Human factors influencing decision-making: tendencies from first-line management decisions and implications to reduce major accidents

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ABSTRACT: Decision-making processes are in the helm of organisations, constituting an essential capability to promote companies' missions. Major accidents, however, can deeply affect the continuity of operations, and many of the findings arising from recent investigation reports relate to poor managerial decisions, triggering operational sequences which result in undesirable outcomes. Thus, the purpose of this study is to analyse first-line management decisions, in order to reveal common patterns affecting human factors and improve decision-making processes. Management decisions from the worst accident occurred in offshore Brazilian waters in the past fifteen years are scrutinised, using the publicly-available investigation report from the regulatory bodies as basis. Then, a data mining approach will be applied to a major-accident dataset, and analogous tendencies are revealed and compared with the case study. Problems arising from human factors associated with the lack of managerial rules and principles are investigated, and implications to improve decision-making processes are discussed.

1 INTRODUCTION

Decision-making processes are in the helm of organisations, constituting an essential capability to promote companies' mission and objectives. Although researchers exploring the fundamental causes of disasters (Pigeon & O'Leary, 2000, Hopkins, 2005) indicated that keeping the focus on top management is crucial, it seems to be reasonable to assume that a successful safety program will rely on the implementation capacity and on numerous local decisions from lower hierarchical levels. Many of these decisions are not trivial and involve constant trade-offs between safety, productivity and quality requirements. These trade-offs, particularly the conflict between safety goals and production, were summarised by Reason (2000), who pointed out an interesting paradox: although both safety and production are deemed to be equally indispensable, production is, in reality, the attribute that pays the bills. Therefore, while responsible for guiding employees, directing everyday objectives and dealing with production efficiency and safety, first-line management is expected to deliver satisfactory (and sometimes daily) results to upper hierarchical levels, mainly concerning companies' pre-defined productivity goals.

Major accidents, however, can deeply affect the continuity of operations and put an end to productivity goals, dramatically shifting the stakeholders' attention from periodic and consistent productivity indicators (e.g. barrels per day, in an offshore production platform) to the search for causes of the adverse event. Many of the findings arising from some well-known recent investigation reports (e.g. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011, Kurokawa, 2012) relate to poor managerial decisions in all hierarchical levels, which triggered operational arrangements that resulted in undesirable outcomes.

In February 2015, an explosion at the Floating, Production, Storage and Offloading Unit Cidade de São Mateus (FPSO CDSM) resulted in the most shocking accident occurring offshore Brazil in the last decade, and one of the top-three worst offshore disasters in Brazilian Offshore Oil & Gas history. Nine people passed away, and twenty-six workers sustained from minor to serious injuries after a hydrocarbon leakage and its consequent ignition at the FPSO's pump room. The facility was producing non-associated gas and condensate by the time of the event. The investigation from the Oil & Gas regulator (ANP, 2015) identified seven causal factors and twenty-eight root-causes, highlighting inadequate managerial decisions which exposed the facility to unmanaged risks. The investigation report from the Maritime Authority (DPC, 2015) mentioned that inconsistencies from the safety management system gave room for improvised decisions, ultimately resulting in non-conformities. Those supposedly flawed decisions involved middle and operational management working in the field, where dealing with dynamic pressures related to the facilities' result (e.g. time constraints to solve a failure, improper incentives) can be a substantial challenge.

The conclusions arising from those investigations leave us with some important questions regarding decision-making processes and the practicability of adopting alternative approaches to ensure facilities are designed and operated in a safer way. To what extent were these decisions actually poor, in the face of organisational scenarios and operational challenges encountered by decision-makers? Were these decisions improvised and unreasoned, or did they follow a well-defined and recognisable pattern, which could be considered natural and predictable if the outcome was different? How can we turn people in-between top management and workers at the sharp-end of operations into better decision-makers?

The overriding purpose of the current work is to analyse decision-making processes by using the real-life event that occurred in offshore Brazil waters to uncover the intricate conditions leading to questionable (at least in hindsight) human decisions. The ultimate objective is to give some indications on how to tackle decision-making limitations by improving managerial rules and principles.

