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Understanding Project Uncertainty in Safety-critical Industries

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Abstract

Increasing attention in the project management literature is being paid to the theme of *uncertainty*: its origins and how it impacts projects (Atkinson, Crawford, & Ward, 2006; Perminova, Gustafsson, & Wikstrom, 2008). The purpose of this exploratory study was to investigate the determinants and impacts of project uncertainty in the context of safety-critical industries in the United Kingdom. Seven current projects across two such safety-critical industries, civil nuclear and aerospace, were studied by means of in-depth interviews with senior project managers. The authors posit a framework, incorporating four determinants of uncertainty that are prevalent in large-scale projects in these sectors. The framework comprises project content, context, organisational capability, and culture. We then explain how these four determinants of uncertainty may impact on the delivery of project outcomes. Future work is now required to test the validity of these preliminary conclusions against a larger sample size, and to compare the determinants and impacts of uncertainty on safety-critical projects in the context of locations other than the United Kingdom.

Introduction

The management of uncertainty in projects has emerged as a sub-domain within the project management field over the last ten years. Evolving from the study of project risk management, the extant literature on project uncertainty provides a number of definitions of uncertainty (Hillson, 2002; Ward & Chapman, 2003; Perminova et al., 2008), the typical sources of uncertainty in projects (Ward & Chapman, 2003; Atkinson et al., 2006; Cleden, 2009; Winch, 2010) and a variety of approaches to tame, if not eliminate uncertainty (Chapman & Ward, 2000; Pich, Loch, & De Meyer, 2002; Hillson, 2004; Thiry, 2004).

Safety-critical industries are defined as those industries in which safety is of paramount importance and where the consequences of failure or malfunction may be loss of life or serious injury, serious environmental damage, or harm to plant or property (Falla, 1997; Wears, 2012). Commonly quoted examples of such industries are nuclear power plants, off-shore oil platforms, chemical plants, commercial aviation, and rail transport (Baron & Pate-Cornell, 1999; Amalberti, 2001; Kontogiannis, 2011; Wears, 2012). Project managers in safety-critical industries must be particularly mindful of the uncertainties at play in their projects, as the major challenges facing current civil nuclear new build projects in both Flamanville in France and Olkiluoto in Finland bear witness to (Ruuska, Ahola, Artto, Locatelli, & Mancini, 2011). The task facing project managers in these safety-critical industries is how to determine the myriad of risks and uncertainties present in projects and assess their impact on project outcomes. Based on interviews with project managers on seven current large-scale projects in civil nuclear and aerospace sectors in the United Kingdom, this paper seeks to explore responses to the following research questions: What are the main determinants of uncertainty in projects in safety-critical industries? And how do these uncertainties impact on the delivery of projects?

The paper is structured as follows: The first section summarises the literature on the sources of uncertainty in projects, and the second describes the study methodology. Subsequent sections articulate the findings of the study, and the implications of these observations on the practice of managing future projects in safety-critical industries.

Literature Review

There are many complementary, and in some cases competing definitions of uncertainty in the project management literature. A number of scholars define uncertainty in the context of project risks (Hillson, 2002; Ward & Chapman, 2003; Sandsaewerson, 2012), whereas others focus on uncertainty as the absence of the required information (Atkinson et al., 2006; Meredith & Mantel, 2010; Winch & Maytorena, 2011). As an

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example of the former, Hillson cited in Olsson (2007) states that *"risk is measurable uncertainty, uncertainty is unmeasurable risk"* (Olsson, 2007, p. 747) In contrast, Meredith and Mantel (2010) state that uncertainty relates to "*having only partial information about the situation or outcomes*" (Meredith & Mantel, 2010, p.13). Howell, Windahl and Seidel (2010) provide a helpful definition that attempts to straddle this divide, stating that uncertainty in its broadest sense "*encompasses not only probabilistic or undefined outcomes but also ambiguity and lack of clarity over situational parameters."*(Howell et al., 2010, p.258). Indeed, perhaps theoretical attempts to pin down the notion of uncertainty in projects are ultimately doomed. Rather like the fascinating yet esoteric world of quantum physics, the more precisely we try to define uncertainty, the less certain we can be that we have captured its many nuances and facets (Cox & Forshaw, 2011).

