Managing Uncertainty (opportunities and threats) in Megaprojects

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**Abstract:**

Megaprojects inherently contain high levels of uncertainty, due to their scale, complexity and heterogeneous one-off delivery nature. Dealing with uncertainty (a ubiquitous phenomenon) in projects requires numerous approaches on multiple fronts (e.g. at an individual, organisational and inter-organisational level). Uncertainty is viewed as the unknown opportunity or threat that could emerge from multiple external and internal sources and has an influence during the project evolution. This paper draws on existing conceptual and empirical findings to understand uncertainty in megaprojects, this includes the megaproject context (underlying organisational dynamics), characteristics of uncertainty and management of uncertainty. Based on the initial findings, the key emerging ideas are developed into a set of preliminary propositions to guide research on understanding uncertainty within megaprojects. The conceptual findings provide the foundation required for further empirical research to explore and identify the key challenges and solutions of managing uncertainty and its characteristics through a multi-perspective approach.

**Keywords:** Uncertainty; Opportunity; Threat; Risk; Uncertainty Management; Megaprojects.

1. **Introduction**

Organisations are required to embrace adaptive approaches to cope with emerging uncertainties and fast-paced environments (Lawrence and Lorsch, 1967; Eisenhardt and Tabrizi, 1995). This is especially the case when delivering large, complex projects, also known as ‘megaprojects’, they tend to be highly challenging, fragile and vulnerable to emerging threats, where adverse effects can lead to diminishing their returns on investment, which are only realised after many years (Miller and Lessard, 2001; Ansar et al., 2017). Megaprojects face risks and uncertainties from numerous sources, such as the increasing developments in technology, climate change and social-economics, which causes result them to overrun in cost and time (Miller and Lessard, 2001; van der Vegt et al., 2015; Flyvbjerg, 2017). The uncertainties facing megaprojects are further amplified due to majority of these projects being delivered by the construction industry, which is criticised for its underperformance and lack of innovation in comparison to other industries (Morris and Hough, 1987; Latham, 1994; Flyvbjerg et al., 2003; ICE, 2015; McKinsey Global Institute, 2017). In contrast, due to the high complexity of megaprojects, many of the uncertainties emerge as opportunities (Shenhar and Dvir, 2007), and where these opportunities are novel, they can potentially be successfully exploited into innovations, provided that effective dynamic and flexible approaches are adopted (Davies et al., 2009; Lenfle and Loch, 2010).

These challenges signify the importance of exploring, identifying and adopting effective approaches to deal with uncertainty (either as a threat or opportunity). This is especially important as megaproject (such as infrastructure) performance can highly impact the setting they are delivered within, either transforming and underpinning the well-being of the wider social-economics of regions (Frischmann, 2013) or impacting the natural ecosystem (Qiu, 2011). Significant worldwide investments are made into megaprojects to meet the current and future needs (McKinsey Global Institute, 2013; OECD, 2013), these investments are irreversible once a megaproject is completed (Miller and Lessard, 2001).

Considerable research and development has been made into the management of project risk through numerous frameworks and strategies, and going further by recognising the need to expand the scope of risk through uncertainty in its positive and negative form (e.g. De Meyer et al., 2002; Ward and Chapman, 2003). Also, various strands of research emphasise that megaprojects need to go ‘beyond risk management’ and towards uncertainty management, in
order to effectively manage and ‘organise for the unforeseen’ or ‘unknown unknowns’ (De Meyer et al., 2002; Pich et al., 2002; Loch at al., 2006; Davies et al., 2017).

Whilst acknowledging previous research in developing our understanding of uncertainty, there are calls for further research to explore uncertainty in megaprojects (e.g. Lenfle and Loch, 2017; Loch, 2017) or important organisational concepts under the conditions of uncertainty, such as innovation, learning and teamwork (e.g. Alvarez et al., 2018). This study examines conceptual and empirical findings of the various strands of studies on uncertainty and its management related to megaprojects and highlights some of the key emerging areas requiring further research in the growing megaproject research field.

The findings of this article cover several interrelated areas. This includes, when investigating uncertainty (a ubiquitous phenomenon) within a megaproject, it requires us to carefully take into consideration the dynamic and complex nature the setting uncertainty is situated within. Uncertainty types can be classified into several characteristics (e.g. source, level and impact), these are interrelated and form the basis for managing uncertainty. There are numerous approaches and perspectives on dealing with uncertainty, where unforeseen uncertainty is the most challenging, either as threats, opportunities (including novel opportunities). The aim of this paper is to develop propositions and guide research based on the theoretical foundations that are underpinned in the following sections, namely, the megaproject context; the characteristics of uncertainty; and the management of uncertainty in megaprojects. Finally, the paper concludes with a discussion of the findings and suggestions for further research.

2. Megaproject context

This research conceptualises projects as an endeavour to achieve a goal through a temporary organisation using people and resources (Davies, 2017). Megaprojects are very large and complex type of projects that cost 1$ billion or more – in cases these project’s capital costs are comparable to the GDP of nations (Flyvbjerg, 2014). Their complexity and scale make it difficult to fully understand their transformational effects, for example, the effect on the wider environment and social-economic of regions and countries (Gellert and Lynch, 2003). The types of megaproject range from, high-speed rail line, airports, the Olympics, nuclear power plants, dams, oil platforms, development of new aircrafts and national broadband (Flyvbjerg, 2017).