2 ANALYSIS METHOD

Moura el al. (2016) developed a major-accident dataset, which contains 238 disasters from different high-technology industrial sectors, including nuclear, aviation and oil & gas. The Multi-attribute Technological Accidents Dataset (MATA-D) was fed with information from detailed investigation processes conducted by independent investigation commissions, regulators, insurance companies and experts, in order to disclose the circumstances surrounding the undesirable events and prevent their reoccurrence. Although each investigation team followed particular directives, procedures and terminology to scrutinise the major accidents, the dataset classification method based on Hollnagel (1998) facilitates the application of a single framework, allowing the comparison of events from different industries and the search for common patterns. Previous work (Moura et al., 2017) successfully applied a clustering approach, i.e. Kohonen (2001) self-organising-maps, to identify major design shortcomings and develop a checklist focused on the improvement of design. The development of this design checklist was based on common features identified in Cluster 3, where accidents containing design failures interfaced with human factors in most of the grouping cases. Figure 1 presents the clusters' arrangement after the application of the self-organising maps algorithm.

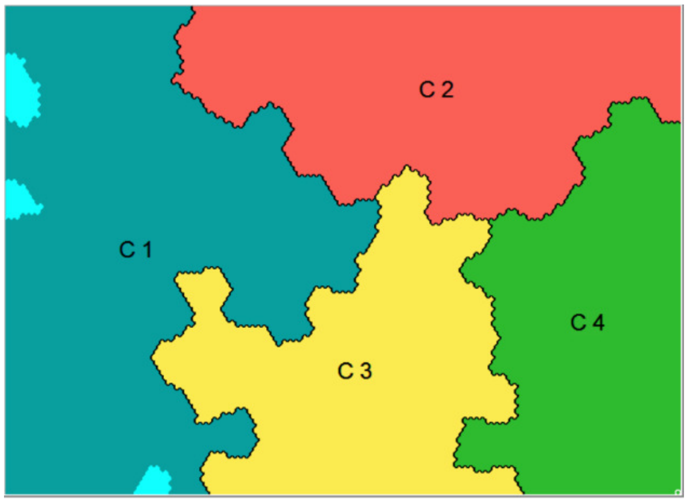

Figure 1. MATA-D Clustering Results using SOM, adapted from Moura et al. (2017)

The SOM data mining results will be revisited, in an attempt to disclose new links associated with decision-making processes and support the understanding of critical FPSO Cidade de São Mateus management decisions prior to the major event occurred in February 2015. Examples from the cluster of interest will be given, in order to illustrate similarities. The reports on the FPSO CDSM accident (ANP, 2015, DPC, 2015) provide very detailed information about the disaster, based on engineering analysis of the facility, examination of documents and investigative interviewing of company staff in different hierarchical levels.

Therefore, after presenting the intricate interactions among different levels of an offshore production oil & gas facility management, basic responsibilities regarding safety will be assigned, in order to make the decision-making process exposed for further analysis. Based on the aforementioned in-depth accident accounts, critical decisions which were identified as contributing factors or root-causes of the event will be highlighted.

The deficiencies in the case study decision-making process will be then considered in the light of the tendencies disclosed by the application of the SOM algorithm, in order to enable the discussion of inherent conditions which increase the likelihood of flawed judgments and mistaken choices in a high-technology industrial facility.

3 RESULTS

3.1 *MATA-D mining for decision-making shortcomings*

In the current work, the intention is to recognise common patterns associated with decision-making processes. In this regard, the statistical results from the SOM map indicated that Cluster 1 was dominated by the contributing factor named "Inadequate Task Allocation", identified in 95% of the cases within this grouping (Cluster 1's shadowed region in Figure 1).

The overwhelming incidence of this factor highlights situations where managerial instructions were poor and lacked clear rules or principles, task planning was largely inadequate and/or work execution directives were poor. Table 1 presents the leading features for Cluster 1, which contains 80 major accidents. Contributing factors in italic attained slightly higher scores in other clusters, but were still significant for the grouping.

Table 1: SOM Cluster 1 Main Statistical Results

Human Factors	Execution Error	Wrong Place	52.50%
	Specific Cognitive Functions	*Observation Missed*	*20.00%*
		Faulty diagnosis	26.30%
		Wrong reasoning	*20.00%*
	Temporary person-related functions	Distraction	11.30%
	Permanent person-related functions	Cognitive bias	15.00%
Technology	Procedures	Inadeq. procedure	78.70%
	Interface	Incomplete info	36.20%
Organisation	Communication	*Communic. failure*	*16.30%*
		Missing information	37.50%
	Organisation	Maintenance failure	56.30%
		Inadeq. quality ctrl.	81.30%
		Design failure	*85.00%*
		Inadeq. task alloc.	**95.00%**
		Social pressure	17.50%
	Training	*Insufficient skills*	*56.30%*
		Insufficient knowledge	60.00%
	Working Conditions	Irregular working hours	10.00%

In Cluster 1, the map region occupied by the Inadequate Task Allocation factor was combined with design shortcomings, quality control problems, maintenance failures, training issues and communication difficulties, from an organisational perspective. The most relevant technological problem was having inadequate (incomplete or ambiguous) procedures. Inaccuracies in sequences of operational actions due to incorrect diagnosis of a situation or a faulty reasoning were also frequent.

