. It might be different or similar in different contexts, which requires more investigation.

At the intragroup level that communication occurs between the groups, units, or divisions within an organisation; more information is pooled. Experts (mostly middle managers) are equipped with a particular domain of knowledge; consequently, members of the group have an understanding about the type of information that they possess, while others do not and vice versa. Therefore, even having only one member possessing enough information to mention an item is sufficient in order to recall aggregation of information, resulting in more efficiency. At the same time, the probability of sharing the unshared information will increase since

members mutually know one another's responsibility for specific domains of information, resulting in a better quality of decision-making (Stasser, Stewart, & Wittenbaum, 1995). Also, the high conflict in preferences between decision-makers in this level raises a consideration of sharing information which facilitates open-mindedness toward alternative solutions and the broader and more critical analysis of a decision problem; consequently, this conflict mediates the quality of decision-making (Brodbeck, Mojzisch, Frey, & Schulz-hardt, 2002). The conflict in decisions that a minority of the group disagrees with one alternative prevents confirmation bias that can lead to overlooking, reinterpreting or rationalising information (Kahneman 1984, 2011; Hudson & Thorogood 2012). So, at the intragroup level information pooling promotes comparison to other levels. Finally, at the intragroup level, the number of decision-makers increases compared to the interpersonal level.

More information pooling in an intragroup level as a result of increasing the number of decision-makers with various different domains of knowledge promotes not only the accuracy of decisions but also the efficiency of decisions. The results revealed that partially shared decision-making (75%) was prominent at this level, then unshared decision the remaining 25%. We should take into account that the probability of equally shared decisions at this level is rare as a result of imbalanced information pooling. Besides, conflict at this level is usually higher than at the interpersonal level because of differences in values, functions and tactical objectives. The greater conflict is not a disadvantage since partially shared decision-making at this level, with great conflict, mediates not only the efficiency but also the quality of decisions and can help prevent decision-making biases like confirmation bias. It appears that an organisation can take the best decision with fewer biases in this level.

In the third level that two or several parties communicate with each other because of interdependency in their functions, not only may there be more conflict, but also the communication is more complex and indirect, which can also influence the type of decision-making. Conflict is significant due to conflicting values, the variety of functions, mostly high-stakes decisions for parties, uncertainties and ambiguities, and even various strategic objectives. As an example, the ambiguity of responsibilities and misperception of regulation about safety supervision and safety permitting caused conflict between the NOC and the maintenance company. The NOC company is a production company with production as the highest principle strategic objective, while in the maintenance company meeting deadlines had the topmost priority among objectives.

Pooling of information in these cross-functional teams between representatives of different parties is more complex, and there are more consensus costs incurred in terms of time and quality at this level. In this study, we had only three cases of decisions in the intragroup level that had a range of conflict from less to high. In one side when few decision-makers who were familiar with each other and their responsibilities, and they had the same objective made a

decision for the establishment of criteria for inspection of vessels. So, information was pooled quickly and they achieved a consensus decision in a short time. However, what we noticed from conversations was that there were several meetings and negations before this final meeting. In another case, there were a great many conflicts as a result of the ambiguity of responsibilities and misperception of the regulations about safety supervision and safety permits by two companies (the NOC and the maintenance company). Although the CEO of the NOC invited the CEO and other experts in specific domains from the maintenance company to solve this problem, they had to have more meetings to reach a final decision. It means that in high conflict, two companies achieved this decision by having more negotiation in order to solve the problem. Finally, for a decision about omitting some instruments that were supposed to measure the quality of gas, there was one middle manager, who was the representative of the NOC, who disagreed with this decision because it could influence the quality of the gas delivered. The secretary of the group did not accept his argument. He stated that they had a deadline to explain their ideas for supporting or against these instruments, while the NOC and some other companies did not pay attention to the deadline. This example does not confirm the unshared decision-making manner; instead, it supports partially shared decision-making. According to the results, we assume at this level, decisions use partially shared decision-making and equally shared decision-making manners, while the probability of unshared decisions is rare at this level because of lower power distance at this level, a greater extent of knowledge and more variety in objectives.

One core question in consensus decision-making is which group members contribute most to the consensus decisions in an organisation. The results of the case study confirm that middle management is the most important group in a consensus decision. Middle managers are involved in all three levels of communication that can impact on the type of decision: (1) At an interpersonal level, decisions are made mainly by supervisors and middle managers who are empowered to make decisions. (2) At an intragroup level, middle management constitute the prominent group members who contribute to consensus decisions. Consensus decisions are also mostly partially-shared decisions and communication occurs between departments and units; so, decisions are made by groups of middle managers as well as senior management. Since the number of middle managers in these decisions is more than senior managers, they may contribute to the final decision more than senior management. Besides, in this level, middle managers have access to various information sources gained from interpersonal communication in different departments; by sharing information, they contribute to the decision-making. (3) At an intergroup level, the number of middle managers who attend in these types of decisions are high as representatives of an organisation. Negotiations in this level were performed mostly by middle managers.

The presence of informed individuals in the group who are mostly middle managers is substantial to direct other members of the organisation and to improve the accuracy and the

efficiency of decisions (Dyer et al., 2008). On the one hand, where a decision involves a significant conflict of interest and information is inevitably communicated in an imbalanced manner, the group is dictated by the majority; so, a group achieves an agreement in early stages of decision-making, thus improving the efficiency of the decision-making (Dyer et al., 2008). On the other hand, at an interpersonal level, middle managers take a leading role in discussions, and they get high status in the group (Brodbeck et al., 2002).

Finally, the results revealed that the underlying mechanisms, which is a way through which a decision is reached (Conradt & Roper, 2005), are self-organizing rules and negotiation rather than voting. Self-organizing rules that were observed in the case study included both '*ideal'* and '*ought'* self-guides. However, *ought* self-guides, which are goals or standards that must be met or the minimal goals or necessities, were prominent in the NOC; therefore, decision-makers were concerned about the presence or the absence of adverse outcomes (Hall, Crowe, & Higgins, 1997). It was evident, especially in safety and environmental related-decisions, on the other hand, that there was evidence that supports the desired end-states for production was maximal goal (*ideal* self-guide rule) that led them to focus on the absence or the presence of positive outcomes (more information about underlying mechanisms was presented in Chapter5).

7.4.3 Decision-making processes in emergency response

Several key themes emerged from the analysis of the findings in this stage. First, similar to safety-related decision-making in normal and abnormal conditions, emergency response is a naturalistic decision-making process instead of a process of rational decision-making. The analysis of the findings confirms characteristics of naturalistic decisions in emergency conditions. They consist of "ill-structured problems, competitive and shifting objectives, time constraints, high stakes, multiple players, uncertain and dynamic environment, influence of organizational norms and goals that must be balanced against the decision makers' personal choice and multiple event-feedback loops" (Jenkins et al., 2010). The difference is that in normal and abnormal decision-making some dimensions such as competitive and shifting objectives, high stakes, multiple players, and organizational norms and goals are predominant; in emergency conditions, some characters such as time constraints, uncertain and dynamic environments, and multiple event-feedback loops are highlighted more often.

Second, decision makers focus on situation assessment to find the criteria for choosing the decent alternative, since environmental factors critically influence the priority of one option against another one. However, it does not mean that decision makers do not focus on option judgement. The assessment of a situation helps them to find the criteria for judgment. Emergency centres responded to incidents based on feedback that they got from their initial

reactions because it requires less sophistication and less knowledge of environment; this is a proper method in emergency response in which the environment is changing within a short time (Selten et al., 2012); consequently, they can take more efficient decisions.

Third, decision makers classify decision problems, interpret them and take decisions based on both knowledge and experience. They have acquired this knowledge from the assessment of the conditions, and communication with others both inside and outside of the industry. The knowledge gained depends on the availability of information and the extent of information. They also make decisions based on their experiences as is confirmed by the quotation below.

"*During interviews, emergency responders indicated that they were concerned for the safety of the butane sphere, in light of a recent commemoration of the 1956 incident in which the failure of a vessel in similar service caused 19 fatalities"* (CSB, 2008).

Additionally, decision makers evaluate the appropriateness of an alternative based on satisfaction (Simon, 1983) rather than optimisation. Since time is a determining and critical factor in emergency response, the desirable level is satisfaction. According to Selten et al. (2012), solving a complex dynamic problem within a limited time is difficult because there is a time lag between decision, action, outcome, and reporting feedback which prevents reaching an optimal decision. In emergency response, actors also have to correspond to constraints restricting the set of actions. Besides, decisions in emergency response team are usually consensus decisions so that incurring extra decisional cost is inevitable (Conradt & Roper, 2005).

Typically emergency response is teamwork consisting of different tasks that combine not only rule-based decisions, when actors are performing familiar tasks, but also knowledge-based decisions when they are confronted with unfamiliar conditions with high uncertainty that may trigger strong effects that need an analytical evaluation of the situation and the comparison of multiple options. But a systematic evaluation is limited by less knowledge about the environment and high uncertainty about the outcome; therefore, decision-makers in these situations place more emphasis on the consequences of decision-making rather than the probability of the outcomes.

Both cases revealed a contrast with one principle of the RPD model in which a decision maker generates a single highly likely option one at a time rather than a generation of many alternatives. The results showed that decision-makers produced multiple but limited numbers of alternatives and since they are faced with limitations like time pressure and resources, they do not wait to find which option is rated the highest (Klein,1991). They execute various options in parallel, which enables them to react to the condition faster and more efficiently. The results revealed that they try to perform various options instead of relying on only one option, execution of these options, observing the result and getting feedback continuously.

This is a useful technique to prevent losing time and decreasing the outcome severity of incidents. It seems that they apply multiple barriers instead of only one barrier at a time. These results are similar with some cases in the context of the NOC when they were faced with abnormal conditions with high uncertainty about outcomes of alternatives, so they tried several options at the same time.

Although the RPD model and the current study are focused on illustrating the decision-making process in a natural setting, we found two fundamental differences between this study and the RPD model. First, the methodology is different. In his RPD model, Klein focused on describing the recognition strategies of experts by interview, while this study analyses the accidents regarding activities and task analysis to find what kind of decisions they actually made. Document analyses applied in this study were unable to identify the pattern strategies implanted by decision-makers and it is hard to find other alternatives that they may consider while they were rejected because of the criteria. Second, based on the RPD model, decision makers are supposed to rely on a single highly probable option at a time. However, actual emergency response analysis revealed that they consider several alternatives and instead of choosing the highest rated alternative or a highly likely option they sometimes select multiple alternatives at the same time when they have similar value, and their probabilities are equal.

7.5 Conclusion

In this Chapter we have combined several methods in order to answer the three research questions #8, 9, 10. This Chapter has led us to the following results:

- Most of accident databases and incident investigation reports suffer from lack of information about latent errors which cause accidents, this shortage in organisational level factors and decision making is even worse.
- Middle managers are involved in various types of decisions and various steps of decision-making. However, they do not make decisions based on a complete set of criteria and alternatives, as well as using mathematical and rational ways for their choices. Instead, they exhibit naturalistic decision-making in which middle managers search for information progressively, accompanied by changes in the formulation as a result of new information. Equipped with knowledge and experience, middle managers can recognise patterns and apply them in their decisions that finally cause quasi-automated decision process.
- Democratic decisions have been taken mostly instead of despotic decisions in the NOC context; this can result in less extreme outcomes and lower cost. Among these democratic decisions, consensus decision is the primary type of decision-making and then partially shared decisions are prominent at all levels in organisations. We found that the presence of informed individuals in the group who are middle managers

within the organisation has substantial influence in directing other members of the organisation into organisational objectives. The presence of middle managers, who have access to information, makes them effectively the nerve centre of organisations and therefore places middle managers in a unique position where they can use information as an input to play significant decisional roles.