Project managers, however, need to be pragmatic individuals and can appear less concerned with theoretical definitions of uncertainty. Instead, acknowledging that uncertainty is an unavoidable fact of projects (Atkinson et al., 2006) project managers are more exercised with how uncertainty arises, shapes, influences and impacts on their day-to-day project reality. Addressing this, scholars have identified a number of sources of uncertainty in the literature. Complexity is one such source of uncertainty in projects (Cleden, 2009; Winch, 2010). This complexity may arise from the functional requirements of the product, the choices of technology or the diversity of actors involved in the project (Danilovic & Sandkull, 2005). To complexity, Weick (1995) adds a further two sources of uncertainty in projects: that of information load (the volume of ambiguous information that must be processed) and turbulence (the rate at which project facts change and the randomness of their timing and direction of change). Sheer lack of information or lack of understanding of what the salient issues are in the project may also increase project uncertainty (Cleden, 2009), with this tension manifesting itself most forcefully at the project definition phase. At this stage in a project, the scope may be very fluid, costs and timescales little more than unsubstantiated estimates, and the required trade-offs between competing project objectives are only beginning to emerge (Ward & Chapman, 2003). In addition, the relationships between parties involved in the project will be inchoate – with the potential for misunderstandings and conflict high (Hong, Nahm, & Doll, 2004). Uncertainty may also arise due to factors in the external environment, for example, institutional decision making processes, or the competing and conflicting demands of project stakeholders, or even from external industry and market risks (Jensen, Johansson & Lofstrom, 2006; Winch, 2010; Aaltonen, 2011).

Amidst this swirling torrent of uncertainty, the thoughts of the project manager will be dominated by one question: "Will my plans and preparations deliver the required project outcomes?" (Turner & Müller, 2003) In safety-critical industries the question is even more emotive, as project managers in these environments are asked to bear the weight of responsibility for the delivery of safety-critical systems (Perin, 2005). Here the price of miscalculation can be severe and potentially disastrous and it is for this reason that this study has been undertaken. Its aim is to establish what the determinants and impacts of project uncertainty are in safety-critical industries. The study is an exploratory one, best viewed as a preliminary excavation into the largely unsurveyed depths of the management of uncertainty in safety-critical industries.

Methodology

The study reported in this paper is focused upon the UK civil nuclear and aerospace industries. To study 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 of nuclear plants, or building ever lighter and more fuel-efficient gas-turbine aircraft engines are expected to deliver long-term, multi-billion pound projects to the satisfaction of a myriad of internal and external stakeholders. The uncertainties at play in these 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 can we design in safety for a nuclear power plant that will remain in service for 40 years with only minimum access to critical components during this time? In this study, the authors begin from the ontological position that there are a number of determinants of project uncertainty in safety-critical industries, and that by probing practicing project managers we can begin to gain insight into these determinants. This approach is consistent with the call by Cicmil, Williams, Thomas, & Hodgson (2006) for project management research to be situated in the *actuality* of projects and centred on project managers' *lived experience of projects*.

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The study uses a cross-sectional, qualitative research design, based on eight semi-structured in-depth interviews of experienced project managers involved in seven projects in nuclear power generation, nuclear decommissioning, and civil aerospace industries. This enabled data to be collected from a range of project contexts, allowing the researchers to induce topics, themes and associations from the interview data. The interviewees were selected through a combination of purposive and convenience sampling, using industrial contacts to identify experienced project managers currently involved on a large-scale nuclear and civil aerospace new build, maintenance, or upgrade project. Due to commercial restrictions, the organisations and projects studied are not listed in detail, but an anonymised summary is provided in Exhibit 1.