3.2 *The Decision Structure at the FPSO CDSM*

The Offshore Installation Manager is typically the top authority on-board and the designated Offshore Incident Commander in case of an emergency. He is the key decision-maker and his personal judgment will direct the response efforts. Thus, his decisions will be now defined, considering the existing information and the available choices.

The standard organisation of a Production Oil & Gas Platform (Figure 2) is instantly transformed to respond an emergency, according to previous definition from the company's Emergency Plan. Figure 3 depicts the new roles for the operating staff.

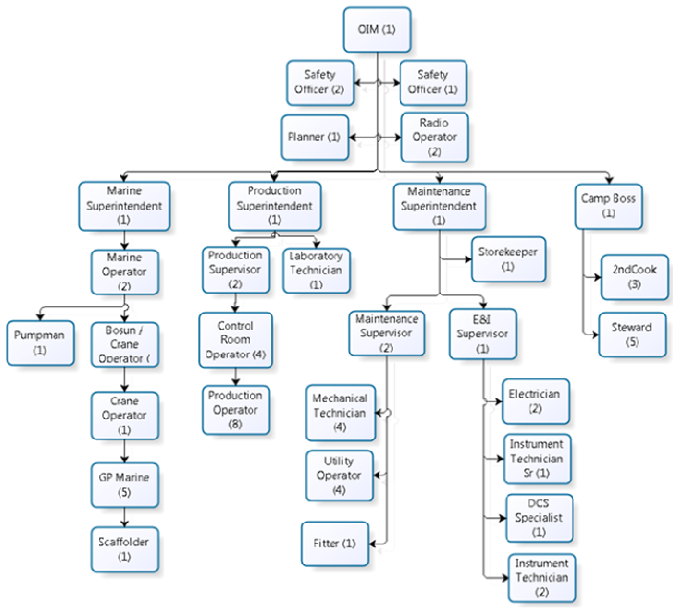

Figure 2 - Standard Organisational Chart, after ANP (2015)

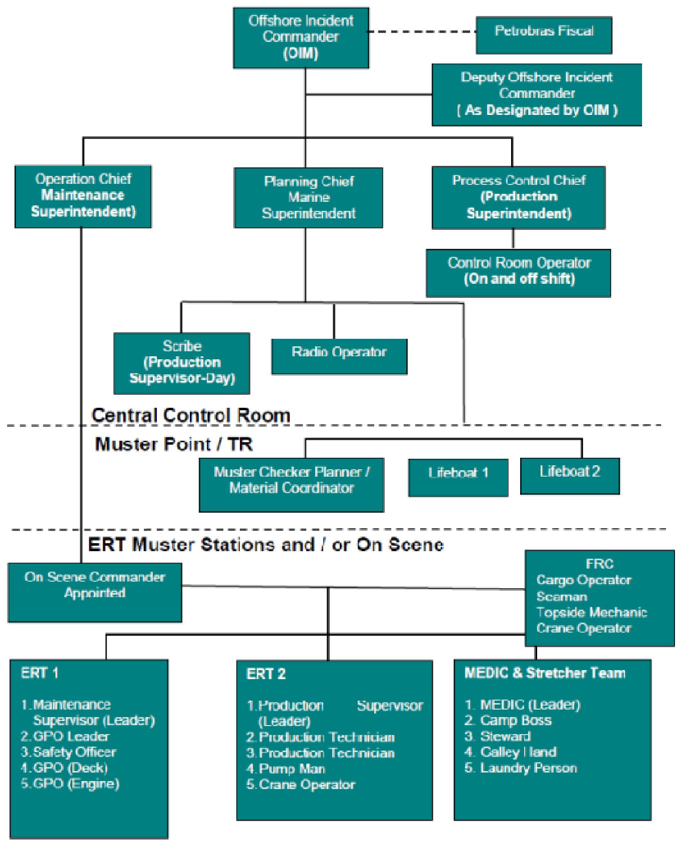

Figure 3 - Emergency Response Organisational Chart, after ANP (2015)

Three groups were effectively involved in the Offshore Installation Manager decisions in the case study: (i) the Decision Board; (ii) the Emergency Response Team; and (iii) the Technical Advisory Response Team. The decision-making response structure for the FPSO CDSM is typical, having well-defined actors to pick a solution, to discuss options and recommend alternatives, to provide technical information about potential choices and their effects, and to confirm the capability and execute a sequence of tasks. Table 2 relates the FPSO CDSM personnel functions with standard roles of a classic decision or problem-solving structure.

