Confronting uncertainty: Perceptions and practices of project managers in safety-critical industries

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Abstract

In safety-critical industries, such as civil nuclear and aerospace, managing uncertainty is of particular importance as the consequences of failure can be catastrophic. The challenge facing project managers in these operational environments is confronting uncertainty in pursuit of successful project outcomes. Drawing on literature from project management and high-reliability organisations, this paper analyses how project managers prepare for uncertainty, based on interviews with civil nuclear and aerospace project managers. Its findings are that managing project uncertainty is a mindset, rather than a process; it is about learning to dwell amongst questions and assumptions rather than answers and knowledge.

Keywords: Project Management, Behavioural Operations, Uncertainty

Purpose

The civil nuclear and aerospace industries are two examples of highly-regulated safety-critical industries in the United Kingdom. The civil nuclear industry is concerned with the design, operation, maintenance and eventual decommissioning of nuclear power plants, with these activities being closely supervised by a multiplicity of external regulators whose mission is to ensure the safety of all nuclear operations. The civil aerospace industry operates along similar lines: a tight-knit community of engineering and commercial personnel deliver complex products to the aviation industry, where errors and failure can lead to huge financial and reputational damage. To enter the environment of these safety-critical industries is to enter a world dominated by "*massive machines, extraordinary engineering and procedural complexities*" (La Porte, 2006). The project managers charged with delivering the next generation nuclear plants and submarines, or building ever lighter and more fuel efficient gas turbine aircraft engines must have broad shoulders, able to bear the weight of responsibility for the delivery of these safety-critical systems (Perin, 2005). These highly skilled and experienced project managers are expected to deliver decade-long, multi-million pound projects to the satisfaction of a myriad of internal and external stakeholders. The uncertainties at play in these immense projects are legion and non-trivial in nature. For example: what values can we assign to the costs of a nuclear new build programme, when the

design has yet to be approved by the UK nuclear regulator. Or how do we determine the development timescales of a nuclear submarine propulsion system when the UK based supply chain is fragile and skilled resources highly limited. In response to this challenge, and drawing on both project management and "high-reliability organisations" literature, this paper proffers an analysis of how project managers confront project uncertainty, based on in-depth interviews with project managers on a number of large-scale projects in civil nuclear and aerospace companies in the United Kingdom.

Theoretical Background

The management of uncertainty has become an increasingly important topic for discussion in the project management literature (Hillson, 2002; Atkinson et al., 2006; Perminova et al., 2008; Cleden, 2009). This scholarship provides us with several definitions of project uncertainty (Hillson, 2002; Ward and Chapman, 2003, Perminova et al., 2008) and the development of a variety of approaches that project managers might adopt to navigate their way through project uncertainties (Chapman and Ward, 2000; Pich et al., 2002; Hillson, 2004; and Thiry, 2004). The literature on high-reliability organisations (see for instance Rochlin, La Porte and Roberts, 1987, Weick, 1987, Roberts and Rousseau, 1989, Rochlin 1993, Boin and Schulmann 2008) also proffers insights into the management of uncertainty, particularly in the high-hazard environments such as those investigated in this study.

Cleden (2009) defines uncertainty as "*the intangible measure of what we don't know"* (Cleden, 2009, p. 5). Project uncertainty may arise through a paucity of information on or understanding of an issue, or may manifest itself due to the inherent complexity of the project, or due to changes in the timescales or tempo of a project (Weick, 1995, Cleden, 2009, Winch, 2010). Uncertainty is inherent in all projects and project managers are constantly required to make informed and conscious choices from a series of alternative actions, within constraints and areas of unclarity and unknown (Perminova et al., 2008).

One approach to managing project uncertainty that has found traction in the literature is to extend project risk management processes to incorporate uncertainty (Chapman and Ward, 2000, Hillson, 2002 and Atkinson et al., 2006). Here the traditional risk management process is augmented with the use of SWOT analyses and double probability impact matrices, enabling positive opportunities as well as negative threats to the project to be identified, analysed and, where practicable, mitigated. In their extensive work on risk management Chapman and Ward have developed a first pass approach to improving estimation in projects, a major source of uncertainty (Chapman and Ward, 2000), and the 6 W's framework for managing uncertainty, which poses questions such as, "who the parties involved are" and "what do they want to achieve" (Chapman and Ward, 1997). Atkinson et al., (2006) argue that uncertainty needs to be addressed at each stage of the project with particular emphasis on the definition of objectives, clarifying the priorities of different performance objectives and making the ownership of uncertainty explicit.

