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Sensemaking of Rework Causation in Offshore Structures: People, Organization and Project

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Abstract:

Cost and schedule overruns are norm in offshore hydrocarbon projects. With increasingly complex commercial and contracting arrangements, technical challenges, changing local economic and regulatory conditions and a shift toward project's being undertaken in peak oil frontier regions, the risks of overruns increase. A major factor contributing to such overruns is rework. Twenty three in-depth interviews with leading oil and gas industry practitioners were undertaken to acquire knowledge of their experiences of rework causation in offshore projects. Analysis of the dialogue and narratives obtained enabled a nomenclature for rework causal factors to be classified as *People*, *Organization* and *Project* for different types of offshore structure. The determination of rework causal factors provides the foundations for appropriate risk management strategies in future projects to be determined.

Keywords:

errors, change, sensemarking, offshore projects, rework

1 Introduction

The catastrophic failure of offshore structures such as Piper Alpha, Sleipner A, Petrobas-36 and Ranger I resulted in an intense period of introspection that resulted in major changes to safety, reliability and engineering assessments and standards (e.g., Moan, 2009). Detailed investigations and subsequent analysis of these accidents have attributed the causes of failure to be associated with an array of human and organizational errors (Bea *et al.*, 2010). Such errors not only have been found to contribute to system failure and accidents, but also cost and schedule overruns in projects (Love *et al.*, 2009). Between 1993 and 2003 one in eight major offshore developments with a capital expenditure (CAPEX) ranging from US\$1 million to US\$3 billion were deemed to be a financial disaster. These projects exceeded cost and/or schedule growth by 40%, or within the first year of operating were producing less than 50% of production capacity (Morrow, 2003a,b). Furthermore, more than 40% of capital offshore projects in excess of US\$1 billion overran budget by more than 10% (Morrow, 2003a,b). More recently, it has been estimated that the average cost overrun for offshore construction programs is 35% and average delays total seven months (Eriksen, 2010). The most common factors contributing to cost overruns in offshore projects are (Eriksen, 2010):

- the placing of orders before engineering is completed;
- the implementation of new technology without qualification;
- insufficient engineering with regard to operational robustness and maintainability;

- problems with component deliveries and documentation when transferring fabrication;
- fabrication yards having to build competence and resources during the project, and
- poor interface management.

Complex commercial and contracting arrangements, increased technical challenges, changing local economic and regulatory conditions, and a shift toward projects being undertaken in frontier regions (e.g., Bangladesh, Ecuador, Kazakhstan, and Peru) are increasing the risk of overruns, failures and accidents.

Failure to deliver megaprojects on budget and on schedule often generates negative publicity in the national and international news, thus adversely impacting stakeholders' perception of a company's ability to meet commitments. Poor project performance is not acceptable when capital markets are looking for predictability and strong returns (Love *et al.*, 2011a). Projects that underperform, perhaps due to rework, are often explained away as being an isolated instance of unfortunate circumstance and considered not to be a part of normal practice (Love *et al.*, 2009). Put differently, rework in such circumstances may be analogous to being a 'Black Swan' (Taleb, 2007); an outlier event within projects. In spite of its outlier status, explanations and justifications for its occurrence, after the fact, are often made by organizations in an attempt to make the event explainable and predictable (Taleb, 2007). The quandary is that many organizations are reluctant to admit to problems that may exist within their systems and processes for fear of being judged irresponsible by their stakeholders. To reduce the probability of cost and schedule overruns, failures and accidents, rework risks need to be identified and classified before they can be assessed, managed, and mitigated. A series of unstructured interviews with leading industry practitioners was undertaken to acquire knowledge about their experiences with rework in projects that they had been involved with. The dialogue and narrative derived provide valuable insights that enabled 'sensemaking' of rework causes to be identified for various different types of offshore structure.

2 Rework and Latent Conditions

Rework has been defined as "the unnecessary effort of redoing a process or task that was incorrectly implemented the first time" (Love, 2002:p.18). It has been identified as a problematic issue in construction and engineering projects and a major contributor to cost and schedule overruns (Hwang *et al.*, 2009). Rework, on average, contributes to 52% of a total cost overrun incurred and can increase schedule by 22% (Love, 2002). Rework costs have been found to range from 5 to 20% of contract value in construction and engineering projects (Love *et al.*, 2011a). To date, there is limited knowledge available about rework costs and its causes in offshore projects.