- The rule-based decision is more frequent and proper than risk-based decision in safety-related decisions. This assisted middle managers to show interdependencies and nonlinear relationships that exist between different criteria as well as uncertainty. These rules were established by regulations, by procedures or by evidence from experience. The rule-based decision is a simple, accurate and reliable judgment to deal with uncertainty caused by incomplete, vague, or imprecise information. Besides, decision makers do not leave without having clear criteria to make a decision, while in conventional risk assessment methods so much effort is essential for a comprehensive numerical risk evaluation and sometimes it is not possible as a result of ambiguity of outcomes or probability.
- In some decision cases decision-makers do not select only one alternative based on the sets of criteria. Sometimes, in abnormal and emergency conditions when they were faced with uncertainty about the outcomes both for value and probability, they prefer to try several options, still with a limited number of alternatives. In this way, they increase both the accuracy and the speed of the decision-making, which is of substantial benefit in these situations.
- To sum up, the audio task recording provided an excellent opportunity to get rich data and obtain insights into the functions and mechanisms of collective behaviour and consensus decision making in a process organisation with middle managers. Our study has produced two sorts of knowledge. First, in addition to conditions where decision makers generate multiple numbers of alternatives and they find the option which rated the highest, and conditions in which decision makers choose a single highly likely option one at a time rather than a generation of many alternatives. There are conditions in which decision makers choose several options at the same time when the probability of alternatives are equal, and alternatives are middle-truth-value. Secondly, we have presented a conceptual model of consensus decision-making in an organisation.

8. Conclusions and recommendations for future research

8.1 A short introductions to the outcomes

This chapter presents a brief review of the findings, the contributions and implications of our research, the limitations of the research, and finally indicates possible directions for future studies. The main objective of this thesis was to explore the role of middle management in safety and the process of middle managers' decision-making that was then divided into several sub-questions. To answer them, the following main steps were taken:

The current decision-making models, their assumptions, and their structures were analysed, and their appropriateness to be applied to middle management's decisions was examined.

To link the decision-making models with middle management, a critical analysis was carried out of the concepts of decision-making and middle management functions in organisations.

The availability of data about decision-making in safety-related decisions was examined. Since most of the databases failed to provide enough information about decision-making, we carried out a documentary analysis to explore decision-making and the concept of middle management in Chemical Safety Board reports that provided more elaboration of accident analysis than other databases.

The interview, questionnaire, and audio task recording were carried out to explore how middle managers actually make decisions. The critical analysis was done on decisions both on historical view and real-time decisions and some patterns raised from the results.

Options for improvement in decision-making modelling were explored, and the consensus decision-making in organisation emerged and has been discussed. Table 8.1 shows a summary of the results, while the main results are be given below in more detail.

8.2 Answering the research questions

In Chapter 2, we reviewed documented accident investigation reports in the oil and gas industry. The results demonstrated that adverse events occurred as a result of poor decisions because of the following reasons: First, the absence of guidance, so leaving decision makers in vague conditions for taking a decision (e.g. the LPG fire at the Valero-McKee refinery accident, the blowout in the Gulf of Mexico). Second, the lack of setting a minimum criterion (e.g. the LPG fire at the Valero-McKee refinery, the Tesoro accident). Third, improper criteria and the lack of a written decision-making protocol for a shutdown in non-routine works (e.g. the LPG fire at the Valero-McKee refinery, the Tesoro accident). Finally, failure to apply a priority ranking system (e.g. the Chevron incident). These errors in decision-making in turns resulted from systemic and organisational factors. They included the safety culture, prioritising production over safety, lack of knowledge, the availability heuristic, normalisation of warning signs, cost cutting, blindness to process risks, and tunnel vision. They also

occurred as a result of the lack of authority for doing some functions or on another extreme, giving the authority to decide about safety issues to lower levels, where managers are concerned more with production rather than with safety objectives.

Table 8.1. A summary of the outcomes of the thesis

Outcome	Research question	Related Chapter
Identifying the roles and impact of middle managers in organisation	1, 3	3
Viewing safety-related decision-making models	4, 5	4
Exploring the role and influence of middle managers in safety	2, 6	6, 5, 7
Exploring the process of decision-making in routine, non-routine and emergency conditions	6, 7	2, 5, 6, 7
Identifying how poor decisions led to catastrophic accidents	2	2
Framing and conceptualising the consensus decision-making in an industrial setting	7	5, 7
Emerging the parallel decision-making in decision-making models	6, 7, 8	7
Develop a consensus decision-making in an industrial organisation	6, 7, 8	7

In the third Chapter, we found that middle management are almost entirely overlooked in the safety literature, while Chapter 2 revealed that poor decisions closely linked to middle managers as they are located in pivotal positions. The critical literature review in Chapter 3 demonstrated that middle management impacts organisations in various ways by performing multiple roles. We also found that researchers were more focused on the strategic, communication and cooperation roles of middle managers, while other roles, particularly decision-making roles of middle management, were often overlooked in the management domain.

As Mintzberg (1973) asserted, decisional roles can consist of resource allocation, entrepreneurship and a disturbance handling role. Keeping the decisional role of middle managers in mind, identifying the best decision-making model for middle managers was the next objective of this thesis. We conducted a literature review on safety-related decision-making methods to find out whether the current models of decision-making can be implemented for safety-related decisions of middle managers. The literature review in Chapter 4 revealed the lack of any appropriate decision-making models for middle management decisions. More specifically:

- They are more decision support systems that rely on engineering and technical aspects to overcome the uncertainty of risk assessment, rather than a general decision-making method.
- They are some applications of common decision-making models, mostly at the risk assessment step, while decision-making is not exclusively risk assessment intended to prioritize the safety risks. Instead, decisions are taken in various stages of safety management.
- Statistical analysis revealed that the normative (prescriptive) decision-making methods had been preferred to be studied by safety scientists, while they have little or nothing to do with how decisions are made in safety-related decisions, and they suffer from the lack of applicability in most real safety-related decisions.
- Attempts to demonstrate the process of decision-making and to find the patterns of decision-making in safety have not attracted much attention. The studies are concerned with individual decisions, while group decision-making processes are not necessarily comparable to individual decision-making; they ignored analysis of networks of connections in organisations that can significantly influence decisions.
- In conclusion, we have identified a wide range of decision-making approaches that could have been used in the field of safety management but there is no evidence pointing strongly in one direction or the other with respect to which techniques are to be regarded and recommended as the best.

The main contribution of this thesis is evaluating the decision-making and influencing factors simultaneously within a process industry. As discussed in Chapters 2, 5, 6 and 7, unlike other studies, in this research, decision-making was analysed in dynamic circumstances. We assessed the decision-making process in routine, non-routine, and emergency conditions in complex techno-social systems. Under these conditions, decision alternatives and criteria emerged rather than just being pre-defined by decision-makers. In addition, middle managers had to resolve the dilemmas created by making a balance between different objectives.

In Chapter 2, which described the incident scenario analysis, the methodology enabled us to understand the errors in decision-making and influencing factors that led them to make those poor decisions. Using the actual accident scenarios also prevented the shortcomings of artificial scenarios that include abstract and unrealistic examination, the lack of external validity, and failure to reflect the real world (Jarzabkowski et al., 2015).

Chapter 2 contains the thesis's first evidence for decision-making failures and the driving factors (research sub-questions #2 and #7). One essential factor that led to incidents in the oil and gas sector was leaving decision-makers without any criteria or with ambiguous criteria. For instance: absence of a transparent method for design decisions; lack of demonstrating robust controls and inherent safety design in decisions to achieve ALARP level; not providing

a written decision-making protocol for determining the time to shut a process down for executing repairs; absence of criteria for performing works safely in non-routine works; or the lack of a minimum requirements to prevent HTHA failures. Those data demonstrate that there are many circumstances in safety-related decision-making where decisions were not based on various predetermined criteria. In fact, there were not any criteria or there were only vague criteria for decision-making. In this way, Chapter 2 elucidated that the most popular decision-making methods in safety, which are first Fuzzy and second the AHP methods, were not applied in practice. The former is under the law of comparative judgment as a structured way to make the decision based on a pairwise comparison of the alternatives against the criteria (Caputo, Pelagagge, & Salini, 2013; Saaty & Shih, 2009). The latter is also a structured way to achieve an optimal choice with the maximum degree of satisfaction on both goals and constraints simultaneously for vague criteria (Fuzzy Review 2000). This is evidence showing a clear gap between theory and practice in safety-related decision-making. Instead, they revealed that decisions were made under time pressure (e.g. Tosco Avon Refinery fire incident), inadequate information (e.g. Chevron accident), poorly defined procedures (e.g. e.g. LPG fire at Valero-McKee refinery, Tesoro accident) which mitigated against the feasibility of rational decision-making in abnormal and non-routine activities within process industries.

The results of Chapter 2 also revealed that managers were faced with multi-objective decision-making. However, instead of considering various goals at the same time without dominance, the revenue generation objective commanded top priority in these companies, resulted in a different trade-off against safety and actually increased the likelihood of catastrophic outcomes. Consequently, biases like normalisation, tunnel vision, and confirmation bias occurred as a result of prioritising profit risks against safety risks. Therefore, hazards were missed or underestimated, giving rise to poor decisions.

The documentary analysis also disclosed that factors such as safety culture, improper management of change, and changing the organisational design structure were driving factors for failures in decision-making. Safety culture caused confusion over roles and responsibilities. Changing the organisational structure caused those line managers who were at the low level, and were relatively cost-focused, to take decisions in the BP Macondo disaster. Improper management of change accrued as a result of not evaluating the new applied techniques; they did not assess risks after changes in their systems, which gave rise to missing the risk; or there was a lack of clear accountabilities and poor communication, which together resulted in confusion in the workforce over roles and responsibilities.

The fact that management was responsible for the majority of failures in decision-making, and that middle management's roles were not given attention in accident investigations were drawn from Chapter 2.

Chapter 3 deserves attention as it illustrates the definition and the role of middle management. Three criteria were applied by researchers for the definition of middle managers, namely their functions, the organisational structure; in other words, the context of organisation, and finally, the purpose of the researchers. These results indicated that there is no one definition that is a tight and unambiguous, and covers the generally accepted meaning of that word. However, we found no substantive difference between them. In our cases, we considered managerial function in the HSE management system and the organisational structures that distinguish this group from other managerial groups.

The lack of consistency in a holistic typology of middle management roles was another result of Chapter 3. However, the middle management roles that were mentioned in the literature were categorized into 5 prominent roles: strategic roles, administrative roles, leadership, decision-making, and communication. There is a considerable overlap between elements of roles and the extent of functions depending on the context of the organisation, time and attitudes of middle managers. However, that role classification clarified the distribution of responsibilities for middle management.