Table 2: FPSO CDSM Decision Structure, adapted from Herrmann (2015)

FPSO CDSM Personnel	Roles (Spetzler, 2007)	Roles (Rogers & Blenko, 2006)
- Offshore Installation Manager	- Decision-maker	- Decide
- Marine Sup. - Production Sup. - Maintenance Sup.	- Decision Staff	- Recommend Alternatives
- Technical Advisory Response Team - Emergency Response Team (x2)	- Content Experts - Implementers	- Provide Input - Agree (confirm feasibility) - Perform

The Decision Board was composed by the Offshore Installation Manager, the Marine Superintendent, the Production Superintendent and the Maintenance Superintendent. There were two Emergency Response Teams aboard, composed of five members of the crew and having Safety Officers as leaders. The technical advisory response team had been created by initiative of the Offshore Installation Manager and was not on the formal Emergency Response Plan of the platform. Based on his experience in other platforms, he felt that it would be useful to have a technical advisory team to be consulted upon particular topics. It was made of relevant technical staff, e.g. the Pump Man. The informal group has participated in the three decision meetings, and its members accompanied the on-site fire brigade to the Pump Room in all occasions.

Although the investigation report (ANP, 2015) had suggested that the Onshore Emergency Central was contacted as soon as the gas alarms sounded, there was input from the land staff to the Decision Board until the emergency had escalated after the explosion.

All decision meetings took place at the Central Control Room, and additional people (e.g. production supervisor, control room operators, radio operator) were available to perform any action and modify the production system configuration.

3.3 *Response for a multiple-alarm event in the FPSO CDSM Pump Room*

Dealing with a multiple-alarm indication in the Pump Room was a non-routine event, and its possible causes and effects were neither certain nor obvious to the crew. Formal emergency response procedures contained general instructions: (i) to deploy an equipped operator (with portable gas detector) to examine a single detection, or initiate general alarm for a multiple detection; (ii) use the Public Address System to announce an indication of a fire or gas release; (iii) Order a local evacuation in the single detection case, or direct personnel to muster points under a multiple detection; (iv) confirm the designed automatic shutdowns (only for multiple detection); (v) Inform the Offshore Installation Manager.

According to the ANP's (2015) investigation report, there were no further formal procedures, and the Offshore Incident Commander (the Offshore Installation Manager in the case study) was responsible for assessing the situation and deciding what to do, after the initial steps above. For that reason, the Emergency Response Plan was considered incomplete by the investigators, and thus one of the root-causes for the accident.

The first response group assembly took place approximately four minutes after multiple alarms sounded. It was attended by The Decision Board and the Technical Advisory Response Team. The supervisory control and data acquisition system had automatically isolated the Pump Room by closing the ventilation dampers and entering the air circulation mode (DPC, 2015). Also, visual and audible alarms were activated in the whole facility and the personnel were directed to the muster points by the Public Address System. The Onshore Emergency Centre was also informed. As the leaked substance and its volume were unknown, the Incident Commander ensured the pumps stoppage (to eliminate possible ignition sources and reduce the leakage) and deployed a response team (members from the official Emergency Response Team and from the informal Technical Advisory Response Team) to the Pump Room, in the search for additional information. Gas detectors were inhibited and alarms were silenced to facilitate radio communications.

The first response team successfully executed their mission and brought new information. They identified the leakage point (i.e. liquid dripping from a flange) and encountered a two square meters pool. The second decision meeting took place approximately fifteen minutes after the initial assembly. On this occasion, the Emergency Response Team joined the Technical Advisory Response Team and the Decision Board to evaluate the current situation. The Incident Commander decided to partially restore the ventilation system, in order to avoid any electrical overheating and maintain production, and a second team was deployed to the Pump Room to define the corrective measures required.

The second team accomplished their goal and communicated via radio the required tools for the repair implementation. The team left the Pump Room, allegedly to breathe fresh air, and the Emergency Response Team leader and one member of the Technical Advisory Response Team went to the Central Control Room to join the third decision meeting.

The third decision meeting occurred approximately fifteen minutes after the previous one. As a result, non-essential personnel were authorised to leave the muster points and have lunch. The necessary apparatus (e.g. absorbent pads, tools, fire hose, and ladder) to repair the piping joint was prepared, and a cleaning and repair team, composed of five workers, was sent to the Pump Room.