More sweeping changes to the methods of the project manager in managing uncertainty are demanded by a number of scholars (notably McGrath and MacMillan, 2000; Loch et al., 2006; Olsson, 2006; Weick and Sutcliffe, 2007). Cleden (2009) advocates identifying trigger points and early warning signs of uncertainty through a combination of forecasting, scenario planning, anticipation strategies and fast-learning loops. He argues that uncertainty can be tamed provided project managers understand what uncertainty is, how it arises and the different methods that we have at our disposal to keep it under control. This approach is supported by Pich et al., (2002) who propose two methods of managing highly uncertain

projects – that of learning and selectionism. Learning involves scanning the environment to search for unknown-unknowns coupled with continuous problem solving and changes in direction to the project as new information emerges. Selectionism entails undertaking multiple explorations to achieve the same outcome and making a decision on which is best during or after the process. Olsson (2006) contends that uncertainty can be managed by maintaining flexibility in the project. This is achieved through the use of late locking, staged development gates and the rigorous use of project contingencies. Managing uncertainty can also be approached by means of the project manager maintaining a sense of mindfulness and vigilance (Weick and Sutcliffe, 2007) throughout the project delivery, or by managing by assumptions and discovery driven planning rather than the traditional deterministic view of project planning. Here the project manager can start work in an environment of high uncertainty, learning from the outcomes of early work to inform the future direction of the project, gradually allowing assumptions to be converted into knowledge (McGrath and Macmillan, 2000). Many of these approaches to managing uncertainty, notably flexibility, anticipation, learning and an attitude of mindfulness find resonance in the literature on high-reliability organisation to which we now turn.

High-reliability organisations are those which have been able to demonstrate sustained safe and reliable performance in safety-critical environments where errors can lead quickly and uncontrollably to catastrophic failures (Lekka, 2011). The foundational research on high-reliability organisations was carried out in three organisations: the US air traffic control system (La Porte, 1988), electrical operations and power generations at the Pacific Gas and Electric Company which included the Diablo Canyon nuclear power plant in California (Schulmann, 1993) and flight operations aboard two US navy aircraft carriers, USS Enterprise and Carl Vinson (Rochlin, La Porte and Roberts, 1987). Although the three seminal case studies were diverse in their activities, the researchers found similarities in that *"they all operate in an unforgiving social and political environment, an environment rich with the potential for error, where the scale of consequences precludes learning through experimentation, and where to avoid failures in the shifting sources of vulnerability, complex processes are used to manage complex technology"* (Weick et al., 1999). There was also commonality found in terms of the studied organisations prioritising safety highly, demonstrating hierarchical yet decentralised decision making, possessing redundancy both in design and operational equipment and procedures, and strong organisational cultures that fostered openness, learning, individual accountability and constant vigilance in anticipating and responding to potential safety threats (Weick et al., 1999, Roberts and Bea, 2001). Weick speaks of mindfulness as being of central importance in high-reliability organisations (Weick et al., 1999). Mindful organisations work in a way that they noticed the unexpected early, they try to hold its development or they contain it and if they can't contain it then they focus on getting the system back up and running quickly.

Since the late 1980's the Berkeley centred initial high-reliability research has also been extended to industry sectors beyond the original context of the research. The healthcare and oil and gas industries in particular have been at the forefront of efforts to translate the findings of "high-reliability organisations" research into practical improvements in patient and worker safety respectively (Roberts, 2009).

Methodology

This study was designed within the social constructionist research perspective (Easterby-Smith et al., 2008). Here the focus is on the notion that *"reality is determined by people, rather than by objective and external factors"* (Easterby-Smith et al., 2008, p.59). Social constructionist research is therefore about meaning and context; about explanations aimed at