Chapter 5 contains the thesis's other evidence for decision-making in real conditions to answer research sub-question #7. It began with a methodology that was applied for this purpose, which was daily task recording. In a majority of research designs, researchers focus on single case studies, while our research compromised multiple methods, within similar industries to explore the different types of decision-making. One methodological contribution of our research is applying the audio task recording by a senior middle manager to record his diary.

This method is a real-time method for measurement of decision-making that is similar to an observation of contemporary behaviours without interference with the participants by a researcher. Audio task recording was appropriate for our purpose because we could consider a middle manager as an agent in the company who serves to bridge with other agents. By assessing one (key) agent in this system, researchers were capable of capturing the whole picture of the company involving the current conditions of the company, the behaviour of middle managers, a network of interactions between middle managers and other entities in an organisation and even the relations with external organisations. Applying audio task recording and selecting this case enabled us to track a network of activities consisting at least 32 other actors at various levels and in different departments. So, decision-making and influencing factors were evaluated more extensively than concentrating solely on individual middle managers, as in an interview, would allow. Furthermore, this microscopic technique was appropriate for exploring what was actually happening in a real world, allowing us to focus on the middle managers, their actions and their reactions in dynamic and real-time conditions while they implemented different tools to accomplish their firms' objectives. Consequently,

the study of the decision-making process and the influencing factors in organisations of actual conditions was possible with a high degree of accuracy.

The audio task recording that recorded behaviours and events (Koopman-Boyden & Richardson, 2012) can provide more relevant, complete and accurate datasets and is proper for recalling information without missing them (Crozier & Cassell, 2016). The method applied in this study is even more precise than the common type of audio recording because it records all the activities, behaviours and events without being influenced by the perceptions and reflections of participants. The method has the advantages of both tape recording for meetings and audio diaries. Besides, it mitigates the contamination due to the social desirability response bias that means participants try to answer what a researcher is wanting to hear, as can happen in an interview, instead of what is actually the case (Khayatzadeh-Mahani, 2012). Social-desirability forms a significant bias influencing the validity of many social science research studies (King and Bruner 2000; Nederhof, 1985; Peltier & Walsh, 1990).

The next methodological contribution of this study is applying Activity Theory for analysing data in safety domain. Activity Theory was discussed in ergonomics as an appropriate technique which can support researchers in the identification and interpretation of units of analysis (Karwowski, 2006), but we could not find any practical application of this theory to safety. In our study, activity theory enabled researchers to explore the structure and interrelation between different components of a company which itself forms a complex socio-technical system. Applying this theory enabled us to clarify the ways of performing tasks and to understand the manners of interactions and communications between individuals, both internally and externally. This study provides practical evidence that confirms that Activity Theory is a useful analytical technique to help find the hidden and root causes of failures in a safety management system. Other methods of risk analysis are mostly concerned with only the technical or social aspects. However, Activity Theory can enable researchers to find more complex and interconnected causes and to go through them in detail, so it is a tool for systematic and comprehensive analysis and for addressing both technical and social components in safety management processes.

Chapter 5 showed evidence of real-time decision-making in an oil and gas company that confirms again dependency and incompatibility between strategic objectives, while the outcome of these priority settings was usually trading off safety objectives against production and environmental objectives. Several fundamental factors caused this trade-off, the safety culture, regulations, the differences in reference point of objectives, and other stakeholders. The organisational culture in which revenue generation and environmental objectives commanded the top and the second priority that had been started by the senior manager, spread to middle managers and supervisors and finally included front level workers, was

influenced by external factors like regulation. Environmental regulation has more power than safety regulation and people, external stakeholders, were more aware of environmental effects of industrial activities than safety effects, as evidenced by flaring. The reference point for production objectives was set at an aspiration level, while for safety objectives and environmental objectives, the reference point was determined by regulations. This makes a great difference in priority setting between strategic objectives and motivation of individuals to prioritize one objective relative to others. Therefore, one solution for improvement of the integrated management system could be moving from the minimal reservation point determined by the regulations to an aspiration level. In other stakeholders, including contractors, consumers, central organisation and regulatory organisations with different priority settings, lack of cooperation and ambiguity of responsibilities also influenced all the strategic objectives of the NOC company negatively. The greatest negative impacts in achieving the safety objectives of the company were made by contractors. It is necessary to take into account that giving the first priority to production does not only occur in the NOC case, both investigations of the accident analyses and interviews pointed to the same priority setting in other cases in process industries in other parts of the world. The accident analysis confirms the effect of these priority settings of objectives in occurring accidents (e.g. the Tosco Avon Refinery incident, BP's Texas City refinery explosion and BP's Blowout in the Gulf of Mexico).

Chapter 6 focused on identifying the role of middle managers in organisations, and more specifically in safety management to answer sub-research questions #1 and 2. In this Chapter, all the actions determined by using activity theory were classified into ten managerial roles defined by Mintzberg (1973). The results confirmed the multiple roles of middle managers as spokesperson (40.7%), leadership (23.5%), monitor (12.0%), and disturbance handler (10.7%) had the highest frequencies amongst the ten roles. Spokesperson and monitor are among the informational roles, leadership is among the interpersonal roles and disturbance handler is among the decisional roles. Mintzberg (1971) and Pavett & Lau (1983) pointed out that there is a relation between the hierarchical level of management and their roles. So, lower managers tend to do more internal roles like disturbance handler, negotiator, and leader than do upper-level managers who focus on strategies and planning performing external roles (e.g. liaison, monitor, figurehead). Our results indicated that middle managers perform both internal and external roles. Although, decisional roles did not have the first priority among middle management roles, one role - disturbance handler - is among the most frequent roles. Besides, as asserted by Mintzberg (1973), there is a considerable overlap between elements of roles and finally, in safety, we are often faced with conditions that deviate from abnormal conditions. So, in safety, some roles like leadership, disturbance handler, and informational roles are more important than others. Accessibility to information in short time intervals and more informational sources about process parameters and failures in equipment enhance the

identification of safety risks by middle managers. Consequently, they can make more accurate and effective decisions in safety issues. They act as informal safety auditors and provide 'soft' alarm systems in safety management. Finally, they are actively involved in the control of the process safety.

Chapter 7 examined the process of decision-making in the case studies to answer the sub-research questions #6, #7 and #8. We use multiple methods to analyse safety-related decision-making in routine, non-routine and emergency conditions. The main results in this Chapter are as following:

- Safety-related decisions had the highest frequency of various decisions in the NOC context.
- Middle managers are involved in a wide variety of decisions in organisations.
- Middle managers did not apply the common scientific rational decision-making techniques such as AHP and Fuzzy decision-making. They were even not familiar with those decision-making techniques decisions, in various cases; confirming an apparent gap between theory and practice.
- Middle managers considered a limited number of alternatives and criteria in their decisions, substantial evidence supporting the notion of bounded rationality which is based on the simple search rules, the simple stopping rules, and the simple decision rules (Gigerenzer & Selten, 2002; Roth, 1999; Simon, 1972; Wierenga, 2011). This strategy is useful to overcome internal constraints like limited memory and limited information processing power; as well as external constraints such as time, money and energy (Gigerenzer and Selten, 2002). It also improves the consistency in decision-making.
- There was not any difference between safety-related decision-making with other decisions in applying the notion of bounded rationality in decisions.
- Middle managers take quasi-automated decisions as asserted by Salas, Rosen, & Diaz Granados (2009). This arises from applying the breadth of their experiences across a variety of disciplines which are sometimes unique and sometimes overlapping. Besides, decisions are taken based on feedback that requires less sophistication and less knowledge of the environment. Finally, they are faced with operational problems that are typically repetitive patterns with predictable outcomes (Littauer et al., 1976).
- Similar to the medical domain, in safety-related decisions middle managers rely on small samples and they have a tendency to avoid the worst outcomes rather than using the actual probability (Lejarraga, Pachur, Frey, & Hertwig, 2016; Pachur & Galesic, 2013; Waters, Weinstein, Colditz, & Emmons, 2007) because of lack of a large amount of data that represents conditions where decisions have to be made for rare events, with high uncertainty, and less knowledge about the environment.

- Middle managers not only took risk-based decisions but also made rule-based decisions; however, managers did not weight options based on a mathematical framework. Instead, they have their judgment and the method of weighting was influenced by the organisational context such as the culture of the organisation, regulation and stakeholders that influence the process of priority setting of objectives.
- Rule-based decisions were more frequent than risk-based decisions in the NOC company. Rule-based decision-making implemented by middle-managers contains a set of if–then rules including simple if–then rules including logic connectives (e.g. and/or, else) with the if–then rules. Such rules assisted middle managers by showing interdependencies and nonlinear relationships which exist between different criteria as well as the uncertainty of outcomes (Rezaei & Dowlatshahi, 2010). So, aligned with Hopkins, we argued that rule-based decision-making is more accurate in the safety domain since it is a deterministic approach that decision makers do not leave without having clear criteria to make decisions. In this way, middle managers overcome the limitation of conventional risk assessment methods in which it is not feasible to carry out a comprehensive numerical risk assessment (Hopkins, 2011). It is also more proper for non-routine tasks because it prevents the inevitable tendency to underestimate the risk in order to do what individuals want, meaning preventing confirmation bias. It also prevent less competent risk assessment where risk-based decision-making which is coupled with a set of budget priorities makes it very difficult to give a greater weight to process safety compare to expenditure. Besides, the risk-based approach in which a risk is a product of likelihood and consequence fails to show the accurate level of risk in some process risks when their likelihood is extremely low. Finally, there is a level of uncertainty about risk assessments even they are made by experts and competent people.
- Middle managers applied and shared rules with others for representing and reasoning. These rules established by regulation, procedures or evidence (self-organising rules). This is a simple and practical tool to deal with uncertainty caused by incomplete, vague, or imprecise information in these multi-criteria decisions. It is also a valuable method for an accurate and reliable judgment. However, evidence showed that decision-makers did not determine a referential set for each antecedent attribute and their consequences; In other words, those "if–then" rules were incomplete and composed a selective collection of if–then rules ,while other rules ignored. The managers might use a selective group of if–then rules to show the relative importance of each antecedent attribute as well as a relative importance of a rule (Yang et al., 2006) that may result from the knowledge or experience of managers.
- One significant emerging result is that decisions consisted of both parallel and serial decisions. It means that decision-makers choose the final decision by either

eliminating other alternatives until only one alternative remained; or sometimes the final decision involved applying two or multiple options at the same time. Then they take actions or order to take actions simultaneously for selective alternatives until they are certainly sure that one option is working better or faster than the alternatives. Otherwise, they continue to perform several options in parallel simultaneously. It is a beneficial strategy to both overcome the uncertainty and to limit the decision costs. As results demonstrated, this kind of decision is proper in abnormal and emergency conditions when the probability of alternatives are equal and options are middle-truth-value. This result confirms the study of McKinstry et al. (2008) who identified a parallel competition when a decision maker selects from multiple options at the same time.