Rework has been attributed to latent conditions that reside within the organizational and project systems (Love *et al.*, 2009). Reason (1997) states that "latent conditions are to technological organizations what resident pathogens are to the human body" (p.10). For example, at an organizational level this may include insufficient training, resourcing levels and lack of a quality management focus. At a project level, lack of supervision, competitive tendering, and contracting strategy have been found to provide the conditions for errors to manifest (Love *et al.*, 2011a). In effect, latent conditions lay dormant within a system until an error comes to light. Invariably, they arise as a result of strategic decisions taken by senior management, government, regulators, designers and key decision-makers. The impact of these decisions spreads throughout an organization and project, shaping their culture and creating error-producing factors within individual workplaces (Reason, 1997).

Errors can take the form of violations, mistakes, slips and lapses (Reason, 1990). Violations arise to due aberrant behaviour and are analogous to omission errors, though they may not always result in an error being made. Violations are deliberate deviations from practices deemed necessary (Reason, 1990). Before errors become apparent, participants often remain unaware of the impact upon project performance that particular decisions, practices or procedures can have (Love *et al.*, 2009). Until errors are identified or a failure occurs they remain in a state of incubation and become an integral

part of everyday work practices (Reason, 1990). If an error is identified, then rework can be undertaken. If schedule pressure becomes a problem during the rectification of the error, then there is a potential for safety to be compromised and accidents to occur (Goh *et al.*, 2011).

Active failures are unsafe acts committed by people who are in direct contact with a system. They are often difficult to foresee and cannot be eliminated by simply reacting to the event that has occurred. When latent conditions combine with active failures, then the error consequences that arise can be significant (Reason, 1990). Active failures, such as those identified above, have an immediate impact and are committed at the human-system interface (Reason, 1997). Latent conditions provide an environment for increasing the likelihood for active failures to occur by creating the local factors that promote an individual to commit an error or violation (Reason, 1997). Through proactive management latent conditions can be identified and remedied before an adverse event occurs (Goh *et al.*, 2011).

2.1 Project Complexity and Uncertainty

The management of errors in offshore operations has been extensively examined from a human and organizational perspective (Ren *et al.*, 2008). Such research has been initiated by accidents and catastrophes that have occurred. While considerable advancements in the ability to reduce and predict their likelihood, errors have been made and still continue to prevail. A possible explanation for this can be derived from Tversky and Kahneman (1974) research on judgment and uncertainty. People are guided by their previous experiences and therefore will be inclined to underestimate irregularities in the future. Thus, they will plan for fewer contingencies than will actually occur. Tversky and Kahneman (1974) have suggested that people are influenced by the representativeness and availability of heuristics that are available to them. When people rely on individual representative heuristics they are likely to judge causality on the basis of perceived similarities between the cause and effect of events they have experienced, or to their knowledge. If people rely on the availability heuristic then they will predict the frequency of an event, or a proportion within a population, based on how easily an event can be brought to mind. This is also compounded if a person believes that a given event has only one underlying cause (Nisbett and Ross, 1980). Love *et al.* (2011a) suggest that the causes and effects of committing errors are not unidirectional or linear, but are reciprocal or looped in their relationships. Understanding how such relationships emerge and interact with one another is necessary in the pursuit of error and rework reduction. The ideal error reduction approach is to view errors as symptoms of underlying problems, and in so doing, they become information sources that help explain how systems work. While underlying events may be similar in nature, the dynamic and chaotic nature of projects may produce large variations in system behaviour if a shift or deviation from initial conditions arises. Such a phenomenon is referred to as *sensitive dependence* (Hilborn, 2004).

Another issue that may explain why projects continue to experience cost and schedule overruns is the use of conventional project management within chaotic environments. Classical Newtonian scientific philosophy is somewhat akin to conventional project management and implies that order should be imposed from above (leading to top-down command and leadership) and that structures should be designed to support decision-makers. As projects have become more complex in nature, this philosophy to managing projects is deemed ineffective in reducing failures and assuring successful outcomes. Inherent within complex projects are unintended consequences and counterintuitive outcomes due to the structural complexity and uncertainty that prevails. According to Williams (2002) structural complexity is derived from the interaction between the number of elements that form the project and their interdependence. Uncertainty is derived from a lack of clarity concerning project goals and an absence of appropriate means with which to achieve those goals (Williams, 2002). The result is that project elements interact in complex and unpredictable ways, which can increase the likelihood of rework occurring (Love, 2002). This situation is further exacerbated when activities are undertaken concurrently due to issues associated with schedule pressure.