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	Operations 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

Exhibit 1 – Study participants by industry and role

All interviews were carried out during the second quarter of 2012, with each interview being audio-recorded and transcribed. Analysis of the interviews was based on the five-step process described in McCracken (1988). This process involves reviewing the transcripts and relating observations made by interviewees to develop themes and patterns. The interrelationships between these themes and patterns are then developed into more general themes, drawing on the academic literature to make sense of the findings. Acknowledged limitations in the study were the lack of data triangulation and the small sample size. However, given that the study was exploratory this should not detract materially from the reliability of the findings at this stage and the authors make no claim for the wider generalisation of the findings.

Findings and Discussion

This study sought to answer the following research questions: What are the main determinants of uncertainty in projects in safety-critical industries? And how do these uncertainties impact on the delivery of projects? The findings from the interviews are organised around these two questions. Respondents were asked: “What are the determinants and impacts of uncertainty facing project managers in civil-nuclear and aerospace projects?” Determinants were defined as “factors or circumstances that influence or determine” and impacts as “the effect of uncertainty on the project.” Respondents gave rich responses to this question; but common themes did emerge in terms of both determinants and impacts of uncertainty.

Determinants of Uncertainty in Projects within Safety-critical Industries

The determinants of project uncertainty were structured into four substantive themes: the content of the project, its context, the organisational capability, and culture. Exhibit 2 highlights the main points raised by respondents in each of these four themes.

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Theme	Points raised by respondents
Project Content	Size Complexity Timescales Phase of project Clarity of scope Project priority within organisation Number of project parties
Project Context	Political, economic, social, technological, legal, and environmental influences Regulatory framework – number of and role of regulators Sensitivity of business case to external influences Project stakeholders
Capability	Experience and skills of project team Maturity of project management processes Resource management and resource constraints Industry skills base Length and complexity of supply chain
Culture	Organisational propensity for uncertainty Decision-making ability of organisation

Exhibit 2 – Determinants of project uncertainty

The content of the project

Project content was the first key determinant of uncertainty in a project. Echoing Cleden (2009) and Winch (2010), the size of the project, its perceived complexity and timescale were viewed as central to the level of uncertainty present in a given project. For example, the project manager of a major new nuclear project stated:

"As soon as you go beyond a five-year horizon then you are much more likely to experience some kind of change that will cause a perturbation in the project."

Clarity of project scope was also seen as a key determinant of project uncertainty (Ward & Chapman, 2003), with project managers needing to understand how well-defined the project scope is, how clear the project outcome is ex-ante, and the level of knowledge within the project team regarding the proposed solution. At this early stage of the project, in the words of another nuclear project manager there is:

"*Uncertainty about what the end product looks like, what the shape of the team is, and what the cost of the programme is."*

The influence of the content and context of the project on the level of project uncertainty was eloquently articulated by another civil aerospace project manager:

"*If you don't set yourself up well in the first place it just makes life harder as you go through. You just make a bed that is more and more uncertain as people embed themselves in different positions in the pool of uncertainty and that becomes their reality. As you move on without a solid platform it just gets tougher….*"

In theory, as a well-defined project progresses, the uncertainty should gradually reduce (Winch, 2010), but there may still be spikes in uncertainty as a consequence of unforeseen events. Respondents suggested that the phase of a project has a stronger influence on the level of uncertainty than the type of project (e.g., new build or upgrade and maintenance). Other elements of project content that determined the level of uncertainty were the priority of the project within the organisation and the number of stakeholders and parties involved (Ward & Chapman, 2008). To paraphrase the previous quotation, the more stakeholders there are to the project, the more important it is to embed them effectively in the project.