- The results also shows the possibility of some decision-making biases, like the conformation and availability biases, that can cause catastrophic outcomes. Middle managers can be inclined to conformation bias in order to conform socially and go ahead which can lead to "overlooking, reinterpreting or rationalizing information" (Hudson & Thorogood, 2012). However, it is more related to the organisational structure than to middle managers per se (Dutton et al., 2001). The availability heuristic is related to the ability to recall the information from our minds. Usually, a decision maker retrieves information which is more familiar or more vivid and easier to remember (Kahneman, 2011; Mantel, et al., 2006). This is a bias that can happen both in individual and group decisions in various levels, not only in middle management decisions.
- Finally, middle managers are mainly involved in consensus group decisions rather than combined decisions or individual decisions.
- The integration of different methods for the design of the study on decision-making contributed to identifying one essential factor – personal conflict - in decision-making that had not attracted much attention in the decision-making literature, while the analysis of the data illustrated that is an inevitable element in decision-making. Recall Chapter 5, which showed that conflict between different actors can occur in group decision-making and can be intensified by any failure in other components of the system consisting of tools, rules, communication and collaboration.
- We develop a consensus decision-making framework in an organisation, in Chapter 7, that represents essential elements in consensus decision-making including conflict, communication, multiple decision-makers and outcomes. The consensus decision-making framework provides a theoretical and practical roadmap to managers, decision-makers, safety experts, IT, and learning intervention in workplace settings.

8.3 Research contributions and implications

Our study has provided knowledge on safety-related decision-making in various situations including normal, abnormal and emergency conditions. This knowledge about decision-making can be used by different researchers to design models of decision-making.

Our study provides several methodological contributions for development of research design in the safety and decision-making domains. First, in this study, we applied audio task recording as a real-time measurement tool to capture decision-making process. By implementing this method, researchers can explore both more comprehensive and richer data. This method can be applied as a straightforward method in other sectors too. Next, we implemented multiple methods from fundamental qualitative methods such as interview and questionnaire to rare and novel methods like linked-in as a social media to gain enough data. Also, some methods failed to provide enough data for our research but we suggest other researchers implement these new and simple methods in their researches.

To our knowledge, we applied Activity Theory in safety for the first time. The activity theory was discussed in ergonomics as an appropriate technique. Karwowski (2006) pointed that Activity Theory can support researchers in identification and interpretation of units of analysis as well as for exploring the structure and interrelation between different components. Applying this theory enabled researchers to clarify the way of performing tasks; and to understand the manners of interactions and communications between individuals, both internally and externally within a company. This research confirms that activity theory is a useful analytical technique to find hidden and root causes of failures in safety management system. It is also proper for capturing the complexity of complicated systems. Activity theory enables researchers to find more complex and interconnected causes and to go through them in detail, so it is a tool for systematic and comprehensive analysis and for addressing both technical and social components in safety management processes.

A combination of task recording and activity theory supported researchers in identifying an emergent issue that is the personal conflict between different actors. We considered three levels that conflict occurs in a process industry. We also found that conflict is not necessarily a limiting factor in decision-making. In contrast, it can prevent confirmation bias and it improves the quality of decisions.

Another contribution of this thesis is a consensus decision-making framework in an organisation. The identified elements, which are conflict, communication, subjects, their interrelations and outcomes, enabled us to identify a framework for the most common form of decision-making in a process industry. Literature review on decision-making revealed that core elements and underlying concepts namely communication and conflict between decision makers, which can influence the final decision, were mostly overlooked in decision-making studies. We presented them in a consensus decision-making framework in Chapter 7. The

framework is an appropriate one to capture the properties of decision-making within an organisation more systematically and comprehensively, providing a great flexibility with different settings in various organisations. This framework then can support scientists to understand the decision-making process better and to improve decision-making. The consensus decision-making framework might be used as a theoretical and practical roadmap by managers, decision-makers, safety experts, and training intervention in workplace settings.

8.4 Limitations

The main limitation of this study stems from characters of the research problem, which consists of inter-connected and socio-technical components that demand qualitative research methods to get an in-depth understanding of the phenomenon under study. We collected and analysed a large amount of data. However, there are some constraints for performing this type of study. While the interview was initially adopted as a main source of collecting data, and questionnaire for triangulation, the number of participants in both methods was relatively low due to constraints, primarily political and due to the international embargo, and the contextual conditions both in university and industry. To deal with this problem we applied other sorts of research methods such as document analysis and audio task recording. So, we gained a deep insight into decision-making and influencing factors in an interconnected and complex system. However, it was traded off against time and cost interests.

While audio task recording supports researchers in uncovering the complex phenomenon under study and to capture the realities in the safety and decision-making domain, application of this method might not be feasible in other cases, particularly in industrial firms where there are more constraints about the confidentiality of information. If such data could be released for scientific research, it will be a great support to get a better insight about current approaches to safety management. Audio task recording is relatively time-consuming at the point of transcription. Usually, an interview takes time between 30 and 90 minutes, while task recording took 8 hours per day. Therefore, it requires more time for transcription and analysis but gives a considerably better picture of what happens. It is not filtered through the lens of a short interview, the constraints of predetermined interview questions in the case of structured and semi-structured interviews and the restrictions on memory of the interviewee determined by biases such as availability and representativeness (Kahneman, 2013). Applying Activity Theory with audio task recording that provided a framework for units of analysis helped reduce the time involved.

Another limitation of audio task recording in this study is recording daily functions of one middle manager in operational part. We nevertheless tracked the activities of 32 other actors and identified the influence of hierarchical level in middle management's roles, which is the main purpose of this research. However, we could not explore the influence of functions in middle management's role. We selected a manager in operations who plays a crucial role in

process and safety process; however, we could not identify the influence of functions on the role of middle managers in safety in middle managers in supporting units or departments such as financial and human resources. These middle managers may have different roles in safety management from operational middle managers. We had the same problem in the interview as interviewees were volunteers and we had more communication with HSE department, so we interviewed HSE managers as well as operational and maintenance managers in the middle level, not managers in supporting functions.

The consensus decision-making framework proposed in this thesis is based on the practical results. However, before using this framework, we must further evaluate the framework by implementing in some other case studies and making the changes, if needed. The application of our model also depends on the acceptance of such a consensus decision-making view by practitioners and scholars in organisational decision-making and safety. At the moment, the dominant view in safety is on prescriptive methods. The directions for future research on the descriptive methods or integrating the prescriptive with descriptive method can facilitate the acceptance of such a view.

The next limitation of this study was the language barrier, which can occur not only during interviews, but also translation of interviews and audio task recording. Language barriers can arise when the language of the researchers and participants are not the same which was a case in this study. Both interviewees and interviewer were not native English speakers, which may affect the results of the study. In audio task recording method, the native language of both the principle researcher and participants was Farsi, but a language barrier might happen in translation. To address this issue, some parts of the translation were assessed by the middle manager to minimize the effect of the language difference in the results.

In the document analysis method used to analyse the accident investigation reports by the CSB, there are two types of limitations in this sort of research method for assessment of decision-making process. First, there was not a large amount of data to analyse the decision-making in emergency conditions. Second, the analysis was according to the performed activities, so it was not possible to describe the recognition strategies or to identify the strategies implanted by decision-makers.

8.5 Recommendations for future research

As has become clear from the literature review on decision-making, one of the main objectives of developing decision-making models has been the requirement to quantify components of decision-making and influences. However, before quantifying any decision-making model, it is essential to gain an in-depth insight into the decision-making process and the organisational influences that govern such decisions. What has happened in decision-making studies is studying 'the elephant' from their individual perspectives, so that nobody can see exactly what decision-making is, while everybody has a vague understanding. This

study forms the first step to providing a well-articulated and rigorous qualitative model to show how decisions are made in an organisation from different lenses, which requires more study in the following aspects.

Although an attempt has been made to provide details as much as possible in the consensus decision-making framework, this framework can open up many possibilities for research by generating more theoretical work or by carrying other case studies in other settings. One recommendation for future research is the application of this consensus decision-making framework in other domains that may have different contexts like supply chains where the relationship between organisations is more international, rather than national, or applying it in different cultures, as some cultural factors can influence the elements of the framework. In this way we can enrich the framework by some changes if needed. Studies to qualify the components of this framework would be useful too.

One theoretical contribution of this study was identifying the role of some individuals within a group of decision makers who are mostly middle managers who can contribute to the decision making more than others. So by focusing on this group and providing training or decision-making support systems primarily for this group when there are constraints in resources, we can improve the quality of decision-making with minimal resources.

One barrier for data collection in the safety domain is the lack of common accident classification schemes for providing data illustrating the human and management factors. Currently, there are different classification structures, which make it impossible to compare between various databases. In addition, our research revealed that accident causation reports have failed to give insight into the process of decision-making; so, it is urgent to develop industry-wide schemes that are comprehensive and compatible with each other that allows data from various data sources can be compared or integrated.

The main barrier that impacted this study, as well as other studies in this university is the contextual condition, not only in industrial firms but also in the university. Just to give some examples, there are various strategies to support Ph.Ds. in various steps of the study from highest for those who have a scholarship or employment from the university to the lowest for external Ph.Ds. Second, it was expected that in developed countries there is more relationship between industry and university and political issues should not influence scientific researches. However, in practice, the centre in TPM that is responsible for making a connection between industry and faculty had a passive role by only forwarding the requests to the industry without perusing them. Solving these problems and more involvement of industries or other organisation are essential to increase capabilities of researchers and to save the time for carrying research in the future.

This research is one example in which a simple and more precise method of collecting data is presented. In addition the activity theory from another domain was integrated in safety

domain to analyse the data comprehensively. We also used Linked-In as a tool for gathering the data. Although the last one did not provide enough information in our case; attempts to apply high technology in safety as well as implementing the new and straightforward methods borrowed from other domains can be potential methodologies to carry research in the future.

