



Tackling the planning challenges in megaprojects: A case study from greenfield infrastructure megaprojects in Scandinavia

Mohsen Faizollahi & Christian Akukwe

Supervisor

Wen Pan Fagerlin

Karlskrona, Sweden

May 2021

This thesis is submitted to the Department of Industrial Economics at Blekinge Institute of Technology in partial fulfillment of the requirements for the Degree of Master of Science in Industrial Economics and Management. The thesis is awarded 15 ECTS credits.

The author(s) declare(s) that they have completed the thesis work independently. All external sources are cited and listed under the References section. The thesis work has not been submitted in the same or similar form to any other institution(s) as part of another examination or degree.

Author information:

Mohsen Faizollahi

Mohsen.faizollahi@gmail.com

Christian Akukwe

chrisakukwe@gmail.com

Department of Industrial Economics

Blekinge Institute of Technology

SE-371 79 Karlskrona, Sweden

Website: www.bth.se

Telephone: +46 455 38 50 00

Fax: +46 455 38 50 57

Abstract

Background: Megaprojects are large-scale, complex industrial projects typically costing over 1 Billion USD and characterized for their super large size, long duration, ambiguity, uncertainty, complex interfaces and integration, cross-functional environment, multidisciplinary works among others. Being associated with cost overruns, schedule delays, and benefit shortfalls, megaprojects seems to be recession tolerant and continue with strong demand in recent years. Among many challenges in managing megaprojects as to project management in general, the planning challenges of megaprojects are considered most critical ones. Despite the increasing attention on megaproject (even during the pandemic) little is known about how to plan for megaprojects and the specific challenges associated with the planning. A theoretical framework of megaproject's definition, characteristics, motivation, and failures was developed in this thesis based on a literature review. Project management concepts such as Project/Program Management Office (PMO), and fast-tracking method were investigated in this thesis.

Purpose: The main purpose of this research is to advance our understanding of the challenges associated with megaprojects, especially concerning the planning challenges regarding project uncertainty and complex interface. An additional purpose is to find some practical way in mitigating these challenges.

Method: A qualitative case study based on eight semi-structured interviews with directors and managers mostly from three greenfield infrastructure megaprojects was conducted for the thesis work. The main case site was at a lithium-ion battery manufacturing plant located in Scandinavia.

Results: Using the Gioia's method of qualitative data analysis (1st order theme, 2nd order concept and aggregation), the findings indicate a list of key success factors for managing megaproject, namely human aspect (decision making, leadership, culture, communication), project characteristics (risk, uncertainty, ambiguity, complex interfaces, limited resource), project management tools (supply chain integration and coordination, fast-tracking). The findings also suggest new emerged features such as 'mega-cross cultural effect', and 'schedule procrastination'. We aggregate the layers of findings into 'multi-faceted challenges', including both human aspect, and the intermediate milestones as solution to managing complex interface.

Conclusions: The thesis contributes to the stream of megaproject literature by a deep understanding of the characteristics and managerial challenges of managing megaprojects with a special focus on the planning phase. Three propositions are suggested to conclude the study. The theoretical implication suggests that tools such as PMO and routinized meetings between stakeholders may mitigate some of the challenges caused by a complex interface, risk and uncertainty, and thereby increase the performance of megaprojects. Managers should improve their cross-cultural skills, making standardized PMO a must in megaproject management and invest in competent employees. For future study, a quantitative study is recommended to test key success factors and the effects of using more resources during the front-end stage, standardized PMO, and collaborative (routines) on megaprojects.

Key words: Megaproject, Complex Interfaces and Integration, Uncertainty, Project Management Office (PMO)

Acknowledgments

Throughout the writing of this dissertation, I have received a great deal of support and assistance.

I would first like to thank my supervisor, Dr. Wen Pan Fagerlin, whose expertise was invaluable in formulating the research questions, methodology, and analyzing the findings. Your insightful feedback pushed me to sharpen my thinking and brought my work to a higher level. I would like to thank you for your valuable guidance throughout my studies. You provided me with the tools that I needed to choose the right direction and successfully write my dissertation.

I would like to thank my wife, Shima who was always supporting me to finish a job that started with all odds against me, especially under the Covid-19 pandemic situation.

In addition, I would like to thank my two lovely kids for giving me love unconditionally. Finally, I would like to thank my mom for all her devotion and the love that she has always had for me. Without my family's support, I could not have got this done.