The cleaning and the repair activities were executed concurrently. During the cleaning, the absorbent pads were considered ineffective, and a water jet cleaning was initiated. After a request to increase the water jet pressure had been implemented, a major explosion occurred. Figure 4 represents the decision-making flow.

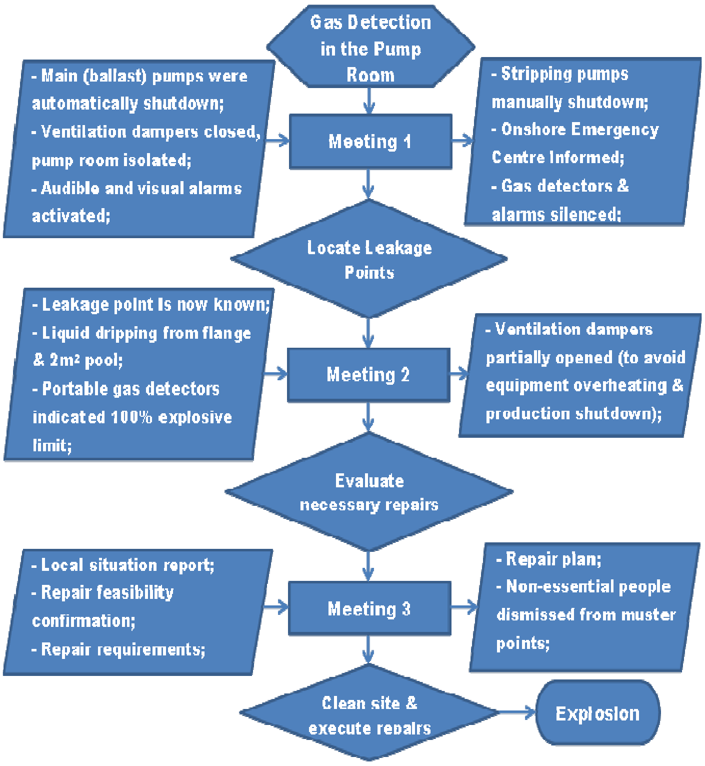

Figure 4 – Decision-making flowchart

3.4 *FPSO CDSM surrounding factors and their connection with MATA-D tendencies*

The application of the SOM algorithm grouped accidents with similar characteristics. The data mining process indicated a particular cluster of interest containing 80 accidents (Cluster 1), which has Inadequate Task Allocation issues as the prevailing contributing factor. The patterns disclosed by the SOM grouping were deeply associated with the sequence of events witnessed in the FPSO CDSM prior to the disaster. The complexity of the operation of an offshore platform is extraordinary, and there are many contextual factors embedded in such organisation which might prove to be pivotal in case of an accident. Latent failures such as design shortcomings and operational weaknesses can deteriorate the system to the point that people cannot compensate for a degraded operating environment.

The FPSO CDSM investigation revealed many surrounding factors contributing to the events on the day of the accident. According to the report (ANP, 2015) the marine team was largely undermanned. The lack of a safety critical function (senior marine operator or marine supervisor) and the regular accumulation of management and operational roles (an operator was performing marine superintendent functions for a long period prior to the event) led to difficulties to control cargo transfer tasks and to undertake judicious handovers between shifts. The handover between Offshore Installation Managers also failed to convey significant information regarding the ongoing cargo transfer manoeuvre (DPC, 2015). Human resources management problems and the lack of clear definition of responsibilities were contributing factors directly identified under the tag Inadequate Task Allocation in Cluster 1 (Table 2) of the Self-organising Map (Figure 1).

There is an expectation that the organisation will provide enough personnel not only to operate the industrial facility under standard conditions, but also to deal with abnormal situations. However, the recurrent approach to operate with low manning levels results in serious vulnerabilities, particularly in case of atypical operational scenarios, a recognisable pattern heightened in Cluster 1 accidents. Many examples are in line with the conclusions from the FPSO CDSM report. The investigation on the Varanus Island accident (Bills & Agostini, 2009), for instance, highlighted low manning levels in various disciplines and having key competences outsourced or restricted to specific members of the team as contributing factors to the disaster. Deficiencies in the shift handover and communication issues were also considered contributors for the Buncefield accident, according to the COMAH report (2011).