improving understanding of a given situation and why people behave in a particular manner. This approach is consistent with Cicmil et al., 2006 call for project management research to be situated in the actuality of projects – a research approach that is centred on project managers "*lived experience of projects*". This study does not claim that there is one best way to manage project uncertainty, rather to explore how a sample of project managers navigate their way around project uncertainties in their day-to-day experienced project reality. The study uses a cross-sectional, qualitative research design, based on semi-structured interviews of experienced project managers in three organisations in the nuclear power, nuclear decommissioning and civil aerospace industries. This enabled a coherent set of data to be collected, from a range of project contexts, allowing the researchers to analyse the data and induce topics, themes and associations from the rich interview data. The interviewees were selected through a combination of purposive and convenience sampling, using contacts of the researchers to identify experienced project managers currently involved on a civil nuclear or aerospace new build, maintenance or upgrade project (see Table 1). The interviews were carried out over a 3 month period in 2012. All interviews were audio recorded, transcribed and the five step process of analysis described in McCracken (1998) followed, whereby the researchers reviewed the transcripts, related observations made by interviewees to develop themes and patterns, and then developed the interrelationships between them into more general themes, drawing on the extant academic literature to make sense of the findings.

There were two main limitations to the study. Firstly the lack of triangulation of the data in that only one method of data collection was utilised and secondly a relatively small number of interviews were carried out. However given that the nature of the study was exploratory and its aims were to investigate how project managers navigate their way around project uncertainties in their day-to-day experienced project reality, this should not detract materially from the reliability of the findings.

Table 1: Study participants by industry and role

Organisation	**Project Type**	**Role of interviewee**
Multi-national energy company	Nuclear new build	Programme Manager
Multi-national energy company	Nuclear new build	Programme Manager
Multi-national energy company	Nuclear maintenance and upgrade project	Portfolio Manager
Multi-national engineering company	Civil aerospace new product development	Project Manager
Multi-national engineering company	Civil aerospace new product development	Project Manager
Multi-national engineering company	Nuclear new product development	Project Manager
Multi-national engineering company	Civil aerospace maintenance and upgrade project	Project Manager
Nuclear technology company	Nuclear decommissioning	Project Manager

Findings

We found four main strategies that were adopted by respondents to manage project uncertainty (See Figure 1).

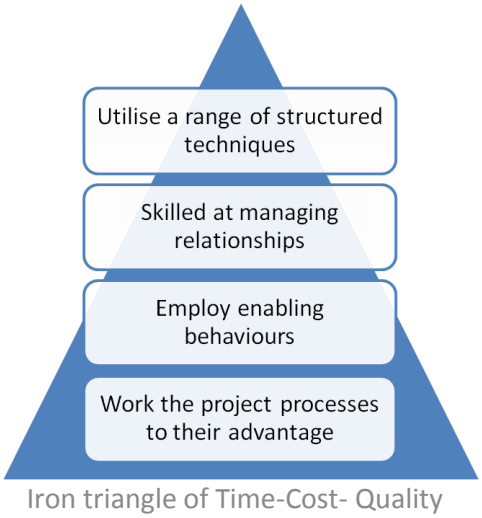

Figure 1: Four strategies for navigating uncertainty

These strategies were described by one project manager as "*coping mechanisms*" when operating in a safety-critical environment with a low tolerance for uncertainty. Firstly project managers worked the existing project processes to their advantage: for example, using markers not milestones in monitoring project progress, or using the risk management process to capture uncertainties even when the process did not make this requirement explicit. Secondly, project managers became adept at employing enabling behaviours such as deliberate decision making, flexibility and maintaining an attitude attuned to the presence of uncertainty. Thirdly project managers became skilled at managing relationships – with sponsors, regulators and other stakeholders in their projects – in order to keep project uncertainties visible. And fourthly project managers employed a range of structured techniques to help them confront project uncertainty; techniques such as brainstorming, horizon scanning and sensitivity analysis. It is important to note here that these strategies were not viewed as mutually exclusive but were employed in parallel as required to navigate the particular project uncertainties they faced.

Working the extent processes to confront uncertainty

The participants in this study conceptualised uncertainty by enacting the various project processes, in particular the risk management, the scope definition and gated review processes. Project managers invoked these processes to provide a framework both to identify uncertainties and as a means of managing them. Steering reviews and gated decision points especially were seen as essential in documenting uncertainties, and converting assumptions to knowledge to ensure the project could be delivered. As argued by (Hillson, 2002; Ward and Chapman, 2003; Atkinson et al., 2006) the risk management process was a key process in navigating uncertainty. However typical risk management processes were perceived as box ticking exercises and were only useful for driving out uncertainties if considerable judgement and intuition were applied to identify knowledge gaps, and to allow areas of uncertainty to

emerge. To quote one project manager "*the process is essentially inert – dead – it must be brought alive in the project manager's head and overall mindset*"

No project manager in the study had access to a documented uncertainty management process and consequently, they often worked outside the formal risk management process, interacting informally with experienced colleagues and documenting uncertainties as assumptions to enable them to move forward in the absence of incomplete information. This echoes the findings from high-reliability organisations where in times of crisis or urgency individuals will privilege the voice of the expert over the statutes of a particular process (Weick and Sutcliffe, 2007).