Stockholm, Sweden, September 2021

Mohsen Faizollahi

I will like to thank Wen Pan Fagerlin for her mentorship through the course of research and writing this thesis. Your knowledge and guidance have been valuable to me.

I will also like to thank my wife Chianu, and my children for all the patience they showed me during this MBA study.

Richmond TX, USA. September 2021

Christian Akukwe

Table of Contents

1.	Introduction	1
1.1.	Problematization.....	2
1.2.	Research Purpose and Question	3
1.3.	Delimitations	4
1.4.	Thesis Structure.....	4
2.	Theoretical Framework	5
2.1.	Definition, Characteristics of Megaproject and the focus on Planning.....	5
2.2.	The most prominent features of megaproject concerning the planning phase	7
2.3.	Motivations behind Megaproject.....	13
2.4.	The Four Main Reasons that may lead to Megaproject Failures	14
2.5.	Managing Megaproject.....	16
2.6.	The preliminary research framework.....	18
3.	Methodology	19
3.1.	Research Approach.....	19
3.2.	Research Design	20
3.3.	Research Methods.....	20
3.4.	Trustworthiness.....	28
3.5.	Ethical Considerations.....	29
3.6.	Limitations.....	29
4.	The Case of the lithium-ion battery megaproject	31
4.1.	A Brief Overview of the Lithium-ion Battery Factory Megaproject	31
4.2.	The Perceived Challenges by the Managers.....	32

5.	Discussion.....	38
5.1.	A Summary of the findings	38
5.2.	Beyond the Listed Characteristics: emerging new features	39
5.3.	Managerial Challenges	42
6.	Conclusions	46
6.1.	Answer to the research question “How to cope with uncertainty and complex interfaces in a megaproject?”	46
6.2.	Thesis Contribution.....	47
6.3.	Recommendations for further research directions.....	47
6.4.	Ethical and Societal Implications	48
6.5.	Managerial Implications	48
7.	Bibliography	50
8.	Appendix.....	59
8.1.	Interview Questions	59
8.2.	Summary of interviews.....	60

List of Tables

Table 1: List of megaproject characteristics and description _____	6
Table 2: Five areas of task complexity in megaprojects (Brockman & Girmscheid, 2007)_____	10
Table 3: Preliminary Research Framework _____	18
Table 4: Interviewees information _____	23
Table 5: Identified themes connected to previous findings and representative quotes _____	24
Table 6: New-found identified themes and representative quotes _____	26
Table 7: Revised Research Framework _____	39
Table 8: New Features in Megaproject Management _____	41

List of Figures

Figure 1: Common characteristics of complexity in projects - Source from (Project Management Institute, 2013) Pulse of the Profession TM In-Depth Report: Navigating Complexity. _____	8
Figure 2: Cost-increasing factors in fast-tracking (adopted from Park 1999) _____	12
Figure 3: Ripple effects of design changes in fast-tracking (adopted from Park 1999) _____	12
Figure 4: Relationship between First order quotes, Themes, and Aggregates _____	28
Figure 5: Managing projects in the case study's organization _____	31

List of abbreviations

CMAR	Construction Management at Risk
DBB	Design Bid Build
DB	Design Build
EPC	Engineering Procurement & Construction
EV	Electric Vehicle
EVM	Earned Value Management
FEED	Front End Engineering and Design
FEL	Front End Loading
FEED	Front End Engineering and Design
ICJV	International Construction Joint Venture
JV	Joint Venture
MOE	Multi-Organizational enterprises
NDA	Non-Disclosure Agreement
PDM	Project Delivery Model
PM	Project/Program Manager
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMO	Project/Program Management Office
TIA	Time Impact Analysis

I. Introduction

Megaprojects sometimes called “major projects” or “major programs”, are major industrial development projects. They are mega engineering and construction undertakings that are large-scale, complex ventures that typically cost more than one billion US Dollars (Flyvbjerg, 2014). They have been characterized by size, duration, uncertainty, ambiguity, complex interfaces and integration, cross-functional environment, multidisciplinary works, diversity of product delivery throughout the project life cycle, and significant political and external influences (Greiman, 2013). Additionally, “*Mega also connotes the skill level and attention required to manage the project successfully*” (Greiman, 2013).