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Appendices

Appendix A: Description, characters and roles of middle management according to literature review

Author	Year	Description	Tasks/ roles
Simon	1948	-	Communicator and coordinator
Thompson,	1967	Differ from upper level managers through their location in the organization's communication system	-
Mintzberg,	1979		
Lipsky,	1980		
Morgan et al.,	1996		
Lynn et al.	2001		
Aiken &Hage,	1968	-	Important differences in roles, tasks, responsibilities, and authority between top and middle managers
Walker & Enticott, Brewer, Walker & Brewer	2004 2005 2008		
Uyterhoven,	1972	They are located below top managers and above first-level supervision in the hierarchy	Access to top management
Dutton & Ashford	1993		Having knowledge of operations
Petit	1975	Most middle management are located within the three subsystem of production, environmental and integrative	Institutional leadership Balancing manager
Mintzberg,	1979	Direct supervisors of the workers in their unit	Supervisor
Brewer,	2005		Hiring, firing and rewarding
Wilkins	2006		
American Management Associations	1982	-	Responsible for individual initiative and judgment Actors under policies and directors of top level Responsible for establishing objectives to assign activities Recommending new or revised policies
Mintzberg, Brewer,	1979,	Service managers or operating core	-
Walker & Brewer	2005, 2008		
Lumsden,	1982	-	Responsible for getting upper management wants
Rainey & Watson	1996		

Author	Year	Description	Tasks/ roles
Broussine,	1983	Accountable to someone above them, although, they have staff accountable to them	Communicator and coordinator Rarely having the authority to formulate policy Answerable for implementing policy
Broussine Brubakk & Wilkinson ,	1983 1996	Classifications depends on the organization	-
Aucoin (Wikipedia)	1989	The intermediate management of a hierarchical organization, subordinate to the senior management but above the lowest levels of operational staff	-
Westley, Floyd & Wooldridge; Ashford, Dutton, Balogun & Johnson	1990, 1992, 1993, 1996, 2000, 2004		Interpretation/translation of the strategy coming down from the top level Formulation and influencing going up
Currie & Procter, Floyd &Wooldridge, Nonaka & Takeuchi, Wooldridge & Floyd Besson,Christian and Mahieu	2005, 1992, 1997, 1995, 1990, 2011	-	Play strategic key roles
Ireland	1992	Employees who have at least two hierarchical levels under them and all staff employees with responsibility for managing personnel	Integrating the intentions of top-level managers with first-level managers
Yammarino, Chun et al	1994, 2009	Report directly to their own leaders ,meanwhile work with distant' followers	Leadership
Nonaka & Takeuchi	1995, 1997	Below a policy-making level Responsible for policy implementation	Filtering information flows between the higher and lower levels Achieving the top pass down directives
Morgan et al.	1996	-	Leadership, networking, allocating resources, budgeting, scheduling, setting rules and guidelines for lower level

Author	Year	Description	Tasks/ roles
Rainey & Watson, Caughron and Mumford	1996, 2012	Embedded leader who reports to another high level leader but is also responsible for leading others	Leadership
Rainey and Watson, Rainey	1996, 2003,	-	Motivator
Brubakk and Wilkinson	1996	They are in the middle of the hierarchy	Coping with conflicts between top management and employees
Floyd and Wooldridge	1997	-	Coordinator Interpret ambiguous and diverse data Frame the perceptions of other managers Change the strategic agenda
Floyd and Wooldridge, Raes et al.	1997 2011	-	Accelerator or inhibitor of strategic changes
Floyd & Wooldridge, Huy, Raes et al.	1997 2002 2011	Stuck in the middle, reporting to executives in higher organisational levels and managing people in lower ones	-
Albert et al	2000	Strategy actors	Transforming, strategizing and constructing the strategy
Huy Raman Hope	2002, 2009, 2010	-	Crucial for success of change
Balogun	2003, 2007	They reports to top-level directly Linking pins or a conduit Pivotal although underscored role	Contributor to strategic decisions Connect top management with the rest of organization Implement senior manager orders Direct supervisors of employees who have long-term contact with lower level Concern on the day-to-day operations of the facility Administrators Responsible for more prolonged

Author	Year	Description	Tasks/ roles
			responsibilities
Balogun& Johnson	2004		Mediators between organisational units and functional levels
Arneson	2008		Problem solving Communicator Arranger and implementer of strategy
McCann& Morris & Hassard, Yang& Zhang& Tsui,	2008 2010)	Vast range of responsibility	Vast range of responsibility
Chun et al.	2009	Expanding higher level leaders Influence over lower level employees	They are responsible for day-to-day tasks and peruse the goals of top level leaders
Hong-hua& Yan-hua	2009	Key factor for sustainable development	
Sun and Anderson,		Either complement or contemplate the top management impact Greater influence on subordinates	
Johnson	2011	Agree with Brewer, Mintzberg and Wilkins and described middle managers based on their tasks.	Gather political support Elevate change Network Influence others (Leadership)
Johansel	2011	They are responsible for managing the operations in a particular, unit, agency or program.	-
Johansel	2011	Their tasks are similar in both private and public sectors	Leadership They allocate resource, network, communicate, and implement policy
Rouleau and Balogun	2011	They lack the formal role authority to act strategically Need to influence upwards as well as downwards	Communication bridge Sense making
Ghorbal-Blal	2011	-	Developers Identify opportunities to control

Author	Year	Description	Tasks/ roles
			costs of projects
Raelin a & Cataldo	2011	-	Unify divergent systems (executive and rank-and-filed)
Caughron & Mumford	2012	Second-tier leader", the leader who follows, as well as leads	Distant leadership Serve simultaneously as leaders and followers
Gentry et al.	2012	They have at least 2 direct reports and at least one boss who rate them on performance	Networking Stuck in the middle They control organisational policies
Chang & Bright	2012	-	Responsible to maintain stability Improve the existing services and policies
Gentry et al.	2012	The direct pipeline for top-level leadership positions	Leadership
Reeves, Walsh, Tuller and. Magley	2012	Direct supervision of employees who have prolonged contact with inmates in either custody or program roles and they focus on the day-to-day operations of the facility, while directly reporting to senior-level administrators	Bridging upper management and line workers Key personnel for organisational performance Supervisor
Chang, Bright	2012	-	Leadership
Caughron , Mumford	2012	Occupy an important but overlooked position	-

Appendix B: Interview questions

- What is your job in a plant?
- What do you do in your (Order of mention)
- Does your boss tell you what to do or do you work out what he wants to achieve?
- What do you understand by safety? [Personal, process)
- Are you given targets?
- Does your boss take safety seriously?
- How do you know ?
- Describe the best manager you met in terms of safety?
- Was it personal or process or both?
- Describe the worst manager you have experienced?
- Why was he so bad? Were there any consequences for him?
- Rank personal importance in your job - then rank in terms of time

1. Safety & environment
2. P & L performance
3. Meeting deadlines
4. Succession development
5. A well run site.

- How much time do you devote to safety? [<10%, 20%, 30%]
- Does safety ever slip off your agenda?
- What do you do when safety and production come into conflict?
- How much freedom do you have to decide what to do? Budget, manpower, equipment
- What keeps you awake at night?
- What was the last major accident you experienced personally?
- Keep thinking back to the last accident you remember. How it happened? Who was involved in decisions ? How was that involvement? Supposed you made a decision when accident happened, what features were you looking for when you formulated your decision ? Describe the nature of situations, the characteristics, and limitations would have changed the outcome of your decision?
- Discuss scenarios [outcomes] vs risks [probabilities)

- When you think in terms of safety do you think in terms of kind of accidents which we call scenarios or do you think in terms of what is most likely and happens which is more in terms of risk?
- Who tells you what are your major risks?
- Do you ever get surprised about safety?
- Anything to add?

Appendix C: The Participant Information Sheet

Research Title: Safety management and safety oriented decision making of middle managers

مدیریت ایمنی و تصمیم گیری های مرتبط با ایمنی توسط مدیران میانی

Titel onderzoek: Safety Management en besluitvorming omtrent veiligheid van *middle managers*

Research Team: Zahra Rezvani – Professor Patrick Hudson- Dr Paul Swuste

محققین: زهرا رضوانی- پروفسور|پاتریک هادسون

Onderzoeksteam: Zahra Rezvani – Professor Patrick Hudson- Dr Paul Swuste

Invitation

You are being invited to take part in a research study which is being carried out as the PhD thesis project of Zahra Rezvani who is doing her PhD Safety at safety group of Delft University of Technology (TU Delft). It is important that you understand why this research is being done and what is involved. Please take time to read the following information carefully.

Uitnodiging

Graag willen we u uitnodigen om deel te nemen aan het onderzoeksproject van Zahra Rezvani, PhD-studente aan de Technische Universiteit Delft (TU Delft). Het is van belang dat u begrijpt waarom dit onderzoek wordt uitgevoerd en wat het inhoudt. Neemt u dan ook alstublieft tijd om onderstaande informatie te lezen.

بدین وسیله از شما دعوت می گردد تا در مطالعه تحقیقاتی که توسط خانم زهرا رضوانی از گروه علوم ایمنی در دانشگاه فنی دلفت در حال اجراست شرکت نمایید.قبل از شرکت در این تحقیق لازم است هدف تحقیق مشخص گردد. بنابراین از شما دعوت میگردد موارد ذیل را مطالعه بفرمایید.

What is the purpose of this research project?

Complex systems require multiple barriers in place to ensure operations remain safe. Such systems also depend on those with responsibility for decision making to maintain their collective ability to recognize developing problems before they become critical. Better understanding of risk management combined with decision making of middle managers would allow much improvement (?), greater reliability and more empirical insights of risk management. In this regard, the main aim of this research is to explore how middle managers decide in practice. It also aims to find out factors influencing priority setting and implementation of safety in decision making.

هدف مطالعه:

عملکرد ایمن در سیستم های پیچیده همانگونه که به اتخاذ سیستم های حفاظتی بستگی دارد به افرادی نیازمند است که مسئول تصمیم گیری بوده وتوانایی لازم جهت تشخیص وقایع و واکنش به موقع قبل از بحرانی شدن آنها را دارند. شناخت بهتر مدیریت ریسک و نحوه تصمیم گیری مدیران میانی ، امکان پیشرفت بیشتر، قابلیت اطمینان بیشتر ودانش بیشتر در زمینه مدیریت ریسک را خواهد داد. بنابراین ، هدف اصلی این تحقیق شناخت نقش مدیران میانی در مدیریت ایمنی و نحوه تصمیم گیری آنها در شرایط واقعی است. هدف دیگر این تحقیق، شناسایی فاکتورهای موثر در تصمیم گیری در خصوص ایمنی است

Wat is het doel van dit onderzoeksproject?

Complexe systemen vereisen meerdere toepassingen om ervoor te zorgen dat de uitvoering veilig blijft. Deze systemen vereisen ook verantwoordelijke leidinggevenden, mensen die beslissingen maken, die de ontwikkeling van problemen herkennen voordat dit ernstige problemen vormen. Het beter begrijpen van risico management en de beslissingen die *middle managers* nemen zal de betrouwbaarheid vergroten en meer empirisch inzicht in risico management bewerkstelligen. Het doel van dit onderzoeksproject is om te ontdekken hoe *middle managers* in de praktijk beslissingen nemen. Daarnaast willen we begrijpen welke factoren van invloed zijn op het stellen van prioriteiten en het implementeren van veiligheid in besluitvorming.

Why have I been selected for this research?

Your participation is optional. I am asking you to take part in the research because I believe that you can provide important information that can make an important contribution to the research. If you do not wish to participate you do not have to do anything in response to this request.

علت انتخاب شما برای این مطالعه:

شرکت شما در این تحقیق انتخابی است. ما معتقدیم که شرکت شما و اطلاعات شما نقش مهمی دراجرای این تحقیق خواهد داشت. اما اگرشما تمایلی به شرکت در این تحقیق ندارید، لازم نیست که به این درخواست پاسخ دهید.

Waarom ben ik geselecteerd om mee te doen aan dit onderzoek?

Uw deelname aan het onderzoek is vrijwillig. Wij stellen uw deelname op prijs, omdat wij geloven dat uw ervaring een belangrijke bron van informatie is voor het onderzoek. Indien u niet deel wil nemen aan het onderzoek, dan hoeft u niet op deze uitnodiging te reageren.

What does participation in this research project involve?