Megaprojects tend to underperform and are challenging to manage due to their characteristics, such as the high number of actors, temporariness, demanding requirements, pace, market volatility and institutional arrangements (Morris and Hough, 1987; Miller and Lessard, 2001; Flyvbjerg et al., 2003; Jones and Candance, 2008; Flyvbjerg, 2017). These characteristics contribute to the high levels of complexity megaprojects experience (Williams, 1999; Shenhar and Dvir, 2007; Davies and Mackenzie, 2014), making coordination, learning and teamwork initiatives difficult to achieve (Berggren et al., 2001; Edmondson, 2012). These initiatives are essential for dealing with uncertainty (Loch et. al., 2006; Shenhar and Dvir, 2007), where uncertainty is one of the greatest challenges embedded in the wider megaproject complexity (Miller and Lessard, 2000; Williams, 2005; Gil, 2009; Geraldii et al., 2011; Davies et al., 2016).

Uncertainty is inherently a dynamic and interdependent phenomenon, when investigated in an embedded multi-level complex temporal system (such as megaprojects), it can lead to observations being misaligned with reality, due to the findings of an investigation not considering the environmental context (Van de Ven and Poole, 1995; Langley and Tsoukas, 2010), resulting in ‘sterile descriptions’ and lack of theory building (Mintzberg, 1979). To avoid this, conceptual lenses can be adopted to provide a clearer picture of the context. There
are a number of studies from management science and project management that have developed concepts to describe the setting that resembles or directly relate to the megaproject context, the concepts overlap or vary in scope and focus on different areas, examples of these concepts include, ecosystem (e.g. Iansiti and Levien, 2004), meta-organisations (e.g. Ahrne and Brunssson, 2005, Gulati et al., 2012), complex product systems (CoPS) (e.g. Hobday, 1998), inter-organizational projects (e.g. Jones and Candance, 2008), temporary organisations (e.g. Turner and Müller, 2003). Based on these diverse concepts and the characteristics of megaprojects, we see the megaproject context as a non-permanent temporal complex arrangement, consisting of actors, events, activities, processes, transactions, interactions and relationships that are formal and/or informal, which tend to be influenced/directed by central organisations with an overall aim of delivering a megaproject in an uncertain environment. The context consists of overlapping dimensions that shape megaprojects, such as project teams working in dynamic temporary arrangements and changing as the project evolves. These teams are collectively responsible for the project performance and dealing with uncertainty and its numerous characteristics. Considering the above, we propose:

**Proposition 1.1** Investigations on uncertainty underpinned by the megaproject context advances the understanding of how uncertainty unfolds and is approached.

### 3. Characteristics of uncertainty

#### 3.1 Uncertainty and risk

Uncertainty is a ubiquitous phenomenon experienced in different degrees and forms. It has been a central concept in many disciplines and explored by many scholars, such as philosophy and logic (e.g. Wittgenstein, 1986), statistics (e.g. Lindley, 2014), sociology (e.g. Zinn, 2008), psychology (e.g. Loewenstein et al., 2001), economics (e.g. Knight, 1921), management studies (e.g. Thompson, 1967) and project management (e.g. Loch et al., 2006). Each perspective provides a unique insight into uncertainty faced and experienced in different aspects of life. A common trend appears to revolve around having incomplete or lack of information/knowledge (doubt/certainty in philosophy) of a state, condition, situation or event. The diversity of the multi-disciplines exploring uncertainty suggests that it is a challenging phenomenon embedded in nearly all aspects of social and economic activities. This is noticeable by organisational theory publications being greatly influenced (directly or indirectly) by the challenges uncertainty pose (Jauch and Kraft, 1986), likewise in project management theory (Perminova et al., 2008).

Knight (1921) is considered to have been the first to make the distinction between the terms risk and uncertainty (Runde, 1998), Keynes (1921) also agrees with Knight, alluding to the differentiation between risk and uncertainty, and in his later works, Keynes (1937) provides a clear distinction or discourse into the difference of risk and uncertainty. A common acknowledged differentiation is that risk is an element (e.g. circumstance) where its probability distribution is known or can be assigned, and uncertainty is an element where its probability distribution is unknown or cannot be assigned. Dealing with the unknown (uncertainty) tends to be more challenging and as the “uncertainty of a course of action increases” so does its “undesirability” (Keynes, 1921).

The definitions of risk have evolved over the years, numerous actors have offered different definitions, such as scholars, international and national standards, governmental institutions and professional bodies. An example of a definition of risk is “an uncertain event or set of circumstances that, should it occur, will have an effect on achievement of one or more of the project’s objectives” (APM, 2004). This definition offers a relatively broad scope of risk by referencing to ‘effect’ which can be a threat or an opportunity (Chapman and Ward, 2011).
Although, the term risk tends to be associated with threat/negativity, which can be problematic by discouraging opportunity seeking (Ward and Chapman, 2003).

There appear to be differing views amongst authors on the extent of distinguishing uncertainty and risk in projects, and whether there is a need to make a distinction. De Meyer et al. (2002) and Loch et al. (2006) argue that projects fail due to the lack of distinction made between uncertainty and risk. Using risk only encourages risk management to be a fixed set of routines and procedures that do not adapt to the unique nature of projects where there are many unknowns. In this paper, we distinguish risk by identifying it as variation/foreseeable type of uncertainty (De Meyer et al., 2002). Based on the vast publications related to uncertainty in the body of knowledge, the type of uncertainty is a function of numerous interrelated characteristics, in the next sections we provide an overview of the main characteristics: sources, levels and impacts of uncertainty.