Megaprojects, in modern times, have notably expanded beyond construction and have entered other fields and industries. Today, megaprojects are found in most areas of life - engineering, infrastructure, oil, aviation, information technology, shipping, and of course space. Examples of megaprojects are high-speed train lines, refineries, oil and gas development fields, seaports, airports, national highways, the Olympics, wind farms, offshore oil and gas extraction, aluminum smelters, the development of new aircraft, the largest container and cruise ships, high-energy particle accelerators, logistics systems used to run large supply-chain-based companies like Apple, Amazon, and Maersk, etc.

There are many examples of failed megaprojects due to extensive overruns or misunderstanding of expectations (or both) despite a few honorable exceptions e.g. Guggenheim Museum Bilbao (Flyvbjerg, 2014); and the Beneluxlijn extension of the Rotterdam metro network in (Mendel, 2012). Failure is not an option due to exorbitant economic loss. Mega capital projects typically experience huge cost and time overruns (50-100% over time and overrun budget), which makes investments questionable, and seldom attaining the expected returns for such massive investment of time and capital (Jergeas & Lynch, 2015). The main reasons for project failure are poor front-end loading¹ (FEL), FEED², and misaligned incentives (Morrow, 2011). This front-end stage which encompassed the strategy, governance, procurement, and all the other processes during the initiation phase of the megaproject do influence the subsequent stage and the ability to achieve a successful outcome (Denicol, et al., 2020). Flyvbjerg (2014) has named weak front-end planning and poor downstream management as two causes of such poor

¹ Fron-end loading (FEL) approach, depending on the industry is also known as front-end engineering design (FEED), pre-project planning (PPP), feasibility analysis, conceptual planning, and early project planning, refers to a project management process whose aim is to increase the probability of achieving project goals in terms of cost, schedule and operability by measuring and increasing the level of project definition.

Barshop defines front-end loading (FEL) as “*a process by which a company translates its marketing and technology opportunities into capital projects. The objective is to align project objectives with the business need and to develop the most efficient process design and execution plan to achieve the project objectives*” (Barshop, 2003).

² See above.

performance. However, Merrow (2011) investigated the “success factors” that impact the success of the projects, measured through the so-called “success indicators” (or criteria). According to Merrow, one of the “success factors” might be detailed front-end engineering and design (FEED) or the early engagement of external and internal stakeholders (Naomi & Locatelli, 2015).

Even though megaprojects seem to have a poor track record of performance, they have never been more in demand. This could thank the resilience of megaprojects that have proven to be remarkably recession tolerant (Flyvbjerg, 2014). Even during the downturn periods such as the Covid-19 pandemic or the 2008 financial recession, the megaprojects business grew further. Megaprojects are as attractive to policymakers as they can create and sustain employment, contain a large element of domestic inputs relative to imports, improve productivity and competitiveness, benefit consumers by high-quality service, and improve the environment (Flyvbjerg, 2014).

Several reasons make megaprojects an extremely complex phenomenon. Some of these factors are but are not limited to the investment size, long duration, technological complexity, and political and social environment (including a large network of internal and external stakeholders). The involvement of multiple stakeholders in a megaproject with diverse interests makes it complex to govern it separately, create multiple layers of complex interfaces and according to Spalek (2014) Project/Program Management Office (PMOs) will be an active agent for supporting project stakeholder relations and are identified as critical success factors. Chapman (2016) listed three characteristics of megaprojects that have a strong probability of introducing complexity in the project like the usage of novel technology, untried contracting strategy, and or a significantly high number of interdependencies from various units. Typically, there is a strong positive correlation between the complexity of a megaproject and complex interfaces (Daniels, et al., 2014).

1.1. Problematization

Megaprojects have a pivotal role and is critical in both the energy and transportation industry, yet they are associated with extremely poor design and delivery performance (Cantarelli, et al., 2012). An analysis made by Cantarelli et al. (2012) regarding a database composed of 806 megaprojects delivered worldwide (energy projects, transportation projects, etc.) shows that average cost overrun of 35.5% with very heterogeneous performance (standard deviation 56.3) (Cantarelli, et al., 2012). Nevertheless, megaprojects are gaining even more popularity and they currently account for more than eight percent of total gross domestic product which causes a problem on a national economic level by the frequent time and cost overruns (Flyvbjerg, 2014). Megaproject will continue to dominate infrastructural development in the future and this is why recently, there has been many calls for increase research on Megaproject characteristic to identify the reasons for their poor performances. Some of these calls are

seen in special issues such as Project Management Journal (Klein & Aubry, 2017) and International Journal of Project Management (Vukomanović, et al., 2021)

There is a vast literature on megaproject complexity, uncertainty, and the challenges of managing complex interfaces. Many researchers have acknowledged that increasing complexity and uncertainty in megaprojects is one of the primary reasons for cost overruns, schedule delays, and benefit shortfalls (Priemus, et al, 2013; Denicol, et al; 2020, Chapman, 2006). However, there are limited details on how best to identify the actual causes of these challenges and how best to manage or mitigate them. Complexity, and uncertainty are a typical characteristic of megaproject because of the extreme size of this type of project which cannot be eliminated. This limited research is also corroborated by the work of Williams et al where they concluded that identifying and measuring complexity is critical to the success of megaprojects (Williams, et al., 2019).