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Project context

The second theme to emerge from the interviews was that of project context. The context provides the hinterland of the project – the backdrop against which it must be delivered. Important determinants of uncertainty that emerged here were: external political influences and geopolitical forces. For example, energy prices and governmental energy policy influence the desirability and affordability of new and existing nuclear power plants, whereas the state of the global economy, oil prices, and governments' aviation policies will impact projects in the civil aerospace sector. These influences are out with the control of the individual project manager but nevertheless loom large as uncertainties in individual projects – particularly where they are long-term. In safety-critical industries, the regulatory landscape contributes significantly to the uncertainty in the project. For example, although there is consensus on which design of reactor is to be used in nuclear new-build projects in the United Kingdom, it is unclear whether the UK regulatory framework will require major changes to the reactor design before formally licencing it for use. Although the Generic Design Assessment (HSE, 2008) has helped to identify specific licencing issues, this uncertainty materially impacts the ability of project managers to accurately define resource needs, scope the technical work required, and hence define project costs (Atkinson et al., 2006).

The influence of industry regulators on project uncertainty is heightened by the complexity of the regulatory framework. Projects in safety-critical industries can find themselves in a position, in which preparation of the safety case or overcoming the required regulatory hurdles define the critical path of the project, and yet the resources capable of preparing the required paperwork sit outside the project team. Another determinant of uncertainty arising from the project context, particularly in civil aerospace, was the commercial imperative for the project. Respondents described the sensitivity of the business case to changes in demand for the project, either due to industry sentiment shifting in favour of a competing product or due to fluctuations in macroeconomic demand having an impact on aviation industry globally. To overcome these contextual uncertainties, project managers spoke of undertaking PESTEL analyses (Johnson, Scholes, & Whittington, 2005) to identify the various political, economic, social, technological, environmental, and legal uncertainties in their projects.

Capability

The third key determinant of project uncertainty in safety-critical industries was the capability to deliver the project. This was described by respondents as operating on two levels: first at the level of the project organisation and secondly at an industry level. At the project-organisation level the major influences on uncertainty were the level of maturity of project processes, for example, the maturity of the organisation's risk management processes and how resource constraints are managed. Securing project resources was a recurring cause of uncertainty across projects in both civil nuclear and aerospace sectors, with respondents questioning their organisation's understanding of project management and whether the organisation had the capacity to meet demand in terms of the people and facilities required to undertake projects. Several respondents also saw it as central to their role to mentor less experienced colleagues, helping foster the skills and judgements required to navigate project uncertainty.

The skills and experience of project team members also contributed to the level of uncertainty in the project; projects that were able to mobilise a highly experienced project team were better placed to manage uncertainty than those that were not. The nuclear industry has attempted to address this issue by introducing the concept of Suitably Qualified and Experienced Personnel (HSE, 2007), but this formal requirement for appropriately approved individuals can have the unintended consequence of increasing the resource constraints under which the project must be delivered.

At the industry level, uncertainty in project delivery arises due to the nature of the industry supply chain and its skill base. Respondents described a "*fragmented and fragile supply chain*" in which contractual frameworks were inadequate, bargaining power limited, and strategic alliances complex. For long-term projects, the presence of an aging workforce and the difficulty in retaining key skills were major sources of uncertainty. This is particularly true for nuclear projects, where almost 60% of the workforce is due to retire between 2020 and 2025 (Cogent, 2009) and where the privatisation and contraction of the industry towards the end of the last century have led to a fragmented and fragile workforce in some key areas. One respondent expressed this eloquently:

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"There is a lot of external work but the supplier base is quite fragile and we can't go overseas because of the nature of our project. So we are stuck with finding UK nationals and companies to work on this project, so even when we go out to find external resources to do the design work and work packages it's really quite challenging. So that is one of the key uncertainties. So, if I need 600 people next year and I only get 450, then that is150 man-years of work not being done. And then that folds forward and you say, well hang on a second, we need to make sure that the most important work is getting done this year, so what's not getting done and you know, if there is any uncertainty around that stuff, then you could find yourself having dropped a piece of work that becomes quite critical next year and the schedule starts to give you problems as well."