3.2 Sources of uncertainty

There are numerous uncertainties megaprojects face due to their characteristics and multidimensional context, these uncertainties emerge from a variety of sources. Authors classify uncertainty sources differently and their emphasis varies depending on the particular problem context under examination. Based on the various streams of literature related to the sources of uncertainty in megaproject, they are either external and internal, we can classify the key sources as: individual/group—cognitive, behavioural, social and cultural dimensions influencing individuals and groups (e.g. Flyvbjerg et al., 2009; Loch, 2017), organisational—decisions, interactions and actions of individual organisations (e.g. Ross and Staw, 1993), inter-organisational—interactions and dynamics that exist between organisations (e.g. Jones and Candance, 2008), internal project—ina organisational project novelty, technicalities, delivery and operations, market—economic and financial influences, institutional—social and political influences (e.g. Miller and Lessard, 2001), environment—natural world related influences (e.g. Gellert and Lynch, 2003) and complexity—interdependences between elements or uncertainties from external or internal sources (e.g. Williams, 1999; Loch et al., 2006). These uncertainty sources are listed in Table 1, along with key examples. The significance of the sources of uncertainty megaprojects face varies depending on the types of project, for example, urban transport projects can have a favourable market and institutional needs, whereas the internal project (e.g. technical and construction) aspects of the project are challenging. Nuclear-power projects would face high internal project and institutional related challenges (Miller and Lessard, 2001). The variety of sources demonstrates that uncertainty is multi-dimensional and ubiquitous, which can emerge from numerous external or internal parts of the megaproject.

Uncertainties emerging from the various sources (Table 1) can occur due to a number of factors, research shows that one of the key factors is the changes that happen during megaprojects, which have significant effects, such as causing delays (e.g. Miller and Lessard, 2001; Dvir and Lechler, 2004; Han et al., 2009). Some of these changes are argued to be rooted from the problematic predetermined optimistic objectives set out at early stages in order to persuade investors and initiate projects (Flyvbjerg et al., 2003, Flyvbjerg et al., 2009). Changes happening during megaprojects are inevitable due to external and internal factors, such as a project spanning across long periods of time and emerging new technologies (Dvir and Lechler, 2004). This inevitability is observed that as the complexity of
Table 1. Classification of uncertainty sources in megaprojects with examples.

<table>
<thead>
<tr>
<th>Uncertainty source</th>
<th>Key example</th>
<th>Description (example)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Flyvbjerg et al., 2009)</td>
<td>Decision Making Optimism-bias decisions (e.g. overestimated benefits). Decisions influenced by social preferences and cultural norms.</td>
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<tr>
<td></td>
<td>(Loch, 2017)</td>
<td>Transparency Opportunism behaviour, where an actor withholds information. Delusional and deceptive behaviour.</td>
</tr>
<tr>
<td></td>
<td>(Winch, 2010)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Flyvbjerg et al., 2009)</td>
<td></td>
</tr>
<tr>
<td>Organisational</td>
<td>(Ross and Staw, 1993)</td>
<td>Escalation Dealing with emerging escalation episodes.</td>
</tr>
<tr>
<td>Inter-organisational</td>
<td>(Jones and Candance, 2008)</td>
<td>Transactional Extent of social embeddedness (e.g. likelihood of shared understandings among members co-producing a product/service).</td>
</tr>
<tr>
<td>Internal project</td>
<td>(Loch et al., 2006)</td>
<td>Novelty Service, process and product innovation (e.g. challenges and opportunities associated with new technologies).</td>
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<tr>
<td></td>
<td>(Miller and Lessard, 2001)</td>
<td>Technical Design requirement changes.</td>
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<tr>
<td></td>
<td></td>
<td>Construction The coordination and integration of resources.</td>
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<tr>
<td></td>
<td></td>
<td>Operational Operational income flows or change of use.</td>
</tr>
<tr>
<td>Market</td>
<td>(Miller and Lessard, 2001)</td>
<td>Demand Changes in demand for a service/product.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Financial Health of financial markets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supply Secure supply of services or products through contracts or ownerships.</td>
</tr>
<tr>
<td>Institutional</td>
<td>(Miller and Lessard, 2001)</td>
<td>Regulatory Regulations influencing the ability of a project to pay back liabilities.</td>
</tr>
<tr>
<td>Environmental</td>
<td>(Gellert and Lynch, 2003)</td>
<td>Natural environment Impact on the ecosystem. Contribution to the development of, for example, landslides and floods.</td>
</tr>
<tr>
<td>Complexity</td>
<td>(Simon, 1962)</td>
<td>Configurational Configurational (knowns/unknowns) Multiple known elements from different sources combine and result in an emerging uncertainty.</td>
</tr>
<tr>
<td></td>
<td>(De Meyer et al., 2002)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Miller and Lessard, 2001)</td>
<td></td>
</tr>
</tbody>
</table>
a project increases so does the potential of having variations and changes compared to what was initially set out (Nightingale, 2000). Organisations are under pressure to carry out tight controls that avoid changes, which can hinder the project’s adaptability, contributing to lack of innovation, collaboration and adverse teamwork relationship (Lenfle and Loch, 2010; Gil and Tetherb, 2011; Eriksson et al., 2017, Davies et al., 2017).

3.3 Levels of uncertainty

Megaproject uncertainty emerging from internal/external sources can be classified into different levels depending on the available and comprehended information of an uncertainty (e.g. predictability, likelihood, influence) and the perspective an uncertainty is being investigated from (e.g. management perspective or individual/cognitive perspective). De Meyer et al. (2002) proposes a set of classifications that are project management driven, by considering the information available on an uncertainty and the potential approaches of their management, these include: variation—unplanned anticipated small influences that combine and once emerged they can be responded by project teams (e.g. planning and monitoring), unforeseen uncertainty—influence that are not certain to emerge, but are identified and analysed by project teams, unforeseen uncertainty—emerging influences that cannot be identified or not considered by project teams during planning, and chaos—emerging (unforeseen uncertainty) major influences that result in changing the structure and main goals of a project (e.g. technology projects that start out with assumptions). A project can face a combination of different levels of uncertainty, depending on the project type and a specific level of uncertainty can have a higher likelihood of emerging (Loch et al., 2006). Project teams find unforeseen based uncertainties challenging and uncomfortable to deal with, as existing decision tools and process tend not be equipped to deal with them (De Meyer et al., 2002; Ramasessh and Browning, 2014).