Despite a few research studied on megaprojects case studies, there is still a huge lack of empirical study on greenfield infrastructure megaprojects which involve major megaproject disciplines such as engineering, architecture, environmental planning, science, business, organization and management theory, project management, and urban planning. When an increasing number of empirical studies on greenfield infrastructure megaprojects within a global context becomes available, there will be more understanding of the origin of complexity and uncertainty in these megaprojects. This will help find best practices to manage the complexity and deal with uncertainty within such megaprojects.

1.2. Research Purpose and Question

The main purpose of the research is to advance our understanding of the challenges associated with uncertainty and complex interfaces in megaprojects, which is usually within a cross-functional environment and multidisciplinary works. Despite of the burgeoning interest in understanding how to manage megaproject from both academics and practitioners, we still know little about the reasons for cost overrun, schedule delay, and benefit shortfalls in megaprojects in this study, we raise the following research question: *How to cope with uncertainty and complex interfaces in megaprojects?*

To answer our research question, we chose a case study approach. We examine the thesis question by interviewing experience project managers involved in the selected megaprojects to help us to explore the project planning challenges and discuss possible solutions to the current issues related to the subject of the thesis area. The case study mostly involves three greenfield infrastructure megaprojects in Scandinavia. These megaprojects have a diversity of product delivery and two of them are a process-driven projects where the scope of the project includes civil work (physical facilities), electrical

installation (transformers, switchgear, cables, lights, etc.), mechanical installation (heat, ventilation, air-condition) and process equipment.

The main case study megaproject brings Europe its first homegrown, mass-production Li-ion battery cell manufacturing capacity. Because of the (1) competencies and the backgrounds of one of the authors and (2) the relevance of the field, which makes it a perfect site for the designed case study. Even though the megaprojects are still in process, they are interesting to study since they are unique projects that have almost all the characteristics of megaprojects as already mentioned at the beginning of this section. However, in this thesis, we do not intend to study all characteristics of a megaproject, but focusing on the most challenging attributes which are uncertainty, and complex interfaces.

1.3. Delimitations

Time constraint: The duration of the study is limited to 6 months since it is a master thesis project.

Sample size: The Sample size is limited to 8 some of the people who were contacted on the case study megaproject did not respond or are bound by an NDA not to release information.

Site visitation: Site visitation was not possible since we are in a Pandemic.

1.4. Thesis Structure

A theoretical framework will be presented in Chapter 2. The methodology used will be explained in Chapter 3. The case study of the lithium-ion battery megaproject can be found in Chapter 4, followed by the discussion in Chapter 5. Finally, the conclusions will be presented in Chapter 6.

2. Theoretical Framework

This chapter provides the reader with the theoretical knowledge needed to follow our analysis and discussion of results. We begin by presenting the most important definitions regarding megaprojects, followed by elaborating the complexity and uncertainty characteristics of megaprojects. Secondly, the motivation behind megaprojects are discussed. Then, we discuss some of the megaproject failure reasons. Additionally, we introduce the reader to the managing megaproject section where the fast-tracking concept and PMO (Program Management Office) are presented. Finally, we develop a preliminary literature framework.

2.1. Definition, Characteristics of Megaproject and the focus on Planning

Mega comes from the Greek word “mega” meaning large, vast, great, big, tall, mighty, and important. Many different authors have tried to define megaprojects with varying results. Yet there is no consensus in the literature for a universal definition of megaproject. We can see two dominant ways when defining megaprojects: one is based on the budget and the other is the size. For instance, Flyvbjerg (2014) defines megaprojects as large-scale, complex ventures that typically cost US\$1 billion or more, taking many years to develop and build, involving multiple public and private stakeholders. Megaprojects are transformational and could have impact on millions of people (Flyvbjerg, 2014). In this thesis, we adopt Greiman's (2013) definition by referring to megaproject as characterized by mega size, long duration, uncertainty, ambiguity, complex interfaces and integration, cross-functional environment, multidisciplinary works, diversity of product delivery throughout the project life cycle, and significant political and external influences.