In an effort to meet a project's schedule completion date, additional resources may be employed, however such action may lead to a contradictory effect (McConnell, 1999). By pushing beyond the limits of concurrency, complexity increases and tasks are delayed, particularly when revisions, repairs and rework occur (Love, 2002). Paté-Cornell (1990) suggests that schedule pressure not only increases the probability of errors occurring but also decreases the chances that they are detected using regular procedures. Design errors that may be deemed minor in nature are likely to be overlooked due to the time that it would invariably take to correct them (Paté-Cornell, 1990). An 'escalation to commitment' may prevail if any ambiguities are identified and invalidate efforts of the initial design and engineering that has been undertaken (Paté-Cornell, 1990:p.1214). The inherent uncertainty that prevails within offshore projects can result in planning being problematic, especially when information is unavailable. Faced with high uncertainty, there is an over reliance on scope changes to solve problems that may arise during construction, installation and commissioning.

3 Research Methodology

An interpretative research approach was adopted to determine the systemic nature of rework. A similar approach has been advocated by Goh *et al.* (2011) who examined the systemic causes of organizational accidents. As limited research has addressed rework in offshore projects 'subjective idealism' was adopted (Farrell, 1996). In this instance, subjects construct their own views and opinions on the phenomena to be investigated based upon their experiences; an inclination to truth and pragmatism is deemed to prevail. This approach is similar in nature to Weick's (1988) 'sensemaking' where meaning is given to experience, dialogue and narratives about events that have occurred through a process of retrospection.

3.1 Data Collection

Twenty three in-depth interviews were conducted over a four month period with a variety of personnel including operations managers, project managers and engineering managers who were working for a major international oil and gas operator. The sample consisted of: operations managers (3), project manager (10), structural engineer (3), procurement manager (2), mechanical manager (2) and Engineering Manager (3). Interviews were chosen as the primary data collection mechanism as they are an effective tool for learning about matters that cannot be observed (Kvale, 1996). The firm was selected as the research team had a direct contact point within the organization that had an interest in understanding 'why' and 'how' rework emerged in projects. For reasons of commercial and individual confidentiality, specific details about the organization are not presented. Personnel involved with the procurement of projects within the organization were invited to participate in the research and interviews were conducted at the offices of interviewees for their convenience. Interviews were digitally recorded and transcribed verbatim to allow for finer nuances of the interview to be documented.

The interviewees' details were coded to allow for anonymity, although all interviewees were aware that it might be possible to identify them from the content of the text. The format of the interviews was kept as consistent as possible following the themes associated with rework identified from the literature. The interview commenced by asking individuals about their experience within industry, and their current role within the organization. Interviewees were then asked to select a completed project they had been involved with and identify a particular rework incident that had taken place. The interviewee was then asked for their perspective how and why they thought it arose. Phrases such as 'tell me about it' or 'can you give me an example' were asked when further information was required. The open nature of the questions allowed for avenues of interest to be pursued as they arose without introducing bias in the response. Interviewees were asked to identify the main sources of rework that occurred in offshore projects that they had been involved with and to suggest strategies could be used to prevent it from reoccurring in the future. Notes were taken throughout the interview to support their digital recording to maintain validity. Interviews varied in length from

one to three hours and sought to stimulate conversation whilst simultaneously breaking down any interpersonal barriers that may have existed between the interviewer and interviewee. Each interview was transcribed and a copy given to each interviewee for comment to check overall validity and accuracy. In conjunction with the interviews, documentary sources for each of the projects were provided.

4 Findings and Discussion

Each interviewee held views as to the reasons rework occurred in projects that they have been involved with, though a high degree of consensus emerged as to the underlying causes and risks that needed to be taken into account to reduce its materialization in projects. When rework in a project was deemed to be equivalent to a series of ‘anaphylactic shocks’ that destabilized a projects’ performance, though the severity of its impact cost and schedule performance depended upon where and when an error was identified and how it was addressed. Narratives from completed projects that interviewees had been intimately involved with from different parts of the world were described. This led to a rich representation of the dynamics and risks associated with rework to be attained. The sharing of dialogue and narratives is pivotal for learning, though there is a proclivity for it to occur at different levels within organizations.