Winch (2010) and Winch and Maytorena (2011) classify uncertainty using a cognitive approach, which is based on the level of information available from a decision-maker’s perspective, these include: known knowns (risk)—condition involving a confident decision on identifying an uncertain event, with its potential influence and likelihood, based on past experiences and data analysis, known unknowns—condition involving a subjective decision on identifying a possible uncertain event, with unclear information on its likelihood or influence, unknown unknowns—a state of ignorance where uncertain events are not identified and unknown knowns—a state of ignorance caused by lack of information transparency. The decision-maker’s perspective of the analysis of uncertainty falls within a continuum ranging from certainty to impossibility (resembling the probability of occurrence of an event or circumstance) (Keynes, 1921). Schrader et al. (1992) argue that ambiguity has to be considered and distinguished from uncertainty when examining decision-maker’s ability to process information surrounding an uncertainty e.g. for problem solving. Ambiguity is the extent of decision maker’s understanding of the problem structure that uncertainty is part of. The problem structure consists of variables with functional relationships that form the decision maker’s frame of reference (Schrader et al., 1992). The distinction between ambiguity and uncertainty from a project management perspective can be conceived that ambiguity causes and contributes to uncertainty within a project (Pich et al., 2002).

3.4 Impacts of uncertainty

Uncertainty can emerge as a threat or an opportunity; in some situations, an uncertainty can exhibit both threat and opportunity, such as problem solving through innovation (Van de Ven, 1986; Loch et al., 2006). A threat is a possible effect with an unfavourable impact and opportunity is a possible effect with a favourable impact (Chapman and Ward, 2011). The uncertainty impacts can have different extent of systemicity—degree of integration and
interconnectedness of an influence with the whole, for example, either present in a specific project part or across multi-project parts (Miller and Lessard, 2001). They also have varying dynamics—degree of change an influence causes (Geraldi et al., 2011), and extent of controllability—degree of flexibility in mitigating or regulating an influence (Miller and Lessard, 2000). Once an uncertainty emerges, either as an opportunity or threat, it can be challenging to identify its source, especially in cases of high complexity where the uncertainty is a combination of multiple connected parts (Ramasesh and Browning, 2014).

The location of the effect (position) is not necessarily the source of uncertainty, the effect can either be internal or external, for example, an emerging adverse social institutional uncertainty (external) influencing the technical design (internal) (Miller and Lessard, 2000). The scope of the threats and opportunities projects face vary in degrees and have different levels, for example, at one extreme, a threat can be a major unanticipated (unforeseen) disaster and at the other end of the spectrum, a threat can be a minor anticipated unfavourable variation (De Meyer et al., 2002). In many cases, threat and opportunity are not two detached effects, for instance, in a situation where resolving a threat opens a window of opportunities or an actual potential opportunity emerges (Chapman and Ward, 2011).

This is also apparent in relation to projects involving innovation, which is “the successful exploitation of new ideas” (Porter and Ketels, 2003). For instance, when an emerging opportunity is potentially developed and exploited into an innovation, the potential innovation carries a risk (threat) of failing in addition to its opportunity of succeeding (Day, 2007) and in cases of radical innovations they have a high degree of threat and opportunity (Shenhar and Dvir, 2007; Posner and Mangelsdorf, 2017). Shenhar and Dvir (2007) identify an interesting observation whereby low-uncertainty projects tend to create limited opportunity and high-uncertainty projects tend to create greater opportunity. These relationships illustrate the dynamic inter-related characteristics of uncertainty. An overview of the relationship between the uncertainty sources, levels and impacts discussed in this section and the previous sections is illustrated Figure 1. Considering the above we advance the following proposition:

**Proposition 2.1** Uncertainty in megaprojects requires to be perceived, understood and approached through a combined threat and opportunity-based framework.
Figure 1. Relationship between the characteristics of uncertainty types (source, level and impact) megaprojects face.

4. Managing uncertainty in megaprojects

4.1 Perspectives on approaching and managing uncertainty

Uncertainty in megaprojects can emerge from multiple sources, expected or unexpectedly. Research shows that their successful management is one of the main contributors to effective project delivery (e.g. Miller and Lessard, 2000; De Meyer et al., 2002; Flyvbjerg et al., 2003). Managing uncertainty requires multiple dynamic approaches, at an organisational and project level (Miller and Lessard, 2000). There are vast streams of publications that deal with uncertainty or its effects in projects or organisations involved in projects (applicable to or focused on megaprojects), ranging from project management, general management and operations management body of knowledge. These publications approach uncertainty through several theoretical perspectives (e.g. dealing with a source of uncertainty), the key perspectives (with examples) are identified through a scoping study (Arksey and O’Malley, 2005), which are listed in Table 1. The key approaches from the listed perspectives are explored and discussed in the next sections to provide an overview of the complexities sounding uncertainty, they include, contingency approaches; variation and foreseen uncertainty approaches; and unforeseen uncertainty approaches. These approaches enable us to unfold the various perspectives according to the megaproject context and the characteristics of uncertainty. The study pays attention to unforeseen related approaches, as the findings suggest it is the main challenge of managing uncertainty.