Another pattern identified in Cluster 1 suited the FPSO CDSM event surprisingly well, i.e. the link between inadequate procedures, flawed safety analysis and inadequate task allocation. The investigation report indicated that emergency procedures were short on detail, lacking adequate hazard mitigation measures for a scenario of confirmed gas detection in the pump room. Moreover, operational procedures (e.g. cargo transfer) and plans (e.g. Process & Instrumentation Drawings) directly related to the manoeuvres which caused the gas leakage were obsolete and mismatched the existing process plant configuration. Many examples showing similar tendencies can be extracted from the cluster, such as the incomplete procedures for cargo transfer (i.e. tank filling) in the Buncefield accident, or the lack of emergency procedures for safe and proper response to a hazardous scenario (i.e. diesel engine overspeed) in the Rosharon plant vapour cloud fire (US-CSB, 2003).

The normalisation of deviance was also a recurring issue in the FPSO CDSM operation. Normalisation of deviance occurs when the group incorporates erratic operational conditions and accept risks as part of their work culture (Vaughan, 1996). In those cases, individual risk perception and consideration of hazards are shaped by group thinking and, in a broader perspective, can be interpreted as a social pressure mechanism. It was known that the seat rings for the cargo transfer valves, which had a key sealing function, were inadequate for the type of condensate stored. The seals manufacturing material was susceptible to chemical attack, but maintenance and quality control measures failed to address the source of the problem, adopting alternative approaches to live with it instead. The storage of condensate itself played a significant role in the event. According to the investigation (ANP, 2015), the design conception and safety philosophy did not anticipate pure condensate storage, as the system was originally designed for petroleum or a mix of petroleum/condensate. Operational studies and safety analyses had taken place, but these were superficial and failed to identify hazards and address increased risks due to the modified storage and cargo transfer process. Other deviations identified, such as the regular use of in-house manufactured blind flanges without ensuring compliance with the adequate pressure class, were also discernible tendencies in Cluster 1, where mismatches between equipment/accessories and the required certification to operate under specific conditions were observed. Correspondingly, unsuitable bunds (were not impermeable) were evidenced during the Buncefield investigation (COMAH, 2011), and fixtures and further fittings in the Rosharon plant (US-CSB, 2003) were not certified for the operational environment.

Further significant design weaknesses, such as the lack of effective blast protection for the living quarters and muster points, also coincided with Cluster 1's patterns. Accidents involving failures in the fire/blast protection and the consequent impairment of relevant equipment and locations were persistent within the grouping. The control room damages after a jet fire in the Castleford Petrochemical plant (HSE, 1994) and the spreading fire to nonproduction areas in the Corbin facility (US-CSB, 2005) which killed eight workers, are examples, to name but a few, of analogous cases.

3.5 *Comparison between the FPSO CDSM decision-making and MATA-D task allocation shortcomings*

The environmental factors surrounding the decision-making process in the FPSO CDSM showed deep correspondence with the tendencies disclosed by the SOM clustering method. Once the scenario is set and the surrounding factors are exposed, the decision-making process immediately preceding the explosion can be disclosed under a well-defined context. The decision context is vital to comprehend the strategy, the objectives and the available choices to solve a problem, i.e. a gas release in the Pump Room.

Snowden and Boone (2007) suggested a context classification scheme for decision-making, dividing it into 5 groups: simple, complicated, complex, chaotic and disorder. According to their approach, the existing decision context in the FPSO CDSM ranged between complicated (relationship between cause and effect is clear but not recognisable by everyone; may contain multiple right answers and thus require investigating several options; requires expertise) and complex (right answers cannot be ferreted out; unpredictability; experiments which can safely fail lead to instructive patterns).

The context faced in the FPSO CDSM is very similar to the patterns from the SOM Cluster 1. The application of the SOM algorithm revealed particular cognitive mechanisms underlying failures to perform a sequence of actions in analogous cases. The diagnosis of system state was incomplete, as the gas presence in the Pump Room was acknowledged, but not its possible effects (i.e. explosion). A faulty reasoning links to the decision-maker strategy, inferring that the solution applied before (enter the compartment and execute repair services) would work well again. Some personal cognitive biases also exist, such as: (i) the belief that the situation was under control (reinforced by two successful excursions to the Pump Room); (ii) the incorrect review of probabilities, after people returned from the Pump Room with portable detectors indicating that the atmosphere was significantly above the lower explosive limit; and (iii) the hypothesis fixation, as the decision-maker was focused on a single solution and thus constraining the sequence of actions to a particular approach which matched his assumptions.