If you are happy to participate in the research, you need to sign the consent form and return it to me. When I receive this, I will contact you to arrange for a meeting in which you will be interviewed. The interview will take around 1-1.5 hours and it will be digitally recorded. It can be by phone or video call or it could take place in your office for your convenient. After completion of the interview, you

will receive the transcribed draft of the interview. You are advised to read it through and let me know whether you agree with the content or not.

نحوه شرکت در این تحقیق:

اگرشما تمایل به شرکت در این تحقیق دارید، خواهشمند است اطلاعات تماس خود را که شامل پست الکترونیکی وشماره تلفن است را به پست الکترونیکی اینجانب ارسال نمایید.و همچنین اولویت خود را در خصوص اجرای مصاحبه و یا پرسشنامه اعلام بفرمایید. کلیه مصاحبه های انجام شده بعد ازرونویسی جهت تایید خدمت شما ارسال می گردد. پرسشنامه به صورت الکترونیکی بوده و پس از دریافت پست الکترونیک خدمت شما ارسال می گردد.بدین ترتیب که شما ایملی دریافت می نمایید که شامل سئوالاتی است که به ترتیب پاسخ خواهید داد لازم به تذکر است که سئوالات به زبان انگلیسی می باشد. اما در صورت تمایل شما نسخه فارسی به ایمیل شماارسال خواهد گردید.

Wat houdt deelname aan het onderzoek in?

Indien u bereid bent mee te werken aan dit onderzoek dan kunt u de akkoordverklaring invullen en naar mij terug sturen. Nadat ik uw formulier heb ontvangen zal ik contact met u opnemen om een interview te plannen. Het interview zal een uur tot anderhalf uur in beslag nemen en wordt opgenomen. Het interview kan zowel in persoon als via de telefoon of als video-call plaatsvinden. We zullen wederom contact met u opnemen wanneer we het interview hebben uitgewerkt. U heeft zo de kans om eventuele misinterpretaties recht te zetten.

What will happen to the results of the research study?

This research will be completed by the 2016 when the final thesis will be submitted to Delft University of Technology. The research results will then be presented at academic conferences and are aimed to be published in research journals. A hardcopy of the thesis is kept at TU Delft University library.

Wat gebeurt er met de resultaten van het onderzoeksproject?

Het onderzoeksproject zal in 2016 afgesloten worden. Het proefschrift zal worden ingediend bij de TU Delft. De onderzoeksresultaten zullen gepresenteerd worden tijdens academische conferenties en eventueel gepubliceerd in wetenschappelijke tijdschriften. Een hard-copy van het proefschrift zal via de bibliotheek van de TU Delft beschikbaar zijn.

نتایج تحقیق در پایان نامه دکترا ، کنفرانس و یا مقالات ارایه خواهد شد. یک نسخه از پایان نامه نیز در کتابخانه دانشگاه فنی دلفت نگهداری خواهد شد.

Who can I contact?

If you want any further information concerning this project or if you have any problems which may be related to your involvement in the project you can contact me at any time via email at: *z.rezvani@tudelft.nl* or *z_rezvani2002@yahoo.com*

Alternatively you can ring me at: *06870420596*

Met wie kan ik contact opnemen?

U kunt altijd contact met mij opnemen indien u meer informatie over het onderzoeksproject wenst of wanneer u vragen heeft over eventuele deelname aan het project.

Email: z.rezvani@tudelft.nl, z_rezvani2002@yahoo.com

Telefoon: 06870420596

اگر شما تمایل به شرکت در این تحقیق دارید یا نیازمنداطلاعات بیشتری هستید می توانید به آدرس پست الکترونیک اینجانب ایمیل ارسال فرمایید

Email: z.rezvani@tudelft.nl, z_rezvani2002@yahoo.com

This information sheet is for you to keep. Thank you for your time and help.

Zahra Rezvani

PhD Student in safety group-Faculty of Technology, Policy and Management (TPM) TU Delft

Bedankt voor uw tijd en hulp,

Zahra Rezvani

PhD student Veiligheidskunde, Faculteit Techniek, Bestuur en Management (TBM), TU Delft

با تشکر زهرا رضوانی

دانشجوی دکترای ایمنی در گروه ایمنی ، دانشکده تکنولوژی، سیاست و مدیریت

Appendix D: Questionnaire

Subject: The role and influence of middle managers in safety management particularly safety related decision-making

Version: V4

Written by: Zahra Rezvani

Date:05-11-2014

Edited by: Zahra Rezvani, Akram Khayatzadeh, Parisa Asadzadeh, Raheleh Barzgar, Frank Guldenmund, Amir Garmabaki

Date: 29-11-2014

SAFETY AND SECURITY SCIENCE GROUP
FACULTY OF TECHNOLOGY, POLICY & MANAGEMENT
DELFT UNIVERSITY OF TECHNOLOGY
THE NETHERLANDS

"The role and influence of middle managers in safety related decision-making"

Dear Sir/Madam,

Thank you very much for participating in this study. This questionnaire is part of a research project we are undertaking at Delft University of Technology on the role and influence of middle management decisions in safety. Given your position in a high hazard company, we feel that you have sufficient experience to help us to achieve our research goals.

The main goal of this study is to understand the procedure of decision-making and contextual factors, both individual and organizational, on safety decision-making in industry. The findings of this study can be used to develop a model to improve the decision-making process.

The questionnaire takes approximately 30 minutes to complete. *Please choose answers that best describe your job, your responsibilities and your decisions.* We will take utmost care to protect your confidentiality and your company's interest. Therefore, your name, your company's name or other identifying information will not appear in any study report.

Thank you again for taking the time to assist us. Your participation is highly valued in this study. If you have any questions regarding the questionnaire or the project, please do not hesitate to contact us.

Thank you.

Sincerely,

Zahra Rezvani (PhD researcher)
Email: z.rezvani@tudelft.nl
Prof. dr. Patrick Hudson (Promoter)
Email: HUDSON@FSW.leidenuniv.nl

Part 1:General information:

1. Which of the following type(s) of operations best describe your company? (Multiple responses are possible)

Type of operations	
Drilling & well services	
Equipment repair	
Exploration & production	
Refining	
Construction	
Manufacturing & suppliers	
Transportation	

Other (please specify): _____

2. Please indicate the approximate number of employees in your company?

Less than 100	
101 - 1,000	
1,001 – 5,000	
5,001 – 10,000	
11,001 – 15,000	
15,001 – 20,000	
20,001 and more	

3. Please state your job title in company? _____

4. Could you please describe your main activities within your company (Please list them)?

5. How long have you been working as a middle manager for this company?

Less than 5 years	
6 – 10 years	
11 – 15 years	
16 – 20 years	
21 – 25 years	
More than 25 years	

6. How much previous experience do you have as a middle manager with this or another company?

Less than 5 years	
6 – 10 years	
11 – 15 years	
16 – 20 years	
21 – 25 years	
More than 25 years	

Part 2:Decision -making in normal conditions

7. Please rank the following options based on priority in your job. (1 is the highest priority, 5 the lowest)

Safety & Environment	
Meeting deadlines	

Profit and lost performance	
Succession development	
A well run site	

Other (please specify): _____

8. Please order the following options according to the time they cost you during one working week .(1 is the highest, 5 lowest)

Safety& environment	
Meeting deadlines	
Profit and lost performance	
Succession development	
A well run site	

9. To what extent do you make or do you engage in following decisions?

	Very Low	Low	Moderate	High	Very High
Technical decisions					
Operational decisions					
Designing decisions					
Safety decisions					
Financial decisions					
Training decisions					
Planning decisions					
Security decisions					
Staffing and de-staffing					

Other (please specify): _____

10. How are safety decisions in your company typically made (more than one option is possible)?

Individual manager's decision	
Group consensus	
Voting	

Other (please specify): _____

11. To what extent do you do play the following roles in strategic safety decisions?

	Very Low	Low	Moderate	High	Very High
I present the criteria to top management					
I introduce alternatives to top management					
I blend strategic and hands-on information					
I facilitate safety training					
I share information between top and operational management					
I revise and adjust their decisions to be applicable					

Other (please specify): _____

12. Which of the following statements are correct when you make a decision?(checking more than one option is possible)

I follow the rules whether I agree with them or not	
I do not comply to the rules if my supervisor agrees with it	
I follow the rules regardless of their consequences	
I do not follow the rules when I think it might influence safety negatively	

I act the same way with the rules as my colleagues do	

Other (please specify): _____

13.How do you measure safety risks? (more than one option is possible)

I use classical risk matrices as the risk criteria for my decision	
I use my own assessment of probability and consequences of events	
I generally act based on the basis of an appreciation of the entire probability distribution of the potential outcomes	
I rather use the summary statistics that represent the underlying probability densities	
I rather concern on the outcomes of accidents (scenarios)	

Others (please specify): _____

14.To what extent do you consider following objectives to optimize safety in your decisions?

Performance	Very Low	Low	Moderate	High	Very High
Costs (overall)					
Losses (potential overall)					
Losses - given severe conditions					
Losses - given rare conditions					
Losses - given the worst case scenario					
Probability (loss exceeds a fixed threshold)					

Other (please specify): _____

15.To what extend do you take into account following aspects in safety decisions?

	Very Low	Low	Moderate	High	Very High
Political conditions (global & local)					
Economic conditions (global & local)					
Laws and regulations related to safety, health & environmental protection					
Health, safety & environmental risks of products					
Health, safety & environmental risks of logistical activities					
Preparedness for emergency situation					
Health, safety & environmental impact of contractors					
Relationships with stakeholders					

Other (please specify): _____

16. Your choice of the best policy for management of risks depends on: (more than one option is possible, in this case rank them based on your priority)(NB.1 is the highest)

Minimization of the risks	
Minimization of the risk without exceeding the expected cost	
The efficiency of chosen policy/method to operationalize the objective	
Your prior experience in evaluating the real, familiar alternatives	

Other (please specify): _____

17.Which of the following models do you use for evaluation of consequences in safety risk assessment.(more than one option is possible)?

Cost-benefit analysis	
Fuzzy Decision Models	
Analytical Hierarchical Process	
Risk Sensitivity	
Simulation models	
Consequence assessment models	
None of them	

Other (please specify): _____

18. Who makes the final decision to implement control actions after evaluation of safety risks?

If it is a risk related to me (my department), the decision depends on my preferences	
It depends on the CEO's decision	
A team involving me and the other managers from different departments at the same level as me	
A team of managers involving me and other managers who are both higher and lower than me	
A team of managers, but I am not involved in these kinds of decisions	

Other (please specify): _____

19. Does safety ever slip off your agenda when there is competition?

	Never	Rarely	Occasionally	Sometimes	Often
Safety slips off my agenda					

20. If yes, Could you please describe one or more occasions when it happened - what was the situation and why did this happen?

21. Could you describe the actions that you took into account when safety and production came into conflict?

22. If your profit is less than the organization's goal for a time-period, what are you doing in the safety area to improve profits?

I concentrate on the mandatory safety requirements to prevent accidents	
I invest less in solely safety-enhancing processes and practices for a short time,	

but when we return to the organizational profit level, we invest more on safety in compensation	
I try to enhance profitability by extending the time between preventative maintenance or delaying shutdowns	
I try to meet the organization's performance goals without considering priority for particular scopes such as profitability or safety	
I continue to spend the same amount of resources on safety as before	

Other (please specify): _____

23. How much is your discretionary spend ? How much you can spend without requiring a decision or signature of a higher level?