The literature has discussed many aspects of megaprojects. For example, Allen Sykes identifies nine characteristics that differentiate megaprojects from regular projects (Sykes, 1998): (1) size and the likelihood of multiple owners; (2) public opposition to the likely social, economic, political, and environmental impacts; (3) time—a decade or more to plan, design, finance, and build; (4) located in remote and/or inhospitable areas; (5) potential to destabilize markets because of the demand on labor and supplies; (6) unique risk, especially when the project spans economic cycles; (7) financing difficulties; (8) insufficient experience, especially in managing complex undertakings; and (9) career risks, because most of the undertakings do not advance past the planning stage and, therefore, pose an unpopular career course for senior managers. Grun (2004) calls them the giant among projects with an emphasis on the aspect of multi-organizational enterprises (MOEs) and characterizes these by (1) singularity, (2) complexity, (3) goal-orientation (technical, financial, time), and (4) the nature and the number of project owners (Grun, 2004). Johansen et al. (2013) described megaprojects as the wild beasts

in the project world, they are hard to tame, known for their complexity, vast size, expensive cost, and long time frame (Johansen, et al., 2013). Based on our extensive literature review³, we summarize the characteristic of megaproject in Table 1.

Table 1: List of megaproject characteristics and description

CHARACTERISTICS	DESCRIPTION	REFERENCE
SIZE	Large scale project, huge scope, captivating	Greiman, 2013; Flyvbjerg, 2014
COST	Exceeds one Billion US Dollar	Flyvbjerg, 2014
DURATION	Program urgency, take over 5 years to complete	Johansen et al. 2013
LIFE SPAN	A lifetime expectancy of over 50 years	Flyvbjerg, 2007
COMPLEXITY	Requires multiple management of different entities. Contains a large element of technological innovation. Complex designs and execution measures	Kumaraswamy, et al., 2017; Flyvbjerg, 2007
IMPACTS	Socio-political impacts Impact on the state budget, environment, and the community	Mann & Banerjee, 2011; Flyvbjerg 2007
RISK AND UNCERTAINTY	Associated with high risk	Flyvbjerg 2007; Denicol, et al., 2020
STAKEHOLDERS	Multiple stakeholders with mostly conflicting interest Poor cooperation between stakeholders Both public and private sectors Involving large numbers of parties	Flyvbjerg 2007; Flyvbjerg 2014; Little, 2011
SINGULARITY	Uniqueness	Flyvbjerg, 2014; Invernizzi, et al., 2018
PERFORMANCE	Cost overruns, Schedule Delays, Benefit shortfalls Poor performance in terms of economy, environment, and public support	Flyvbjerg 2014; Olaniran, et al., 2015

In this Thesis, we will be focusing on the planning phase in megaproject. Effective planning early in the life cycle of a new project big or small is highly recommended. For instance, planning is a pervasive activity that leads to personnel involvement, understanding, and commitment. He further argues that planning ahead helps to unify the task team, provides visibility, and minimizes future development (Thamhain, 2005). The reason of focusing on the planning phase is double folded. First, as a famous quote saying “failure to plan is planning to fail”, planning phase naturally set the premise of a megaproject’s success or failure. More relevantly, planning is such a vital phase in the execution of megaproject as most of the decision taking at this phase have a critical influence on the successful delivery of the project. The bottom line is that we must learn to manage the planning phase in order to fully understand the management of any megaproject. In other words, how can you manage a complex megaproject without determining how and when you are going to manage it? Therefore, even the

³ The literature review comprised both academic articles and official documentation. as well as “grey literature” - Journals, articles, blog posts e.g. - and was sought after on accredited databases like BTH Summon, Elsevier database system, and Chalmers University of Technology Open Digital Repository, as well as Google Scholar which allowed for confirmation of research quality in the sense that published articles are peer-reviewed.

following literature review covers most aspects and phases of megaprojects, a special focus has been put on the planning phase.

2.2. The most prominent features of megaproject concerning the planning phase

2.2.1. Project Complexity

The complicated system is something inevitable when organizations initiate ambitious programs and projects. Moreover, we are living in a world of expanding globalization, the rapid pace of change, fiercely competitive, and innovation paradigm that assumes firms should “do more with less” which is forcing organizations to recognize that their strategies—and the programs executed to achieve strategic goals—these among other reasons are increasing the complexity in megaprojects.