Culture

The fourth key determinant of uncertainty was identified as organisational culture. Different organisations were seen to have differing propensities for coping with uncertainty, with the nuclear industry being particularly conservative and risk-averse in this regard. Respondents from the nuclear sector spoke of a "low tolerance" of uncertainty, due to the dominant safety culture in which certainty was sought wherever possible. This low tolerance for risk manifests itself in projects proceeding in linear steps, following due processes, with the technology solutions chosen remaining conservative. In effect, the onerous safety and regulatory requirements provide a secure stockade around the project, in an attempt to minimise project uncertainties. On the other hand, the civil aerospace project managers interviewed described operating in a more flexible environment: one where conforming to process was important but where innovations and new ways of working were possible and desirable, provided the appropriate sanction to proceed was in place or could be put in place ex-post. This greater ability to tolerate uncertainty is perhaps a direct response to the sharper commercial imperative in the civil aerospace industry.

The other cultural determinant of uncertainty in both the civil nuclear and aerospace industries was the decision-making ability of the organisation (Chapman & Ward, 2002). How decisions are made, who is involved, and the level of accountability for decisions were all perceived by respondents to be a key influence on project uncertainty. One aerospace project manager summed up this view as follows:

"The uncertainties that I find tougher are the internal cultural and political ones. For example my organisation is an embedded matrix one. My project has three legs – operations, technical, and construction – three different sets of people with three different organisations, and very different reporting routes which only coincide at the president level"

The determinants of uncertainty identified by project managers in this study align to a large extent with the sources of uncertainty described in the literature, with the exception of two areas of dissonance. The literature is rich with respect to the role which both the content and context of the project play in determining project uncertainty (Weick, 1995; Danilovic & Sandkull, 2005; Cleden, 2009). However, the capability of the organisation and industry, and cultural backdrop against which the project is delivered are less well addressed. And yet, capability and the dominant culture of conservatism and risk adverseness that are prevalent in the civil nuclear industry was an important factor in clarifying project uncertainty. Taking this into account the authors of this study posit a model, which takes into account not just content and context but also the capability and culture of the organisation in order to determine the uncertainties present in projects in safety-critical industries. This is illustrated in Exhibit 3. Here the content of the project remains firmly at the centre of determining the uncertainties at play, but gives equal weighting to the context of the project, the organisational and industry capability to deliver it and the particular challenges which the organisational culture may present to the project.

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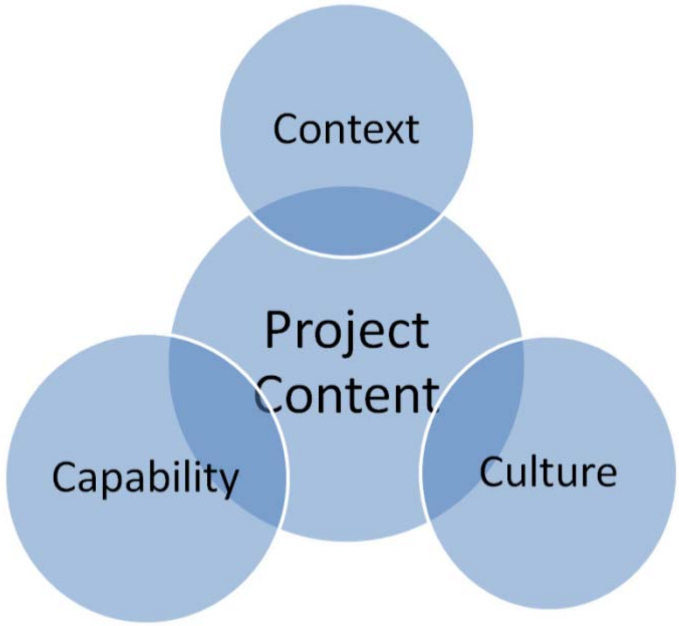