4.2 Contingency approaches

Organisations face challenges to effectively adapt to their changing situational or environmental characteristics, for example, due to developments in science and technology (Lawrence and Lorsch, 1967). To overcome this, various strands of research on project management emphasise that determining the processes, approaches and course of actions to manage project uncertainty requires adopting a contingency approach by considering the
characteristics of a project. Conventional approaches not taking into consideration the project context and its environment are not sufficient, especially in the case of megaprojects (Williams, 2005; Shenhar and Dvir, 2007). A number of studies propose several contingency theory frameworks to avoid the problematic one-size-fits-all approach to project management, by considering the key project parameters, for example, Shenhar and Dvir (1996, 2007) propose a framework based on four parameters: degree of ‘novelty’, ‘technology’, ‘complexity’ (structural) and ‘pace’ – these parameters can be considered as the main sources of uncertainty. Similarly, Williams (1999, 2005) propose the degree of structural complexity, uncertainty and time-limit. Considering these parameters, which can be labelled as project complexity at a broad level due to their interconnectedness, enables the understanding of the context projects are situated within and determining strategies, approaches and processes to effectively manage projects and their uncertainties (Geraldi et al., 2011). Considering this, we suggest the following proposition:

**Proposition 3.1** The effective management of uncertainty is dependent upon determining contingent approaches and processes based on the numerous characteristics of uncertainty and the megaproject context.

4.3 **Variation and foreseen uncertainty approaches**

Uncertainty can be conceptualised to be approached in three domains of organising, these are ‘prospective’ (e.g. carrying out assessments for potential future uncertainty), ‘real-time’ (e.g. responding to the present emerging uncertainty), and ‘retrospective’ (e.g. learning by looking at what happened and should have happened in relation to an uncertainty that emerged in the past) (Hardy and Maguire, 2016). Retrospective domain approaches include organisational learning and inter-project learning transfer (Prencipe and Tell, 2001). Facilitating appropriate approaches for the prospective and real-time domains, is argued to depend on taking into consideration the extent of uncertainty a project or project component faces, for example, if a project has lower degrees of novelty, technology, structural complexity and pace, it would experience less uncertainty (Shenhar and Dvir, 2007), and the predominate uncertainty types (levels) would be variation or foreseen (also known as risk) (De Meyer et al., 2002).

These levels of uncertainty, are addressed through conventional risk management approaches, based on systematic and structured processes (e.g. see OGC, 2009). These approaches can be identified through the numerous proposed risk management frameworks, they tend to be based on four key systematic steps: identification (e.g. brainstorming, root cause), analysis (e.g. critical path analysis, Monte Carlo simulation), response (e.g. sequential iteration, mitigation, shifting) and control (e.g. programming activities with anticipated milestones and buffers, residual risks, fixed governance structures with tight control). These steps provide an overview of the risk management approaches based on numerous streams of literature, which are well-established and form important and useful part of dealing with risks. The conventional risk management approaches are not designed or limited in dealing with unforeseeable types of uncertainty or a complex combination of multiple risks, where projects with high degree of complexity are fraught with them. Relying solely on risk management can have detrimental and destructive effects and neglected exploitation of novel opportunities (Loch et al., 2006). The following proposition summarises our argument:

**Proposition 3.2** The more unforeseen uncertainty project faces, the less efficient and effective risk management approaches/tools are.
Table 2. Perspectives on approaching and managing uncertainty in relation to large complex projects (i.e. megaprojects).