4.1 Rework Costs

Intuitive estimates of rework costs for projects were provided by interviewees. These ranged from 3% to 25% of CAPEX. Such costs are not measured even though they can contribute to increased project costs. Using an Engineering Procurement Construction (EPC) contract strategy, a 10% cost growth, with 5% due to rework, was deemed to be acceptable considering the uncertainty and complexity associated with offshore projects. Taking into account the potential for optimism bias (i.e. over estimating the likelihood of positive events and under estimating the likelihood of negative events), the actual rework costs could be considerably higher.

Cost overruns were deemed to be the norm. Having to undertake rework as a result of errors and omissions was an issue not *formally* recognized during the concept design and Front End Engineering Design (FEED) risk management processes that were in place within the organizations where interviewees had been employed. Despite the use of post mortems from completed projects being used as a formalized learning mechanism for future projects, the inclusion of any form of risk assessment or even acknowledgment of rework was eschewed: it is a ‘taboo’, its costs buried within a project’s contingency sum. To the interviewees knowledge rework is not measured; it exists and occurs regularly, but is hidden deep within an organization’s subconsciousness until a major incident arises. Then, as one engineering manager commented “the blame game begins and the contract comes out, and all hell breaks loose”. An unwillingness to admit that rework was a problem was clearly evident from the opening statement made by a project manager who had more than 15 years experience working in offshore environments who initially stated “we don’t have rework in our projects”. This shielding comment was not the voice of the individual, but that of the organization they were representing. The mere recognition that errors occurred could potentially jeopardize the organizations corporate image and possibly the value of their ‘shares’. As the interview unfolded, the voice and experience of the individual began to surface. It was clear that rework was indeed a costly issue in many projects that they had been involved with.

If rework costs of 5% of CAPEX are an acceptable norm, there is a danger that this ‘norm’ will insidiously creep up further and settle in at an uncomfortable level, particularly as demand for energy and hydrocarbons increases. If rework repeatedly occurs within offshore projects, it may become invisible or viewed complacently as being a necessary evil of doing business. The percentage increase in rework will undoubtedly be added to an organization’s overall costs. If rework accounts for 5% of regular work of an organization, this would lead to everything being increased by 5%: supervision, cycle time for administrative procedures, answering requests for information, and so on. The time element obviously translates into costs, which are then buried in

what would be considered ‘normal’ operating costs. History suggests that those who fail to learn from their mistakes are invariably condemned to relive them again. Insight gained from previous mistakes or oversights made in projects can be gainfully employed in preventing future repetition. Learning from mistakes is difficult, but continuing to make the same ones is far harder and certainly more costly.

4.2 Narrative: Remember the Shareholder

In this narrative, the deck, hull and mooring system were constructed (fabricated and installed) by three different contractors simultaneously and importantly, contracts were let before the detailed engineering had been completed. This posed a problem during hull and Topside fabrication as the number of risers was not determined due to the uncertainty of the hydrocarbon well. In describing this issue a project manager stated:

“We started the engineering of the Topsides when we’d not completed the reservoir simulation works. We were running before we could walk! We over designed on the number risers and wells that were going to be needed. Those assumptions turned out to be wrong. We kept going round in circles because we’d not finished the reservoir works. We were designing for too many uncertainties and complexities. Mistakes were made; we were under considerable pressure to get the project up and running. We always have to remember though that we have shareholders who expect dividends”.

The fabrication process was staged until the number of risers could be finalized and detailed engineering completed. This staging inadvertently delayed the project’s schedule, but it was still expected that the installation process would meet its original schedule. Any delay to the final completion date would adversely influence gas production and the company’s share prices. Audits and reviews of the detailed engineering were undertaken, but this was seemingly done in a haphazard manner due to the imposed schedule pressures. It was not until the platforms components were being installed that engineering and fabrication errors began to materialise. While three-dimensional clash detection exercises had been undertaken during engineering, extensive clashing of pipe work occurred on-site during the installation of the deck and hull systems. A structural engineer revealed that an up-dated software version was used, but unfortunately several engineers were not completely familiar with the ‘nuances’ of the new application. An engineering manager stated:

“We’re experiencing a severe skills shortage. We just can’t get people who have the skills and experience needed. The entire resource sector is experiencing a shortage of labour. We’re just getting who we can and try to train them on the job – I don’t know what we’ll do if and when we get more work. We don’t have time to train people. Sadly, it has to be done on the job. You only have to look at the quality of work undertaken by the contractors and their subcontractors. We have to hold their hands”.