Additionally, the Offshore Installation Manager only boarded on the day of the accident, and was not aware of all ongoing operations, including the one which gave rise to the flammable gas cloud. After the alarm, the organisation adapted to a non-routine arrangement (From Figure 2 to Figure 3), and the required decisions were of uncommon nature. The lack of practical experience to define and perform tasks (lack of skills) and the unsatisfactory theoretical knowledge regarding the scenario and associated risks indicated that the FPSO CDSM manager lost the overall situation awareness.

The decision-maker, with the support of experts, was confident in accomplishing the final goal (stop the leakage by detecting and repairing the escape point), but missed a crucial step: making the compartment safe and serviceable, despite all relevant signals (initial detection from fixed sensors, and later from portable detectors). The task planning was inconsistent, the work procedure was poor and the managerial rule lacked clear principles such as reducing the personnel exposure to risks. All these elements are satisfactory captured under the Inadequate Task Allocation tag, which was the dominant element for Cluster 1, as many analogous examples show.

4 DISCUSSION

The analysis of the MATA-D clustering after the application of the SOM algorithm revealed common patterns linking Inadequate Task Allocation, a key managerial problem, with several surrounding factors found in Cluster 1. Similar patterns and linkages among contributors were disclosed by the post-accident examination of the explosion in the Pump Room of the FPSO CDSM, that occurred in February 2015.

Many contributing factors arose from earlier decisions, such as the modifications of the original design to adapt the operation to new conditions without a thoughtful consideration of risks. Therefore, the decisions with the intent to interrupt the leakage in the day of the accident were taken under a previously degraded decision-making environment, as production objectives appear to have prevailed upon safety in some design, maintenance and quality control choices.

During the event on the FPSO CDSM, the decision-maker was essentially left on his own, as clear instructions on how to proceed in case of gas confirmation in the Pump Room were missing from the emergency procedures. Therefore, he appeared to be in need of further information to decide what to do next. Accordingly, his first objective was to search for additional data, which he accomplished by gathering information from operators in the Control Room and by sending a recognition team to the Pump Room. Before sending people there, he ensured that the pumps were disabled, valves from the cargo system were closed and the air exhaustion system was shut. The leaked gas was certainly confined to the Pump Room. Moreover, he might have assumed that the local system halt reduced the leakage and/or eliminated possible ignition sources inside the compartment.

The first excursion to the compartment was very successful, and this repeated action – groups were sent to the gas-filled room three times – might have reinforced the (wrong) impression that it was safe to go there. Not only the decision-maker appeared to be confident that the developments of the system were under his control, but also the remaining participants of the decision-making process, including the emergency team members. It is important to notice that the investigation reports (ANP, 2015, DPC, 2015) did not capture any signal of opposition to the strategy of entering the compartment, not even from the most vulnerable ones – the people who were responsible for performing the recovery tasks in an extremely dangerous site, and eventually died doing so.

Signals of overconfidence are overwhelming. After the second excursion to the compartment, the Offshore Installation Manager decided to release people from muster points and authorise them to have lunch, retaining only essential people to execute the required repair. The belief that the strategy was good – the leakage point had been identified and a repair plan was conceived – made the members constrain their alternatives to current assumptions, i.e. that the situation was reasonably controlled. This appears to be due to the absence of active ignition sources and the compelling fact that people do have entered the place twice, with positive results.

The whole group – decision-maker, decision staff, experts and implementers – restricted their choices to a sole hypothetic solution. Under an unusual, complex scenario, the individuals immediately jumped to the only definitive solution available (repairing the leakage), disposed to solve the problem as soon as possible and return to a safe operating status. This recognisable hypothesis fixation might have made them skip two alternative solutions. The first one, to conduct operational manoeuvres to ventilate the room, in order to eliminate the explosive atmosphere indicated by the local sensors and later confirmed by the crew. The second option would be a more conservative one: to abandon the ship. If the Offshore Installation Manager had recognised the imminent risk of explosion, he could have commanded an evacuation, aiming at the safety of the personnel.

The uncertainties related with all possible scenarios, even in hindsight, turn the review of probabilities for the outcomes into a subjective problem. We can only be sure that the solution adopted had a negative consequence (thus was an error), but we cannot guarantee that the alternative solutions would present a positive outcome. In the case study, trying to ventilate the flammable gas cloud from the compartment, for instance, is a very complex, high-knowledge dependent procedure. For the first alternative solution, the design of the ventilation system, especially of the location of air outlets, should be understood to the point that people could make sure the discharge would not find an ignition point in a location even closer to the ship living quarters. Special knowledge about the ducts dimension and flow speed would be required, to minimise the possibility of forming an explosive atmosphere in another place. It would be an exceptional operation, without any parallel with the routine of the crew and with no guarantee of success. Additionally, it would still require the repair of the leakage point afterwards.