Project managers also had to acknowledge where they were in the project lifecycle (Atkinson et al., 2006) when assessing uncertainty in projects, to avoid the risk management process spiralling out of control, as one project manager expressed it:

"*So early on in the project, there are very difficult questions out there which we recognise that we cannot answer but we acknowledge them as uncertainties, and in so many months time we will have done x, y and z, so we will better understand that uncertainty and it can be better managed, so you don't get people snowballing uncertainty upon risk*." Project Manager, Nuclear New Build.

Employing enabling behaviours

We have seen that the project processes alone were insufficient to ensure predictable delivery; with their role a supporting rather than a defining one. Foundational to the management of uncertainty amongst participants in this study was the development of the right attitude. In common with individuals in high-reliability organisations project managers had to be prepared for surprises (Weick et al., 1999), and to be comfortable living in a world of questions and assumptions rather than answers (Perminova et al., 2008). Project managers that thrived in this environment acknowledged that uncertainty could not be eliminated; only reduced through pro-active questioning of assumptions, and flexibility and pragmatism in decision-making (Olsson, 2006). In the words of one nuclear industry project manager, this mindset of being prepared (Weick and Sutcliffe, 2007) required *"resilience, the ability to manage conflict, control one's own behaviours and the innate optimism to keep moving forward"* even when the project and operational terrain is uneven and the fog of uncertainty low-lying and dense. Another described the required behaviours as

"*the ability to be open minded and constantly on the lookout for knowledge gaps, and then being quick to change strategy, and make decisions as necessary"* Project Manager: Nuclear Decommissioning

Several interviewees stressed the importance of being able to remain flexible, to maintain focus on the project outcomes whilst operating in the midst of high levels of uncertainty. It may simply not be possible to pin down project schedules, or provide accurate estimates if timescales are long and topics vague. One project manager expressed it as follows *"there is a requirement to live in the grey and flex when required"*. Decision-making must be deliberate: coarse on occasion, as assumptions are made and decisions taken based on assumptions without the required granularity of information. Uncertainty in projects may mean that project managers use markers in the sand rather than fixed project milestones as proposed by McGrath and Macmillan (2000) in their discovery driven planning approach. Managing projects in this way may stress the prevailing organisational culture, particularly if it is a risk adverse one, and it requires tough, politically adept project managers with

excellent soft skills (Crawford et al., 2006; Söderlund and Maylor, 2012). These are individuals who can combine mechanistic analysis of risks and uncertainties with the right dose of intuition and judgement (Gladwell, 2006).

Skilled at managing relationships

To be uncertain is to be in a state of unknowing. Human beings desire certainty, so much so that our minds can play tricks on us, perceiving information to be more certain than in reality it is (Tversky and Kahneman, 1982, Gigerenzer, 2002). Humans crave certainty to an even greater degree if the impact of a particular event is severe (Krebs, 2011), for example, an accident at a nuclear plant or the failure of an aircraft engine in flight. Project uncertainty is no different. The sponsors of a safety-critical project, other stakeholders such as clients, regulators and even the project team will be more comfortable with the known than the unknown, with predictability as opposed to uncertainty. This ability to communicate the big picture is another key characteristic of high-reliability organisations (Bea and Roberts, 2001), one which was employed adeptly by the project managers in this study to confront uncertainty and avoid loss in confidence in the project when the landscape was uncertain. Frequent dialogue with industry regulators was required to ensure that the emerging project design would not spring any surprises on the regulator. Several participants reported the need to make uncertainty visible, constantly communicating it rather than hiding or ignoring it. Obtaining buy-in to the given level of uncertainty on a particular project was seen as essential to managing uncertainty in safety critical projects, although achieving this was not without challenge. To quote a senior project manager from the nuclear industry

"I think one of the things that I have suffered from in projects would be to give people a number and that was it, so when you had gone through preliminary design and were ready to start things have changed but that number is still in people's heads, and if uncertainty had been articulated a little bit better then projects wouldn't be so quickly dismissed as failures. This is not always easy to do as people do not want to hear it, because they can't deal with it either."