So, are organizations prepared to deal with this increasing complexity? According to a report study conducted by IBM, the complexity of operating in an increasingly volatile and uncertain world is the primary challenge of CEOs (IBM Global Business Services, 2021). However, the majority of CEOs stated that their organization has difficulties managing the complexity and four in five CEOs' speculations about the next five years is that the level of complexity will increase.

Complexity has been a popular research topic for many scholars because of its cause to poor performance and delivery (Bosch-Rekvelde, et al., 2011; Mirza & Ehsan, 2017; Qazi, et al., 2016). It is almost impossible to get one single meaning of complexity if you ask different people and in different organizations. Nevertheless, some scholars in project management have come to some sort of definition of complexity in projects (Chapman, 2016). For example, Vidal and Marle defined project complexity as *“the property of a project which makes it difficult to understand, foresee and keep under control its overall behavior, even when given reasonably complete information about the project system”* (Vidal & Marle, 2008). PMI identifies complexity in projects as *“the exponential increase in ambiguity surrounding stakeholder expectations, especially regarding the certainty of program outcomes and schedules.”* (Project Management Institute, 2013). For this thesis, we will be adopting the PMI definition.

Vidal et al. (2011) identifies project complexity as the property of a project which makes it difficult to understand, foresee and keep under control its overall behavior, even when given reasonably complete information about the project system (Vidal, et al., 2011). Senescu et al. (2012) has also used this definition to categorize the complexity into six main characteristics (Senescu, et al., 2012). These characteristics are:

- 1) Multiplicity – the more parts a project consists of, the more complex. Includes the size characteristic of megaprojects.
- 2) Casual connections – the connections between the parts. The more connections, the more complex. The most complex projects have casual feedback loops which through several steps, in the end, affect themselves. This is related to the change characteristic of megaprojects.
- 3) Interdisciplinary – how dependent parts of the system are on other parts. In complex systems, it is not possible to remove any parts without affecting the system's overall performance. If the components of the system influence each other and their actions, the system is complex.
- 4) Openness – is it a clear boundary between the system and its environment? The more blurry boundaries, the more complex.
- 5) Synergy – the system is more complex if the parts combined have a synergistic effect; i.e. one plus one equals three.
- 6) Nonlinear behavior – a system is more complex if changes to one component are not proportionate to the change of the overall system.

There is a research finding that shows several common characteristics of complexity in projects (Figure 1).

Most Defining Characteristics of Complexity in Projects



Figure 1: Common characteristics of complexity in projects - Source from (Project Management Institute, 2013) Pulse of the Profession TM In-Depth Report: Navigating Complexity.

Generally, complexity can come from either human factor or project type and different perceptions and interpretations of complexity by project managers may cause different types of project complexity. According to Baccarini (1996), organizational and technological complexities are two main components of project complexity (D. Baccarini, 1996). Brockmann and Girmscheid (2007) have categorized

project complexity into four different types of project complexity, overall, task, social, and cultural complexity (Brockman & Girmscheid, 2007). Task complexity refers to the density of activities in a time/space segment. An example of task complexity is an activity with several resources allocated with interfaces with other subcontractors where a decision made on this activity has consequences within a temporal and spatial frame on other activities.

Focusing on the planning challenge, in this thesis, we are more interested in studying task complexity. Task complexity in megaprojects can be studied in five different areas as shown in Table 2. Delegating the activity and decentralized decision-making approach is one way to manage task complexity by a functional organization. A well-organized and authorized PMO equipped with highly experienced experts can take the role of this functional organization.

Table 2: Five areas of task complexity in megaprojects (Brockman & Girmscheid, 2007)

AREA	TASK
ORGANIZATIONAL PLANNING	<ul style="list-style-type: none"> • Organization • Organization chart • Competency matrix • Job descriptions • Contract management • Quality management • Safety management • Personnel management • Purchasing • Financial accounting • Cost accounting • Communication • Correspondence and filling
DESIGN PLANNING	<ul style="list-style-type: none"> • Outsourcing of design • Coordination of design • Approval procedure • Design schedule • Documentation (as-built drawings)
WORK PREPARATION	<ul style="list-style-type: none"> • Work estimation • Controlling • Outsourcing • Construction methods • Scheduling • Deliveries • Planning of site installation • logistics
SITE INSTALLATION	<ul style="list-style-type: none"> • Land acquisition • Purchase of plant and equipment • Utilities • Offices, labor camps, canteens, lavatories • Waste
CONSTRUCTION MANAGEMENT	<ul style="list-style-type: none"> • Production processes • Quantity and quality control of materials • Quantity and quality control of subcontracts • Deployment of plant and equipment • Deployment of the workforce • Deviations from contract • Hand-over • Warranty