Exhibit 3 – Determinants of uncertainty in safety-critical industries

The impacts of uncertainty on the project delivery

Less predictability of project outcome

This study identifies three major impacts of uncertainty on projects in safety-critical industries. The first of these is that uncertainty leads to *less predictability of project outcome*. This threat to predictable delivery may endanger the business case for the project or increase the likelihood of reputational damage to the project organisation. It may also manifest itself in diminished confidence in project relationships, since managing the expectations of stakeholders and sponsors is a fundamental part of project management. Unpredictable project outcomes caused by uncertainty, can lead to conservative technical solutions, which may not always be the best solutions, in an attempt to increase the likelihood of a successful outcome, or to sizeable elements of contingency in project budgets, or to increasing levels of project complexity as multiple options must be explored in parallel before a suitable technical solution is identified. Echoing Turner (2005) one respondent spoke of:

"*Undergoing small scale trials to provide information to drive out larger uncertainties*"

And, speaking of a nuclear decommissioning project:

"*When we open the cans of fuel we really don't know what is going to be inside there. You can have a risk register that says we have certain techniques that are quite well developed and understood but what if we open the cans and it doesn't look anything like we expect it to.*"

Effective stakeholder management skills are required to deal with circumstances such as these.

Unpredictability makes sponsors, other stakeholders, and the project team itself nervous: we are all more comfortable with predictability as opposed to uncertainty (Gigerenzer, 2002). Project managers must respond to this need for predictability by making uncertainty visible and constantly communicating issues of uncertainty rather than hiding or ignoring them. Obtaining "buy-in" for the given level of uncertainty on a particular project

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was seen as essential to managing the impact of uncertainty in safety-critical projects, although achieving this was not without challenge.

Additional behaviours from project managers

This leads us to the second impact of uncertainty: that uncertainty demands *additional behaviours from project managers*. Project managers have to be prepared for surprises and to be comfortable living in a world of questions and assumptions rather than answers (Perminova et al., 2008). Respondents who thrive under uncertainty acknowledged that it could not be eliminated but only managed through proactive questioning of assumptions and a combination of flexibility and pragmatism in decision making (Olsson, 2006). Several of those interviewed confirmed how important it is, in their view, to remain flexible, maintaining focus on the project outcomes, while in the midst of uncertainty. One civil aerospace project manager expressed it as follows: "*there is a requirement to live in the grey and flex when required.*" Decision making must be deliberate and coarse on occasion, as assumptions are made and decisions made 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. Managing projects in this way may stress the prevailing organisational culture, particularly if it is risk adverse, and it requires tough, politically adept project managers to work successfully within these tensions (Thomas & Mengel, 2008).

Project life cycle and processes

The third impact of uncertainty is on the *project life cycle and the project processes*. Uncertainty implies an absence of the required information (Atkinson et al., 2006). Uncertainty in the required technology for a particular aircraft engine design or in what elements of a nuclear plant require seismically qualified concrete requires decisions to be made in the absence of complete information. Assumptions, rather than facts may form the basis of many decisions, requiring those assumptions to be documented and revisited periodically as new information emerges. The project processes may require amendment to deal with assumptions rather than facts and to follow more discovery-driven planning approaches (McGrath & Macmillan, 2000) as opposed to classical project management planning and control techniques (Gray & Larson, 2002). Checkpoints rather than milestones may be used to monitor progress. One project manager advocated the use of

"*set moments along the way where we collect together everything and then almost make a declaration, whether that be an interim business case or whatever the document needs to be, so that we have a marker in the sand.*"

One approach to this is the Periodic Safety Review (PSR) used in the licencing of nuclear facilities "*Under condition 15 attached to the nuclear site licence, Periodic Safety Reviews must be carried out by the licensee of a nuclear power plant. The reviews are complementary to the day-to-day regulatory controls which are applied in nuclear power stations. They provide the opportunity to undertake a comprehensive study of plant safety.*" (Office for Nuclear Regulation, 2012, p. 1)

Another process affected by the presence of uncertainty is the risk management process, which in the view of several respondents, is sometimes a box-ticking exercise. In the presence of uncertainty, considerable judgement and intuition are required in enacting the risk management process to identify knowledge gaps, and to allow areas of uncertainty to emerge. If there is no documented uncertainty management process then project managers may be required to work 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 complete information.