None	
Up to $1000	
Up to $10,000	
Up to $100,000	
Up to $1,000,000	
Above $1,000,000	

Part 3:Decision making in emergency conditions

24. What was the worst accident you were involved in personally? This can be as a manager, supervisor or close bystander.. Could you please describe the situation)?
25. To what extent did you face with the following conditions during decision-making in this accident (more than one option is possible)?

	Very Low	Low	Moderate	High	Very High
All the information was not available at the time of formulating the decision					
Situations in which your decision would have turned out differently					
You were uncertain about the reliability of information					
You were uncertain about the relevance of available information					
You were uncertain about the appropriateness of the decision					
You found it was difficult to process and integrate the available information					
You were reminded of previous experiences in which a similar decision was made					
You were reminded of previous experiences in which a different decision was made					

Other (please specify): _____

26. To what extent are the following statements correct about decisions made during the course of the incident?

	Very Low	Low	Moderate	High	Very High
If I had another alternative available, I could have made a better decision					
If I had access to more information, I could have a better decision					

If I had more authority, I would have made a better decision					
If I had more resources I would have made a better decision					
If I had more time I could make a better decision					
If the environmental condition wasn't so bad, I would have made a better decision					
I expected to make this kind of decision					

27. Do you think that you could develop a rule or guideline, based on your experience, which could assist another person to make the same decision successfully?

Yes	
No	

28. If yes, Could you please describe what is this?
29. Do you think that anyone else would be able to use this rule successfully? Why? if not why not?
30. Is there anything else you would like to add that we haven't covered already?

Do you wish to receive the report of this project? If yes, please state your email address?

Thank you for participation and cooperation.

Summary

The purpose of this study was to explore the role of middle management in safety within hazardous industries such as the oil and gas industries. In so doing, the study has answered the main research question, what are the roles and responsibilities of middle managers in risk management and safety oriented decision-making?

To achieve the objectives of safety management, which are primarily the protection of personnel, environment and assets, it is essential to understand the organisational context. An organisation is constructed from different layers of management with interlinked and complex roles. Middle management, who occupy the middle-level positions, is a fundamental management level in an organisation because they are informed managers, operating between people who have a narrow vision which is limited by their own segments, typically front line operatives, and the top/central executive management, who have a broad picture of an organisation that may be unclear as a result of their distance from the operation.

By applying both theoretical and empirical grounding processes, we outlined the relevant knowledge about the role of middle management in safety and the decision-making principles required to develop a decision-making framework in a hazardous process industry. The theoretical grounding process, as described in Chapter 3, was meant to identify the roles of middle managers in safety. It started with defining the concept of middle management. Then the roles of middle managers are discussed. A literature review showed that middle management acts as a crucial link between top-level management and lower levels by providing valuable coordination functions. Middle managers decide by solving more immediate and smaller problems on a daily or weekly basis, than do senior managers, who concentrate on strategic decisions. They bridge policy makers and policy achievers. Despite the potential of middle managers to influence safety management in hazardous industries, the lack of any systematic research and the lack of empirical evidence on the role of middle managers in safety performance are outlined in this chapter.

The theoretical constructs of the decision-making concept are evaluated in Chapter 4 to identify the best decision-making model in safety. The results of the theoretical grounding process have revealed that common analytical decision-making methods are available in safety management to facilitate and to promote decision-making in the risk assessment. They assume decision makers with predetermined criteria and options, so the decision-maker's task is solely the selection of an option among other options based on these predetermined criteria. However, those methods are unable to support decision makers in managing disruptions in abnormal and emergency conditions that are inevitable in a hazardous process industry. A

second group of decision-making models, descriptive decision-making models, are primarily concerned with special jobs like firefighters, commanders, and doctors. They focused on evaluation of decision-making process, considering environmental factors such as time and resource limitations, without taking into account other roles of decision makers. It seems that they assumed decisions are made in isolation from other activities. We argue that two views of decision-making models should not be seen as independent and separate models. Rather they must be regarded as interconnected. Finally, the lack of any studies that uncover decision-making processes in management under real conditions justifies the current research on real-time decision-making evaluation. For analysing the data both activity theory and research software were applied.

After the theoretical analysis, we conducted the empirical part of the study to clarify the roles of middle management and the process of decision-making. To this end, a multi-research method was conducted in several contexts, namely, an oil and gas company (NOC) in Iran, a gas production company as well as a chemical industry in the Netherlands, and an aerospace research center in Iran. Regardless of their different contextual conditions, all cases shared the same characteristics of the workplace as they are high hazard industry with similar processes. We applied multiple methods, such as accident investigation analysis, blogs in linked-in and a questionnaire which all failed to provide appropriate data to obtain any deep insight. Other methods, for instance an interview and a task recording method worked effectively in this research. The task recording was designed as a main source of collecting qualitative data. Finally, to address the research questions more comprehensively we analysed the US Chemical Safety Board completed investigation reports in their oil and gas section.

The results of the empirical part reveal that middle managers are doing multiple roles, based on a well-known taxonomy of managerial roles. The spokesperson (40.71%), leadership (23.49%), monitor (11.95%), and disturbance handler (10.69%) roles had the highest frequency among ten roles. Middle managers also perform both internal and external roles. Additionally, the disturbance handler role, which is among the decisional roles were of high frequency. In safety, we are often faced with conditions that deviate from abnormal conditions. So some roles like leadership, disturbance handler, and informational roles are more important than others. Accessibility to information in short time intervals and more informational sources about process parameters and failures in equipment enhance the identification of safety risks by middle managers. Consequently, they can make more accurate and effective decisions in safety issues. They act as informal safety auditors and provide 'soft' alarm systems in safety management. Finally, they are actively involved in control of the process safety.

The analysis of decisions in Chapters 6 and 7 pinpointed that safety-related decisions had the highest frequency of various decisions taken in the NOC context. Middle managers were

involved in various decisions in organisations. Middle managers did not apply the common scientific rational decision-making techniques such as AHP and Fuzzy decision-making; they were even not familiar with those decision-making techniques, confirming an apparent gap between theory and practice.

Instead, middle managers considered a limited number of alternatives (less than three in 100% of decisions) and a limited number of criteria (less than three criteria in 80% of decisions) which supports the notion of bounded rationality. Similar to the medical domain, in safety-related decisions, middle managers relied on small samples and they had a tendency to avoid the worst outcomes rather than being driven by the actual probability because there was not enough data that could support decision-making for rare events with high uncertainty and less knowledge about the environment. In addition, managers did not weight options based on a mathematical framework. Instead, they use their own judgment and the method of weighting was influenced by the organisational context such as the culture of the organisation, regulation and stakeholders which influence the process of priority setting of objectives.

Middle managers took both risk-based decisions and rule-based decisions; however, rule-based decisions were more frequent than risk-based decisions in the NOC company. In agreement with Hopkins, we argued that rule-based decision-making is more accurate in the safety domain since it is a deterministic approach that decision makers do not deviate from without having clear criteria to make decisions. In this way, middle managers overcome the limitations of conventional risk assessment methods in which it is not feasible to carry out a comprehensive numerical risk assessment. It prevents confirmation bias for non-routine tasks. It avoids conducting a difficult risk assessment where risk-based decision-making, which is coupled with a set of budget priorities, makes it very difficult to give a greater weight to process safety compared to expenditure. Besides, the risk-based approach in which a risk is a product of likelihood and consequence fails to show the accurate level of risk in some process risks when their likelihood is extremely low. Finally, there is a level of uncertainty about risk assessments even they are made by experts and competent people.

One significant emerging result was the type of decisions that consisted of both parallel and serial decisions. It means that decision-makers make the final decision by either eliminating other alternatives until only one alternative remained (sequential); or sometimes the final decision involved applying two or multiple options at the same time. Then they take actions or order to take actions simultaneously for selective alternatives until they are certainly sure that one option is working better or faster than other alternatives. Otherwise, they continue to perform several options in parallel simultaneously. It is a beneficial strategy that both overcomes the uncertainty and can also limit the decision costs. This kind of dynamic decision-making is particularly appropriate in abnormal and emergency conditions when the probability of happening alternatives are equal and options are middle-truth-value.

The results also showed the possibility of some decision-making biases, like the confirmation and availability biases, that can lead to catastrophic outcomes. Finally, middle managers were mainly involved in consensus group decisions rather than combined decisions or individual decisions.

After capturing the theoretical and practical insights, we developed a consensus decision-making framework in an organisation that represents essential elements in consensus decision-making including conflict, communication, multiple decision-makers and outcomes. There is one essential factor – conflict - in decision-making that has not attracted much attention in decision-making research, while the data analysis in this PhD research illustrated that it is an inevitable element in decision-making. The resulting decision-making framework provides a theoretical and practical roadmap to managers, decision-makers, safety experts, IT, and learning intervention in workplace settings.

Samenvatting

Het doel van deze studie was om de rol van middenmanagement bij veiligheidsvraagstukken in gevaarlijke industrieën, zoals de olie- en gasindustrie, te onderzoeken. Daarbij heeft de studie als belangrijkste onderzoeksvraag wat de rollen en verantwoordelijkheden van middenmanagers zijn op het gebied van risicobeheer en veiligheidsgerichte besluitvorming, beantwoord.

Om de doelstellingen van veiligheidsmanagement, die in de eerste plaats de bescherming van personeel, milieu en middelen zijn, te bereiken, is het van essentieel belang om de organisatorische context te begrijpen. Een organisatie is opgebouwd uit verschillende managementlagen met onderling verbonden en complexe rollen. Middenmanagers, die de middenposities innemen, is een fundamenteel managementniveau in een organisatie omdat het goed geïnformeerde managers zijn die opereren tussen mensen met een nauwe visie die wordt beperkt door hun eigen domeinen, meestal frontlijnmedewerkers en de top / centraal uitvoerend management, die een breed beeld hebben van een organisatie, die mogelijk onduidelijk is als gevolg van hun afstand tot de operatie.

Door zowel theoretische - als empirische basisprocessen toe te passen, schetsten we de relevante kennis over de rol van middenmanagement in veiligheid en de besluitvormingsprincipes die nodig zijn om een beslissingskader in een gevaarlijke procesindustrie te ontwikkelen. Het theoretische basisproces, zoals beschreven in hoofdstuk 3, was bedoeld om de rol van middenmanagers in veiligheid te identificeren. Het begon met het definiëren van het concept van middenmanagement. Vervolgens worden de rollen van middenmanagers besproken. Uit een literatuuronderzoek bleek dat het middenmanagement een cruciale schakel vormt tussen topmanagement en lagere niveaus door waardevolle coördinatiefuncties te bieden. Middenmanagers beslissen door meer directe en kleinere problemen dagelijks of wekelijks op te lossen dan senior managers die zich concentreren op strategische beslissingen. Ze overbruggen beleidsmakers en bestuurders. Ondanks het potentieel van middenmanagers om het veiligheidsmanagement in gevaarlijke industrieën te beïnvloeden, wordt in dit hoofdstuk het ontbreken van systematisch onderzoek en het gebrek aan empirisch bewijsmateriaal over de rol van middenmanagers in veiligheidsprestaties beschreven.