The second option, consisting of directing the crew to muster points, shut-down the plant and directing the evacuation, is the most conservative one. Since the accident investigation indicated that the possible ignition sources were static electrical or mechanical sparks introduced by the repair procedure, it would be sensible to assume that the ship abandonment would be successful. However, some individual and corporate negative effects would be certain. The decision-maker was the Incident Commander, but above all he was the full-time Installation Manager, predominantly responsible to deliver a production result to his superiors. If he evacuated the unit and the explosion did not occur, he might have been considered excessively conservative, and jeopardise his career as a manager. Furthermore, having a high-potential event stressed by the abandonment of the unit would put the company in the glare of the media spotlight, and under regulatory scrutiny.

Therefore, the latter option involves a situation where the main objective of the company (continuous production) would be unquestionably compromised (with 100% certainty), against responding and tolerating some degree of risk (in fact, a subjective probability that safety will be compromised) to attempt an immediate solution to the problem.

This is the main reason why the decision-making process outcomes at the FPSO CDSM are not surprising at all. On the contrary, it followed a very well-defined pattern, exposed by the region of the self-organising maps where the work organisation lacked clear framework guidelines and safety values/principles.

5 CONCLUSIONS

The decision-making process developed during the FPSO CDSM event resulted in an unsatisfactory but plausible outcome. Several relevant aspects leading to the disaster, which were embedded in the organisation, were revealed by the two official investigation reports considered in this research. These factors were successfully related with common patterns belonging to one of the areas (i.e. Cluster 1) of the SOM map, indicating that known trends prevailed in the FPSO CDSM accident. It was made clear that the workgroup has inherited many organisational latent failures, including unsound design choices, which might have consciously or unconsciously encouraged an atmosphere of decisions favouring production over safety. Considering the environment and the nature of the position of the decision-maker, it should be anticipated that a predilection for a quick solution, which would pose less impact to his (and the company's) perceived key objectives, would overpower any presumably safer but certainly riskier choice to the production upkeep.

The decision-maker has not entirely overlooked safety principles. He took rational preventive actions before sending the team to the Pump Room (e.g. confirmed shutdown of possible ignition sources and the closure of ventilation dampers to avoid escalation), monitored the risk (through the information he received) and updated his decision-making process in an optimistic way: he believed (and most likely received ratifying indications from local teams) that the repair was possible and reasonably safe. Of course, some measures taken were questionable, such as having members of the Technical Advisory Response Team entering the Pump Room along with the Emergency Response Team. This exposed a larger than necessary group to the explosion and challenged any cautionary principle. It is not very surprising though, as it might be the case that he diagnosed the likelihood of an explosion as extremely low, during his quick mental review of probabilities, and understood that the risk was worth taking.

It is not possible to assume that another Offshore Installation Manager, with the same level of skills and knowledge and under the same scenario, would adopt a different solution. Hence, considering the intrinsic and immediate goals of the work position, the specific training and information required to solve complex, non-routine problems, the normal variability in human behaviour and the organisational pattern in line with many major accidents from MATA-D, it is supposed that improved organisational configurations would be necessary to reduce major accidents.

For example, in the case of production platforms, a conceivable solution to improve emergency onboard decisions would be to dedicate one or two people to damage control. These people would take responsibility for leading emergency operations, immediately exchanging information with the land Emergency Control Centre and gathering data from on-board operational personnel. The key objective of the damage control personnel would be safety, substantially reducing any conflicting goals, especially with production maintenance. Skills and knowledge of these professionals would be planned to improve the understanding and operation of important systems during an emergency. In the case study, gas detectors and alarms were disabled to improve radio communications. It is obvious that the human-machine interface were not ideal. Therefore, it appears that a dedicated console (e.g. a Damage Control Console) would be desirable, in order to provide adequate information for the recovery of emergency scenarios and assist the decision-making process.

Certainly, these changes in the sharp-end of the process would need to be accompanied by high-level measures involving, for instance, the design. In the case study, many latent failures imbedded in the concept of the plant (e.g. lack of blast protection for the living quarters; decision to convert a Very Large Crude Carriers into a Production Platform, inheriting the arguable location of the accommodation module above the Pump Room) appear to have contributed to the event. Those earlier decision-making processes could also be thoughtfully investigated and discussed, in order to identify further improvement opportunities.

6 ACKNOWLEDGEMENTS

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