Evidence of this inexperience became apparent when the platforms components were being installed; poor quality materials and workmanship were prevalent. For example, issues related to weld contamination, and mismatching material grades were identified. During Topside installation, it was observed that material grades had been ‘mixed up’. Type II steel had been used where only Type I had been specified. This was a major concern as the Topside’s structural integrity was brought into question. The Type I steel was subjected to rigorous testing and it was found that it achieved the performance level equivalent to that specified for Type II steel. A simple colour coding system in the fabrication yard would have eliminated these errors. There were instances where a weld had been contaminated by the inclusion of dissimilar materials. Pressure testing of pipe work and equipment during the fabrication process to ensure the integrity of the welds, revealed carbon steel particles had become engrained within a stainless steel weld. Once this happens the weld adopts the function of an anode to the stainless steel cathode, thus accelerating the process of corrosion. A structural engineer suggested that during fabrication the same grinders and steel

brushes that had been used on the carbon steel were probably also used on stainless steel and copper nickel pipe work; a clear indication that the contractor did not implement stringent QC procedures. Minor works were undertaken, but the weld's integrity needed to be constantly monitored.

4.3 Narrative: The Push for Production

In this next narrative, rework costs were estimated to be 3% of CAPEX, which according to the estimates identified above were below the level considered to be a 'norm'. Like the aforementioned project, the determination of the hydrocarbon reservoir was identified as a problematic issue. A project manager project stated:

"It's very difficult determining in the size of a hydrocarbon reservoir. There are so many variables we have to take into account, though with the technology we have today you'd expect some degree of accuracy. When you're dealing with Mother Nature you never know."

Failing to assess the reservoir capacity impacted on the engineering and procurement of the Topside facility. The deck, hull and mooring system were constructed (fabricated and installed) by three separate contractors. The same contractors that had been involved with the project presented above were involved with this project, and therefore were familiar with the client's eagerness to push ahead with the project to satisfy shareholder confidence. Again, contracts were let before the detailed engineering had been completed. Recognizing that a tight schedule had been established, the number of risers required was anticipated based upon preliminary forecasts of the reservoirs capacity and incorporated into the engineering design. Contractors began to fabricate based upon the original engineering design but changes to the design were required to accommodate for an increased production capacity. This resulted in significant changes to the platforms component parts. Fortunately, the rework required was undertaken in the fabricating yard and not on-site. During fabrication the internal side of a caisson and riser guides were found to be unpainted. This was not noticed until they had been installed. Concerns over accelerated corrosion were raised due to water movement within the annulus casing and the removal of the corrosion product, which would have otherwise acted to protect the uncoated surface. It was deemed impractical to coat the internal caisson and riser guides through the small annulus gap. At such uncoated locations, corrosion can be exacerbated and therefore the caisson required continual monitoring; an unnecessary maintenance cost was created.

5 People, Organization and Project

Sensemaking of rework through dialogue and narratives provided by the interviewees revealed high degree interdependency existed between rework events. In Figure 1 the relationship between the nomenclatures of people, organization and project is identified. Apart from the organizational and project related influences, erroneous decisions during FEED can occur due to impaired human cognition. An individual's cognitive *ability* (i.e. measured by aptitude tests) and *style* (i.e. the way an individual thinks, perceives and remembers information) influences their ability to learn. The majority of errors that arise are due to human action or inaction by virtue of cognitive failure (Busby, 2001).

Cognitive failure can be defined as cognitive-based errors on simple and often replicative tasks that a person should normally complete without fault; these mistakes include problems with memory, attention or action (Reason, 1997). The inability to engage and sustain attention is seldom a direct consequence of boredom. Boredom is often described as an adverse affective or cognitive state, but is arguably more fundamentally an inability to engage and sustain attention (Wallace *et al.*, 2002). Decisions taken by senior managers at an organizational level, which are often influenced by the demands imposed on them from their environment, can determine the extent that policies and procedures are adhered too as well as the resourcing capacity for a project. Decisions that are made by individual organizations can increase or decrease the likelihood of rework. Each participating

organization has differing goals, objectives and learning capacity, which may further exacerbate problems that become embedded within project systems and processes. The contracting strategy adopted for a project therefore needs to ensure that goal alignment can be ensured. The current use of an EPC contracting strategy inhibits goal alignment between participating project organizations, especially when competitive price determination becomes a driver for the selection of their services. Instead, alliances with an in-built learning capability and performance incentives should be used to establish a project culture that is able to drive the behaviour of organizations to achieve a successful project outcome (Love *et al.*, 2011b).