2.2.2. Uncertainty and risk

Besides complexity, uncertainty of megaproject not only increase the risk of the project but can also directly lead to its failure. The existing studies have discussed risk and uncertainty of megaprojects in terms of its predominant factors. For example, Denicol, Davies & Krystallis (2020) have addressed risk and uncertainty by identifying three main factors that impose uncertainty and risk into the project (Denicol, et al., 2020). These three most predominant factors are (1) technological novelty: most innovative projects which are first-of-a-kind technologies with no blueprint and are associated with risks; (2) flexibility: quality of being resilient to respond to changing and uncertain circumstances; and

(3) complexity: here refers to a large number of systems, parts and interdependencies between them. The three above factors associated with uncertainty and risk are among the main cause of poor performance leading to time and cost overrun as well as failure to deliver against the objectives used to justify projects (Denicol, et al., 2020).

Thoughtful scholars also provide solutions to deal with uncertainty and risk in megaprojects. For instance, setting a longer FEED phase period in the project is often the best solution in order to reduce the uncertainty level related to new technology. However, it is certainly inevitable to face some extent of uncertainty. Regarding uncertainty related to flexibility, necessary adaptability by reciprocal adjustments in an uncertain, complex, and dynamic environment is constrained by early decision making (formal and informal). Denicol et al. (2020) have listed *“many factors which restrict project flexibility, including centralized decision making, financing, regulatory frameworks, design, commercial arrangements, contracts, and technology, among others”* (Denicol, et al., 2020). Regarding uncertainty related to complexity, the uncertain interactions within the megaproject system linked to numerous moving and evolving parts including their interactions with the external elements are primary causes connected with complexity (Loch & Terweisch, 1998).

The deployment of a fast-tracking project delivery method can also be a cause of uncertainty. As mentioned earlier, fast-tracking is a method that compresses the duration of a project by overlapping sequential activities. Based on a study by Pedwell et al. (1998), the more overlapping, the more cost overruns by comparing the early and late start of overlapping projects. They stated that *“projects, which started overlapping early, had the highest cost overruns with 27%”* (Pedwell, et al., 1998). Fazio et al. (1988) and Park (1999) said that fast-tracking utilization might lead to unexpected extra costs in the project budget (Fazio, et al., 1988; Park, 1999). In addition, Park (1999) has highlighted cost-increasing factors connected to some of the consequences of deploying fast-tracking due to overlapping such as lack of information, insufficient time plan buffer, and impacts of design changes on construction, illustrated in Figure 2.