De theoretische constructies van het besluitvormingsconcept worden geëvalueerd in hoofdstuk 4 om het beste besluitvormingsmodel in veiligheid te identificeren. De resultaten van het theoretische basisproces hebben aangetoond dat gemeenschappelijke analytische besluitvormingsmethoden worden toegepast om de besluitvorming bij de risicobeoordeling van veiligheidsvraagstukken te vergemakkelijken en te bevorderen. Ze gaan uit van beslissers met vooraf bepaalde criteria en opties, dus de taak van de beslisser is uitsluitend de selectie

van een optie uit andere opties op basis van deze vooraf bepaalde criteria. Echter, deze methoden kunnen besluitvormers niet ondersteunen bij het beheer van verstoringen in abnormale en noodsituaties die onvermijdelijk zijn in een gevaarlijke procesindustrie. Een tweede groep besluitvormingsmodellen, beschrijvende besluitvormingsmodellen, houdt zich in de eerste plaats bezig met speciale banen zoals brandweerlieden, commandanten en artsen. Ze concentreerden zich op de evaluatie van het besluitvormingsproces, rekening houdend met omgevingsfactoren zoals tijd- en beperkingen in middelen, zonder rekening te houden met andere rollen van besluitvormers. Het lijkt erop dat ze ervan uitgaan dat beslissingen worden genomen in isolatie van andere activiteiten. Wij stellen dat twee opvattingen over beslissingsmodellen niet als onafhankelijke en afzonderlijke modellen moeten worden gezien. Veeleer moeten ze als onderling verbonden worden beschouwd. Ten slotte rechtvaardigt het ontbreken van studies die besluitvormingsprocessen in management onder reële omstandigheden blootleggen, het huidige onderzoek naar realtime evaluatie van de besluitvorming. Voor het analyseren van de gegevens werden zowel activiteitentheorie als onderzoekssoftware toegepast.

Na de theoretische analyse hebben we het empirische deel van het onderzoek uitgevoerd om de rollen van het middenkader en het besluitvormingsproces te verduidelijken. Hiertoe werd een multi-onderzoeksmethode uitgevoerd in verschillende contexten, namelijk een nationaal olie- en gasbedrijf (NOC) in Iran, een gasproductiebedrijf en een chemische fabriek in Nederland, en een ruimtevaartonderzoekscentrum in Iran. Ongeacht hun verschillende contextuele omstandigheden, in alle gevallen deelden zij dezelfde kenmerken van de werkplek zijnde hoog risico-industrie met vergelijkbare processen. We hebben verschillende methoden toegepast, zoals ongevalsonderzoeksanalyse, blogs in Linked-in en een vragenlijst, die echter allen niet de juiste gegevens opleverde om diepgaand inzicht te verkrijgen. Andere methoden, zoals een interview en een methode voor taakregistratie, werkten effectief in dit onderzoek. De taakregistratie is ontworpen als een hoofdbron voor het verzamelen van kwalitatieve gegevens. Tot slot, om de onderzoeksvragen vollediger aan te pakken, hebben we door de Amerikaanse chemische onderzoeksraad voor de veiligheid (CSB) ingevulde onderzoeksrapporten in hun olie- en gassectie geanalyseerd.

De resultaten van het empirische deel laten zien dat middenmanagers meerdere rollen vervullen, gebaseerd op een bekende taxonomie van managementrollen. De woordvoerdersrol (40,71%), leiderschapsrol (23,49%), monitoringsrol (11,95%) en behandelaarsrol van verstoringen (10,69%) hadden de hoogste frequentie in tien rollen. Middenmanagers vervullen ook zowel interne als externe rollen. Bovendien was de rol van de verstoringsbehandelaar, die tot de beslissingsrollen behoort, van hoge frequentie. In veiligheid worden we vaak geconfronteerd met omstandigheden die afwijken van abnormale omstandigheden. Sommige rollen zoals leiderschap, behandelaar en informatierollen zijn dus belangrijker dan andere. Toegankelijkheid van informatie in korte tijdsintervallen en meer

informatiebronnen over procesparameters en storingen in apparatuur verbeteren de identificatie van veiligheidsrisico's door middelmanagers. Bijgevolg kunnen zij nauwkeurigere en effectievere beslissingen nemen over veiligheidskwesties. Ze fungeren als informele veiligheidsauditors en bieden 'zachte' alarmsystemen in veiligheidsmanagement. Ten slotte zijn ze actief betrokken bij de beheersing van de procesveiligheid.

De analyse van beslissingen in Hoofdstukken 6 en 7 wees uit dat veiligheidsgerelateerde beslissingen de hoogste frequentie hadden van verschillende beslissingen genomen in de NOC-context. Middenmanagers waren betrokken bij verschillende beslissingen in organisaties. Middenmanagers pasten de gemeenschappelijke wetenschappelijke rationele besluitvormingstechnieken zoals AHP en Fuzzy-besluitvorming niet toe; ze waren zelfs niet bekend met die besluitvormende technieken, dat een kennelijke kloof tussen theorie en praktijk bevestigt.

In plaats daarvan beschouwden middenmanagers een beperkt aantal alternatieven (minder dan drie bij 100% van de beslissingen) en een beperkt aantal criteria (minder dan drie criteria in 80% van de beslissingen) die het concept van begrensde rationaliteit ondersteunen. Net als bij het medische domein vertrouwden middenmanagers in veiligheidsgerelateerde beslissingen op kleine steekproeven en ze hadden de neiging om de ergste uitkomsten te vermijden in plaats van te worden gedreven door de werkelijke waarschijnlijkheid, omdat er niet genoeg gegevens waren die beslissingen voor zeldzame gebeurtenissen met veel onzekerheid en weinig kennis over het milieu konden ondersteunen. Bovendien hebben managers de opties niet afgewogen op basis van een wiskundig kader. In plaats daarvan gebruiken ze hun eigen oordeel en werd de wegingsmethode beïnvloed door de organisatorische context zoals de cultuur van de organisatie, regelgeving en belanghebbenden die van invloed zijn op het proces van de prioritering van doelen.

Middenmanagers namen zowel risico-gebaseerde beslissingen als op regels gebaseerde beslissingen. Op regels gebaseerde beslissingen kwamen echter vaker voor dan op risico gebaseerde beslissingen in het NOC-bedrijf. In overeenstemming met Hopkins voerden we aan dat regelgebaseerde besluitvorming meer accuraat is in het veiligheidsdomein, omdat het een deterministische benadering is waar besluitvormers niet van afwijken zonder duidelijke criteria te hebben om beslissingen te nemen. Op deze manier overwinnen middenmanagers de beperkingen van conventionele risicobeoordelingsmethoden waarbij het niet haalbaar is om een uitgebreide numerieke risicobeoordeling uit te voeren. Het voorkomt voorkeur voor bevestiging voor niet-routinematige taken. Het voorkomt ook de uitvoering van een moeilijke risicobeoordeling, waarbij risicogeoriënteerde besluitvorming gekoppeld aan een reeks begrotingsprioriteiten, het zeer moeilijk maakt om de procesveiligheid meer gewicht te geven in vergelijking met de uitgaven voor veiligheidsmaatregelen. Bovendien laat de op risico gebaseerde benadering waarbij een risico een product is van waarschijnlijkheid en gevolg,

niet het juiste risiconiveau in sommige procesrisico's zien wanneer hun waarschijnlijkheid extreem laag is. Ten slotte bestaat er een zekere mate van onzekerheid over risicobeoordelingen, zelfs als deze worden uitgevoerd door deskundigen en bekwame mensen.

Een belangrijk nieuw resultaat was het type beslissingen dat bestond uit zowel parallelle als seriële beslissingen. Het betekent dat besluitvormers de uiteindelijke beslissing nemen door andere alternatieven te elimineren totdat er slechts één alternatief overblijft (sequentieel); of soms was de uiteindelijke beslissing twee of meerdere opties tegelijkertijd toepassen. Vervolgens ondernemen ze acties of bevelen ze tegelijkertijd acties te ondernemen voor selectieve alternatieven tot ze er zeker van zijn dat een optie beter of sneller werkt dan andere alternatieven. Anders blijven ze verschillende opties tegelijkertijd parallel uitvoeren. Het is een gunstige strategie die zowel de onzekerheid overwint als de kosten voor beslissingen kan beperken. Dit soort dynamische besluitvorming is met name geschikt in abnormale en noodsituaties wanneer de waarschijnlijkheid van de alternatieven die goed gaan gelijk is en de opties zijn 'middle-truth-value'.

De resultaten toonden ook de mogelijkheid van een aantal beslissingsvooroordelen, zoals de voorkeur voor bevestiging en beschikbaarheid, die tot catastrofale uitkomsten kunnen leiden. Tenslotte waren middenmanagers vooral betrokken bij besluiten van consensusgroepen in plaats van gecombineerde beslissingen of individuele beslissingen.

Na het vastleggen van de theoretische en praktische inzichten hebben we een consensus beslissingskader ontwikkeld in een organisatie die essentiële elementen vertegenwoordigt in consensusbesluitvorming, waaronder conflict, communicatie, meerdere besluitvormers en uitkomsten. Er is één essentiële factor - conflict - in de besluitvorming die niet veel aandacht heeft getrokken in besluitvormingsonderzoek, terwijl de gegevensanalyse in dit promotieonderzoek aantoont dat het een onvermijdelijk element in de besluitvorming is. Het resulterende besluitvormingskader biedt een theoretische en praktische routekaart voor managers, beslissers, veiligheidsexperts, IT en leerinterventies op de werkplek.

Curriculum Vita

Zahra Rezvani was born in Neyshabour, Iran on August 1th, 1974.She followed her first 12 years of school in Neyshabour. After graduating from high school, she took the first great step in her life by one big mistake in entering the code of field of study. She went to Tehran University of Iran, the first rank University among Medical Sciences Universities in Iran, to study Occupational Health instead of Medicine. She graduated and her M.Sc thesis was on the design and building a pilot scale biofilter system for elimination of aromatic air pollutants such as toluene and xylene. She graduated with a Masters degree (Cum laude) in 2001. Meanwhile, she was a safety and occupational advisor in Gyah Corporation that produces Agricultural and Chemical Products.

Shortly after graduation, she was employed as an academic member of Health faculty at Kurdistan University of Medical Sciences. She had appointed to as a lecturer at the Environmental Health Department. In 2003, she joined to Health faculty of Ahwaz Jondishapour University of Medical Sciences. She has appointed as a lecturer in Department of Occupational Health for a 7 years, while she was responsible to teach and supervise air pollution and safety courses for the undergraduate students. She also was the manager of Occupational Health group consisting 4 laboratories. In this period she supervised two master thesis in Islamic Azad University, Science and Research Branch, Ahwaz.

In 2011, Zahra took another major step, after passing a competitive exam, she received a Ph.D. scholarship from the Iranian Ministry of Health and Medical Education, and accordingly she joined the Faculty of Technology, policy, and, Management (TPM) at Delft University of Technology to start her Ph.D. research abroad. She completed her thesis on "Breaking the clay layer: Role of middle managers in safety management applying decision-making lens."