<table>
<thead>
<tr>
<th>Theoretical Perspective</th>
<th>Publication Example</th>
<th>Problem</th>
<th>Solution</th>
<th>Research Methodology</th>
<th>Uncertainty Type (level)</th>
<th>Project Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavioural/cognitive</td>
<td>(Edmondson, 2012)</td>
<td>Temporary teams with multi-disciplinary or/and inter-organisational partners</td>
<td>Adopting effectiveness project management and team leadership approaches</td>
<td>Conceptual</td>
<td>Foreseen, Unforeseen</td>
<td>The Olympics</td>
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<td></td>
<td>(Flyvbjerg et al., 2009)</td>
<td>Optimism-bias decisions that overestimated benefits and underestimate costs</td>
<td>Reducing optimism-bias by using reference class forecasting to help make unbiased predictions of the future</td>
<td>Quantitative (forecasting)</td>
<td>Foreseen, Unforeseen</td>
<td>Large infrastructure projects</td>
</tr>
<tr>
<td></td>
<td>(Ross and Staw, 1993)</td>
<td>Decisions associated with a project resulting in substantial costs overrun and its abandonment</td>
<td>Temporal model of escalation assisting with how escalation episodes may ultimately be resolved</td>
<td>Qualitative (case study)</td>
<td>Unforeseen</td>
<td>Nuclear power plant</td>
</tr>
<tr>
<td>Contingency theory</td>
<td>(Shenhar and Dvir, 2007)</td>
<td>On-size-fit-all approaches to project management</td>
<td>Typological theory of project management based on the characteristics of a project</td>
<td>Quantitative and Qualitative</td>
<td>Variation, Foreseen, Unforeseen</td>
<td>Several (e.g. large infrastructure projects)</td>
</tr>
<tr>
<td>Flexibility</td>
<td>(Eriksson et al., 2017)</td>
<td>Control focused project management approaches</td>
<td>Flexibility-focused project management practices based on collaboration, explorative learning, and adaptation</td>
<td>Quantitative (survey)</td>
<td>Unforeseen</td>
<td>Large infrastructure projects</td>
</tr>
<tr>
<td></td>
<td>(Gil and Tether, 2011)</td>
<td>Design changes and depending on risk management approaches</td>
<td>Design flexibility (e.g. by incorporating modular based designs, design freeze until last responsible moment)</td>
<td>Qualitative (case study)</td>
<td>Foreseen, Unforeseen</td>
<td>Large infrastructure projects</td>
</tr>
<tr>
<td>Theoretical Perspective</td>
<td>Publication Example</td>
<td>Problem</td>
<td>Solution</td>
<td>Research Methodology</td>
<td>Uncertainty Type (level)</td>
<td>Project Type</td>
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<tr>
<td>Innovation</td>
<td>(Loch et al., 2006)</td>
<td>Risk management limitations in dealing with complex and/or novel projects</td>
<td>Adaptive approaches (e.g. learning and flexibility) for dealing with complex and/or novel projects</td>
<td>Qualitative (case study)</td>
<td>Unforeseen</td>
<td>Several (e.g. large infrastructure projects)</td>
</tr>
<tr>
<td>Operational</td>
<td>(Ramasesh and Browning, 2014)</td>
<td>Assessment of project vulnerability to unk unks in high uncertainty projects</td>
<td>Project management assessment approaches of the main areas where unk unks can arise, ranging from design to behavioural issues</td>
<td>Conceptual</td>
<td>Unforeseen</td>
<td>–</td>
</tr>
<tr>
<td>Organisational capabilities</td>
<td>(Davies and Mackenzie, 2014)</td>
<td>Coordination of complex projects</td>
<td>Systems Integration capabilities to navigate through complexity</td>
<td>Qualitative (case study)</td>
<td>Foreseen, Unforeseen</td>
<td>The Olympics</td>
</tr>
<tr>
<td>Organisational design</td>
<td>(Gil, 2017)</td>
<td>Conflation of resource scarcity, conflicting interests, and concerns with legitimacy complicates</td>
<td>Adopting high-order coordination mechanisms (e.g. relaxing performance targets, building organizational slack)</td>
<td>Qualitative (case study)</td>
<td>Foreseen, Unforeseen</td>
<td>Large infrastructure projects</td>
</tr>
<tr>
<td>(Jones and Candance, 2008)</td>
<td>Inter-organizational projects adaptability, collaboration and managing uncertainty</td>
<td>Considering temporal embeddedness and social embeddedness</td>
<td>Conceptual</td>
<td>Foreseen, Unforeseen</td>
<td>Large infrastructure projects</td>
<td></td>
</tr>
<tr>
<td>Organisational learning</td>
<td>(Prencipe and Tell, 2001)</td>
<td>Learning abilities of project-based firm and inter-project learning transfer</td>
<td>Mechanisms for inter-project learning (i.e. experience accumulation, knowledge articulation and knowledge codification) in various levels (e.g. individual)</td>
<td>Qualitative (case study)</td>
<td>Variation, Foreseen, Unforeseen</td>
<td>CoPS projects (e.g. defence, aerospace)</td>
</tr>
<tr>
<td>Relational</td>
<td>(Davies et al., 2016)</td>
<td>Adverse and temporary relationships in projects</td>
<td>Collaborative and incentive-based agreements that simulate</td>
<td>Qualitative (case study)</td>
<td>Foreseen, Unforeseen</td>
<td>Large infrastructure projects</td>
</tr>
<tr>
<td>Theoretical Perspective</td>
<td>Publication Example</td>
<td>Problem</td>
<td>Solution</td>
<td>Research Methodology</td>
<td>Uncertainty Type (level)</td>
<td>Project Type</td>
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<tr>
<td>Strategic</td>
<td>(Ansar et al., 2017)</td>
<td>Fragility caused by scale of projects</td>
<td>Careful consideration where scaling pays off and where it does not in capital projects</td>
<td>Quantitative (forecasting)</td>
<td>Foreseen, Unforeseen</td>
<td>Large dam projects</td>
</tr>
<tr>
<td></td>
<td>(Zhao et al., 2004)</td>
<td>Investment decision making under uncertainty from numerous sources</td>
<td>Optimal decision making though the adoption of real options by considering multiple uncertainties (e.g. changes in political, social, environmental contexts)</td>
<td>Quantitative (modelling)</td>
<td>Foreseen, Unforeseen</td>
<td>Large infrastructure projects</td>
</tr>
<tr>
<td>Sustainability</td>
<td>(Gellert and Lynch, 2003)</td>
<td>Social, environment and economic impacts from projects</td>
<td>Identify winners and losers; understand projects history and epistemic logic</td>
<td>Conceptual</td>
<td>Foreseen, Unforeseen</td>
<td>Megaprojects (e.g. infrastructure, extraction)</td>
</tr>
</tbody>
</table>
4.4 Unforeseen uncertainty approaches

Front-end

Unforeseen uncertainty requires fundamentally differently approaches in comparison to risk and is more challenging to approach (Teece and Leih, 2016). There are numerous approaches available to deal with unforeseen uncertainty, they range in different project and organisational areas and tend to be less structured, they include, front-end strategizing, planning, collaboration and project teams. Front-end strategizing involves the key decision making that sets out the project direction, such as, its initiation, scale and budget (Morris and Hough, 1987; Miller and Lessard, 2000). Ansar et al. (2017) argue that strategic decision makers need to carefully consider the scale and scope of the megaproject, as ‘bigger’ does not mean ‘better’. This is because increasing the megaproject scale and scope can increase their fragility—this is, their high vulnerability to randomness or unforeseen uncertainty influences, which can lead to irreversible capital failure. In conditions of high uncertainty (e.g. front-end of megaprojects) real-options based frameworks and reasoning can be used to assist with decision-making by identifying options under uncertainty and capitalising on opportunities (e.g. Zhao et al., 2004). The real-options approach originates from the financial options logic (e.g. Black and Scholes 1974), Dixit and Pindyck (1995) and Trigeorgis (1996) developed these into real options approaches to assist with assessing investments in capital assets. Real-options based approaches can be used to embed options into the design to safeguard the future of projects (e.g. modular designs) by increasing flexibility and enabling changes to occur at later project stages resulting in less disruption (Gil, 2009; Krystallis et al., 2015). This enables less emphasis on risk management approaches, which tend to resist design changes occurring during megaproject implementation (Gil and Tether, 2011). Thus, we arrive at the following proposition:

Proposition 3.3 The greater the project scale, the greater the uncertainty that need to be addressed, and the greater the necessity for introducing flexibility in the project.