In this not untypical situation the project manager must display all his political, communicating and influencing skills to maintain senior management confidence in the project and its inherent uncertainties.

Utilise a range of structured techniques

The fourth and final strategy adopted by project managers in this study was to employ a range of structured techniques to help them confront project uncertainty. One project manager expressed it as follows:

"We can all see where we are now and look in the rear view mirror to see where we have been. It is much harder to look out the front window when travelling at speed, through a fog of uncertainty and remain focused on where we are trying to get to". Programme Manager: Nuclear New Build.

Many of the standard tools of planning and control in project management are focused on past performance. Whilst past performance measures how well the project is progressing, focussing on this limits the time available to ponder uncertainties, or future project scenarios or events that may trigger future uncertainties (McGrath and Macmillan, 2000; Cleden, 2009). Project managers in this study maintained focus on the drivers that affected project outcomes as a means of understanding how their project could be impacted by uncertainty.

The use of project contingency (on cost, time and project scope) was viewed as an essential tool in confronting uncertainty (Olsson, 2006), as it provides the project manager with the ability to flex and adapt to the emergence of new information without putting the project delivery at risk. Similarly several project managers used sensitivity analysis to estimate ranges of values on project costs and schedules. Faced with high levels of uncertainty, project managers also sought to keep their options open where possible "*doing this deliberately and consciously, even though it at times seems to increase the latent level of uncertainty on a particular project"*.

Other techniques used by project managers in this study were the use of small scale trials, akin to the learning and selectionist approach articulated by Pich et al., (2002), to drive out larger uncertainties in projects (Turner, 2005). Here the trials were used to reduce knowledge gaps, allowing the project team to learn and subsequently adapt their approach to project delivery. Almost all the participants in the study used brainstorming and heuristics to inform their approach to uncertainty. Brainstorming was carried out both informally through ad-hoc conversations and formally by assembling relevant multidisciplinary experts to advise on particular issues. Heuristics, or rules of thumb from past projects were used both by individual project managers and project teams to help conceptualise new projects at the scoping phase, although interviewees acknowledged that in safety-critical industries where individuals generally hold a surfeit of tacit knowledge, both these techniques can lead to bias and complacency, and an inability to spot those "*blackswan*" events (Taleb, 2007), or "*bolts from the blue*" (Cleden, 2009) that have the potential to derail a project. Interestingly lessons-learnt logs were perceived as an ineffective source of knowledge on project uncertainty, primarily due to problems on indexing and accessing the relevant information. The project managers in this study were much more ready to seek their colleagues' opinions and knowledge about past projects, as this was viewed as a more immediate and contextually rich source of information.

Contribution

How project managers tasked with delivering the next generation of nuclear power plants, submarines and aircraft engines deal with the uncertainty inherent in their project environments is a matter of interest to the academic community, practitioners and public alike. The study reported here provides a rich picture of how a number of senior project managers in safety-critical industries in the United Kingdom prepare for the uncertainties they are presented with in their operational environment. Its contribution to theory is in its analysis of how practicing project managers in safety-critical industries interpret and make sense of project uncertainty, and the strategies and approaches they use to deliver projects in safety-critical environments. The study demonstrated close parallels between the project management literature on the management of uncertainty and the extant literature on high-reliability organisations with the project managers in this study exhibiting many of the characteristics of high-reliability organisations, for example flexibility in decision making, a deference to expertise and mindful behaviour as a means of confronting the myriad of uncertainties in their projects in operating environments which are highly-regulated, conservative and with a low tolerance for risk.

The findings of this study are that confronting uncertainty is much more than broadening the scope of the risk management process to incorporate uncertainty. Rather managing uncertainty is about a mindset, about maintaining an attitude of mindfulness and conscious deliberation when identifying areas of uncertainty. Managing uncertainty is about making uncertainty visible to all project stakeholders. It requires the ability to remain flexible, to

maintain focus on the project outcomes whilst operating in the midst of high levels of uncertainty, and dwell amongst questions and assumptions rather than answers and knowledge. These are difficult skills to learn and confidently deploy particularly in environments which are inherently conservative and risk-adverse. The prize for those project managers that do succeed is however great: the ability to bear the weight of responsibility for the delivery of complex projects in safety-critical industries.

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