The study, reported here, found that contingencies were commonly used as a means of delaying the impact of project uncertainty, although several respondents in both civil nuclear and aerospace had come under intense pressure to reduce contingency budgets or to deliver fixed-price projects irrespective of the uncertainties identified. The presence of uncertainties in projects in safety-critical industries will also have an impact on the project life cycle in terms of increasing the amount of development or exploratory work that may be required. As asserted by Loch, De Meyer, and Pich (2006) multiple investigations and experiments may be required before an optimal solution to a particular design issue is found. At the opposite end of the project life cycle increased volumes of testing may be required to provide the information needed to ensure that the delivered project meets all the regulatory and safety case requirements.

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Conclusions

How project managers tasked with delivering the next generation of nuclear power plants and how civil aerospace engines deal with the uncertainty inherent in their projects is a matter of interest to industry and the public alike. This paper offers the results of an exploratory qualitative investigation of this highly relevant topic, aiming to probe what the determinants and impacts of project uncertainty are in two safety-critical industries in the United Kingdom. Its objective was to enable project managers both to conceptualise the various determinants of uncertainty and to understand how these uncertainties will shape and influence their projects.

"*Uncertainty is an inevitable aspect of most projects, but even the most proficient managers have difficulty handling it. They use decision milestones to anticipate outcomes, risk management to prevent disasters and sequential iteration to make sure that everyone is making the desired product, yet the project still ends up with an overrun schedule, overflowing budget and compromised specifications. Or it just dies"* (De Meyer, Loch, & Pich, 2002, p. 60).

This statement articulates concisely the potential impact of uncertainty on a project. Uncertainty is a challenging beast for even the best project managers; and, before it can be tamed, the uncertainties at play in a project must be understood by the project manager and his or her team. The model of the determinants of uncertainty developed in this study begins to enable project managers in safety-critical industries to do this. In this model, the content of the project (its size, complexity, timescales) remain firmly at the centre of determining the uncertainties present, but given equal weighting are: (1) the context of the project, (2) the organisational and industry capability to deliver it, and (3) the particular challenges, which the organisational culture may present to the project. These determinants do not exist in isolation from one another; rather, they are interconnected and interrelated, each of them shaping and influencing the others in a manner that can magnify the level of uncertainty on the project.

The impacts of uncertainty on a long-term safety-critical project manifest themselves in three broad ways; through increasing the unpredictability of the project outcomes, through demanding additional behaviours from the project manager and by impacting on the suitability and effectiveness of classical project management processes as articulated in the current bodies of knowledge from the Project Management Institute and Association of Project Management (PMI, 2008; APM, 2006). These impacts require project managers to think outside the box; to expect, to prepare for, and to remain vigilant against uncertainty, engaging an appropriate mind set as much as the project processes to achieve this.

The authors note a number of limitations to the exploratory study presented in this paper. It was undertaken within the United Kingdom and only a small number of project managers from a limited number of organisations were interviewed. Therefore, the findings may not be generalisable across other organisations or geographic regions. The findings are also biased towards the civil nuclear industry, given that the majority of respondents were employed in this sector. The authors plan to replicate the study over a larger number of projects in the civil nuclear and aerospace sectors and across wider geographic regions (e.g., the United States and Asia Pacific) to enable a more comprehensive and generalisable set of determinants and impacts of uncertainty to emerge.

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