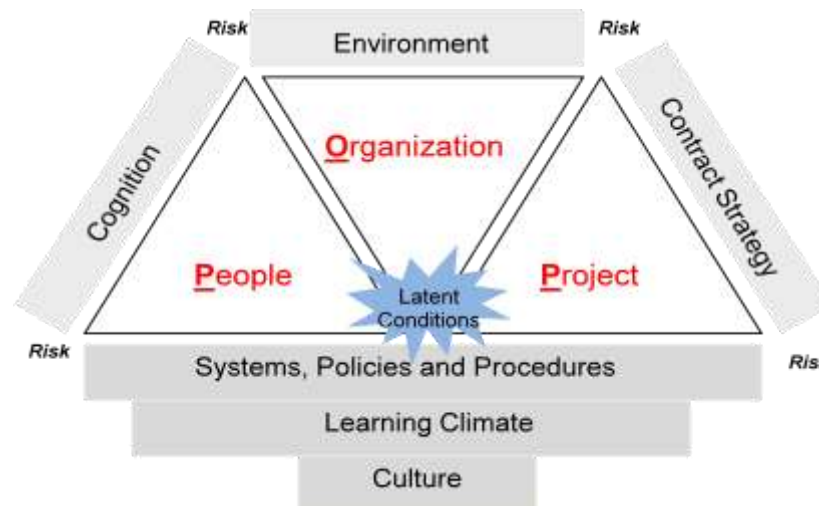


Figure 1. Relationship between people, organization and project

An organization's culture influences its ability to learn, particularly in the context of rework reduction (Love *et al.*, 2000). A culture conducive to learning is necessary for stimulating innovation, as it enables an organization to anticipate and adapt to the dynamics of a changing environment. An organization where a learning culture exists is characterized as one where all its members value learning and strive for high performance through its application to innovative work (Love *et al.*, 2000). A culture adept at learning emphasises open exchange of information and ideas in ways that facilitate exchange and dissemination of knowledge. Culture is based upon the beliefs that are shared within, whereas climate is based upon what an individual's senses about its organizational environment. In the context of a learning climate, it is not the work environment, but the way in which employees are encouraged to respond to it. According to Koppelman *et al.* (1990) it is the 'perceptual medium' through which culture and other work environment factors influence job-related attitudes and behaviours.

It would appear 'learning' is not given the priority that is needed by organizations as excessive cost and time overruns are regularly experienced. The same mistakes are being repeatedly made. Implementing strategies to maximize production capacity and profit to increase 'share price', by unnecessarily accelerating activities, can lead to safety and the environment being jeopardized. Such a strategic risk can cause not only a significant 'ripple effect' throughout the owner and operator's organization, but also other participating organizations in a project as they strive to meet the demands and constraints imposed upon. Mismanagement, mostly made by people with no training in managing risks has been identified as a basic condition contributing to the collapse of BP's Deepwater Horizon (Bea *et al.*, 2010). There is an explicit expectation that BP should have learnt lessons from the incidents that occurred at its Grangemouth Complex in 2000 (HSE, 2003), Texas City refinery accident in 2005, and collapse of the Thunder Horse platform in the Gulf of Mexico in 2006 (Bea *et al.*, 2010). Lack of training, poor communication, poor supervision and fatigue have been identified as contributors to BPs accidents. These findings are not dissimilar in nature to those reported in this paper contributing to rework. A notable difference, however,

pertains to the interrelationships that have been identified from the dialogue and narratives obtained and extrapolated to the nomenclatures of people, organization and project.

6 Conclusion

The increasing demand for and rising costs of energy has stimulated the need to extract and produce greater volumes of oil and gas. Consequently, a large number of offshore projects have been commissioned or built. Many have experienced significant cost and schedule overruns. A significant factor contributing to such cost and schedule overruns is rework, which arises due to errors, omissions and changes. Such rework arises as there is an underlying pressure to complete the project and commence production as soon as possible. If rework occurs, it is explained away as being an unfortunate event. Surprisingly, cost and schedule overruns are expected; a 5% of CAPEX cost increase due to rework is considered acceptable, if it occurs. If rework is anchored at such a level, then the likelihood for accidents and perhaps even loss of life significantly increases. It is only when a major failure, accident or catastrophe occurs that an investigation reveals design, managerial and organizational flaws have occurred. The determination of rework causal factors provides the foundations for appropriate risk management strategies in future projects to be determined.

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