Breaking down project complexity at the outset and identifying potential unforeseeable uncertainties (factors) that could emerge during the project can significantly contribute to effective uncertainty management (Loch et al., 2006). This includes, investigating project elements and relationship interdependences amongst the elements (e.g. amongst systems, tasks, actors, groups), which can be used to identify knowledge gaps and address through appropriate approaches, such as, learning and trial-and-error (Loch et al., 2006). Ramasesh and Browning (2014) propose similar factors that could be used part of the project management processes to sense check projects at the outset and emphasises: complicatedness (e.g. lack of capability), mindlessness (e.g. wilful ignorance) and project pathologies (e.g. dysfunctional culture). These factors ranging from organisational, technical to behavioural issues resemble and stem from the sources of uncertainties identified in the early section. Behavioural factors contributing to understanding uncertainty management seems to require further research and be taken into consideration (Loch, 2017). Considering the findings, we suggest the following propositions:

Proposition 3.4 The importance of the effectiveness of managing uncertainty in megaprojects is determined by the ability in investing in and developing project management capabilities.

Proposition 3.5 The management of uncertainty in megaprojects is determined by the behavioural aspects of the individuals’ interactions prior to developing approaches for dealing with unforeseen uncertainty.
The ability to deal with unforeseen uncertainties can be improved through the adoption of project organisational designs and strategies that encourage collaboration and flexibility. Part of the project organisational design is the governance that places a structure in place in order to achieve consistent and predictable results (Müller, 2011). This can be challenging as megaproject unforeseen uncertainties make predictable results challenging to achieve where changes are bound to happen. This is dealt with by adopting delivery mechanisms that accommodated for the project dynamics (Dvir and Lechler, 2004; Gil and Tether, 2011). Gil’s (2017) findings point out that this can be achieved in megaprojects by “relaxing performance targets, building organizational slack, espousing flexible designs, and creating a structure of umpires to settle disputes that could not be self-resolved”. Collaborative approaches can be encouraged through effective contracts and agreements set out at the front-end. Davies et al. (2016) illustrate this through BAA’s (currently, Heathrow Airport Holdings) development and implementation of the ‘T5 agreement’ at the front-end of the project, which encouraged project teams to work under collaborative processes and behaviours by adapting to different situations (e.g. changing between operations that are exploitation and exploration based and routine or non-routine) to deal with emerging uncertainties. This is in line with other streams of literature that points out adaptive approach to management is essential for managing complexities/uncertainty in megaprojects and collaboration as an important part in achieving this (e.g. Miller and Lessard, 2001; Eriksson et al., 2017). Hence, we suggest the following proposition:

**Proposition 3.6** Adopting organisational design and contractual arrangements that encourage collaboration improves adaptiveness, and improves the prospect of managing unforeseen uncertainty in megaprojects.

**Collaboration, project teams and learning**

Having collaborative approaches amongst partners within a system enables uncertainties to be managed more effectively (Powell et al., 1996; Reeves et al., 2017). Organisations working together collaboratively (e.g. through project teams) in megaprojects can provide a greater potential and opportunity for rearranging project resources and activities (compared it an individual organisation), thus increasing the flexibility and adaptiveness needed to deal with emerging uncertainties and dynamics within projects (Jones and Candance, 2008). This is in parallel with why individuals work in project teams, for example, as individuals would not be able to overcome complex multi-disciplinary challenges on their own (Edmondson, 2012). Teams working together and solving problems is an impotent and essential approach to dealing with unforeseen uncertainty, for example, overcoming challenges in a novel technology (Loch et al., 2006). Project problem solving tends to be achieved through learning, especially problems relating to unforeseen uncertainty (Pich et al., 2002). The types of learning can be categorised into three: single loop (addressing identified challenges through existing project contingency plans, as part of the risk management process), double-loop learning (addressing identified challenges by modifying existing plans and policies, followed by improvisation or experimentation) and deutero learning (addressing identified challenges requires changing the project learning system structure) (Argyris and Schon, 1978; Loch et al., 2006). Deciding on which type of learning, or even adopting an alternative selectionism approach (this involves trying out multiple solutions in parallel) or a combination of learning and selectionism, is based on several factors, such as estimated cost, value, complexity or trade-offs. Learning and selectionism approaches are one of the key ways in addressing emerging uncertainties (Loch et al., 2006), which can be used to deal with project threats or opportunities. Considering the findings, we suggest the following propositions:
**Proposition 3.7** Learning within project teams is an essential approach to overcoming unforeseen uncertainty in megaprojects.

Project teams that deal with unforeseen uncertainty face a number of challenges (e.g. social, cultural or behavioural) that they have to cope with and develop a team ‘mind-set’, due to numerous pressures, which stem from maintaining project continuity and dealing with the unpredictability of how and when a solution can be achieved, as the solution has an effect on the wider project and individual team performance (Loch et al., 2006). Megaprojects consist of inter-organisational multi-disciplinary teams that are temporary and do not have a common culture, pre-existing team relationships based on trust or other attributes of high performing teams which are found in permanent organisations (Edmondson, 2012). Edmondson (2012) highlights that challenges associated with temporary project teams can be mitigated through effective project management approaches (e.g. scoping, group structuring and arrangements based on the level of task interdependency) and team leadership (e.g. emphasising purpose, developing psychological safety and accepting potential failure and conflict that could emerge). Project team effectiveness is influenced by the extent of social embeddedness amongst team actors, which involves the likelihood of shared understandings among participating members (Jones and Candance, 2008). Thus, we propose the following proposition:

**Proposition 3.8** Problem solving abilities associated with unforeseen uncertainty in megaprojects are determined by developing and mobilising collaborative project teams.

**Opportunity and Innovation**

Being able to achieve successful innovations is argued to be based on accommodating for adaptive and flexible approaches, such as being able to accept changes and engage in non-routine activities (Van de Ven, 1986). This is in parallel with Miller and Lessard’s (2001) observation that opportunities emerging during the project evolution can be missed if rigid management approaches are adopted. Project opportunities that have a possible favourable outcome and involve novel ideas, for example, to solve a problem, could be developed and exploited into innovations. Achieving innovations depends on the innovation management strategies, which are underpinned by project management tools and thinking (Lenfle and Loch, 2010). There are different types of innovation projects depending on their characteristics, based on the classifications proposed by Wheelwright and Clark (1992), they include breakthrough, platform and derivative. These classifications are based on the ‘degree of change in process (e.g. design/construction)’ and the ‘degree of change in product (e.g. megaproject and its parts)’ required to achieve an innovation. Both degrees of change range from incremental to radical. A breakthrough project can be considered the most innovative and requiring the highest degree of change (Davies et al., 2009; Davies, 2014). Managing and achieving innovation in megaprojects is highly challenging due to their overall high complexity (Shenhar et al., 2016), and requiring successful implementation and consideration of several contributing factors within the project governance structure, project processes and operational processes (Davies et al., 2009). It is argued that solutions to these challenges are underpinned by flexible and adaptive project management approaches, which entails accommodating for unforeseen uncertainty (Lenfle and Loch, 2010). According to these arguments, we suggest the following propositions:

**Proposition 3.9** The success rate of innovation in megaprojects is highly dependent on the ability to deal with unforeseen uncertainty.

**Individuals and groups**
Individuals or groups are required to make decisions under conditions of uncertainty on a regular basis, they are shaped and influenced by numerous factors, for example, behavioural, cognitive or cultural norms (e.g. see March and Shapira, 1987; Loch, 2017). An example of overcoming some of these challenges is sensemaking, which is considered to be one of the main approaches individuals or groups adopt to deal with ambiguities (Weick, 1995), a source of uncertainty (Pich et al., 2002). Scholars propose various interpretations of sensemaking, Weick et al. (2005) note that it is the “ongoing retrospective development of plausible images that rationalize what people are doing”. An example would be, as a decision-maker gains experience, appreciation and familiarisation of a system/project they would be in a better position in dealing with ambiguity (Ramasesh and Browning, 2014). Weick’s definition can be categorised as a retrospective approach to sensemaking, an alternative sensemaking is a ‘future-oriented’ approach which can be broadly seen as “an unfolding sensemaking process that incorporates past and present orientations” (Gephart et al., 2010). Future-orientated sensemaking is adopted in ambiguous situations where groups or individuals obtain an understanding of the future by developing a future temporal based frame of reference, for example, in innovation and strategy development decision-making situations (Stigliani and Ravasi, 2012). Experimental research findings by Keck et al. (2014) illustrate that in a group setting, decisions are more likely to be ambiguous-neutral compared to individual setting. This indicates that group (e.g. within project teams) based collective sensemaking making can encourage more ambiguous-neutral decision making compared to individual decision making. We thus propose the following proposition:

**Proposition 3.10** Ambiguous situations contributing to project uncertainty can be reduced through effective sensemaking processes applied in the decision-making of groups or individuals.

5. **Concluding discussion and further research**

Uncertainty is a profound challenge, which is increasingly becoming more challenging for organisations to manage as megaprojects increase in complexity and scale. This paper examined several approaches for managing megaproject uncertainty, underpinned by the megaproject context and uncertainty characteristics. The megaproject consists of numerous dynamic and complex interdependent parts that shape the project, which needs to be taken into consideration when investigating a phenomenon like uncertainty. Uncertainty is embedded in the megaproject’s nature, with the potential of emerging from multiple sources in varying levels and impacts. These characteristics demonstrate how complicated uncertainty is, and their effective management is not as simple, as observed from the various streams of literature attempting to tackle it from different perspectives.

Based on the areas covered in this paper, starting from the roots of uncertainty to how it is approached, the challenge lies in dealing with unforeseen uncertainty. There are many promising approaches to deal with this challenge, for example, investing in and improving front-end strategies.

However, further research can be carried out on multiple fronts to unpack uncertainty and its complex characteristics, with particular attention on unforeseen uncertainty. For example, an investigation can be conducted in a similar approach to Geraldi’s et al. (2011) work on unpacking complexity through a systematic literature review. Further research can explore any of the 12 propositions outline in this paper, empirically or conceptually, by expanding them into a set of research questions or hypothesis for further investigation. A new avenue of further research could be developed by exploring the unfolding of uncertainty through multi-perspective approaches, which are outlined in the scoping study of uncertainty as part of this paper.
6. Acknowledgements

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7. References