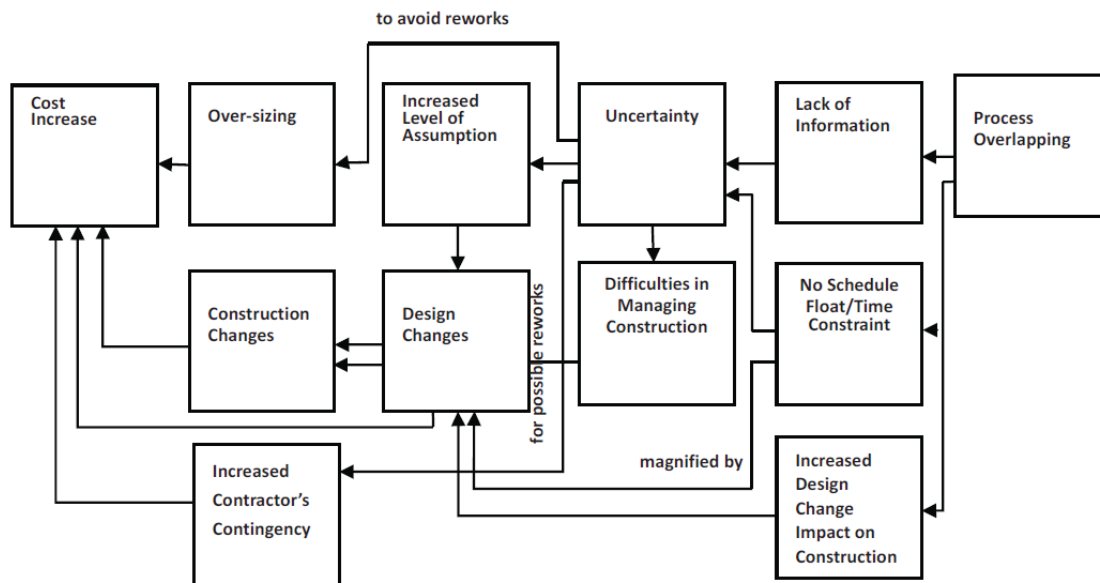


Figure 2: Cost-increasing factors in fast-tracking (adopted from Park 1999)

According to Park (1999) overlapping leads to more interrelationships dependency and compressed schedule in fast-tracking, which also leads to more design changes and longer activities duration which creates ripple impacts and makes more delays, as shown in Figure 3.

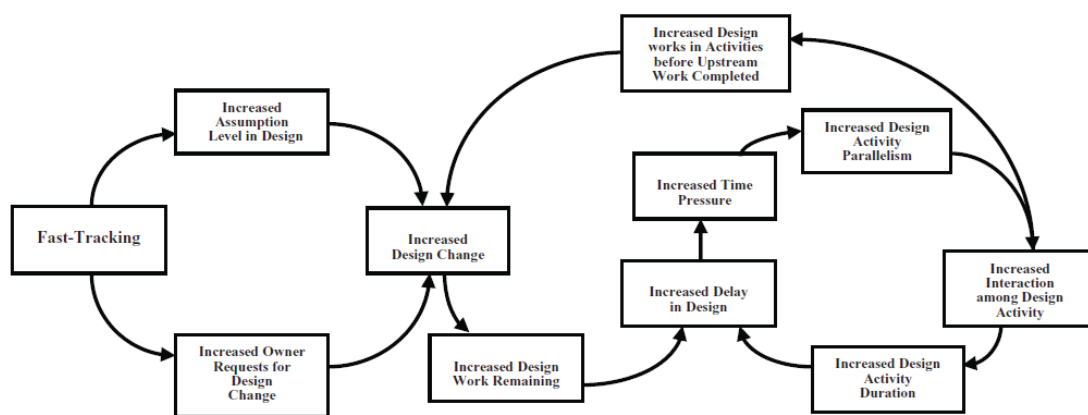


Figure 3: Ripple effects of design changes in fast-tracking (adopted from Park 1999)

In regards to design changes, Loch and Terweisch (1998) have also reflected the uncertainty by defining it as “*average rate of engineering changes and the reduction of modification changes rate over time*” (Loch & Terweisch, 1998). Engineering change or design change is referring to the deviation from the preliminary plans. This deviation causes rework, deletion or replacement and affect downstream work. For instance, assume two dependent activities such as the design phase and the construction phase which are overlapping. The downstream task (construction) will be affected by any change in the upstream phase (design) compared with the original plans. Each design change imposes the modification. Proper

coordination between upstream and downstream before initiating the upstream activity can lead to a reduction in the modification rate.

Managing uncertainty remains a challenge to many managers. Bygballe and Sward also argued that collaborative project delivery models, such as institutionalized partnering through the establishment of routines represent a key means of improving large construction project performance (Bygballe & Sward, 2019). A collaborative model will encourage interest from all parties to the megaproject to share the same interest of aligning the goals of the stakeholders in their respective duties.

2.3. Motivations behind Megaproject

According to the World Bank, the focus on poverty alleviation has reduced by almost half the percentage of people living on less than \$1.25 a day (World Bank, 2011). As of 2011, an estimated 880 million people in the world live without safe water, 1.4 billion lack electricity, 2.5 billion lack sanitation, and more than one billion lack access to telephone services. Total demand for infrastructure investment and maintenance from developing countries is estimated at more than \$900 billion a year, with the greatest needs in Africa and Asia (World Bank, 2011). In order to fill the global infrastructure gap, trillions of dollars are needed over the next decades.

Flyvbjerg (2014) listed the “four sublimines” (drivers of megaprojects) that drives megaprojects development as follows; Technological, Political, Economic, and Aesthetic drivers (Flyvbjerg, 2014). Technological deals with the excitement engineers and technologists get in pushing the envelope for what is possible in “longest-tallest-fastest” types of projects. Most politician wants to model their name in history and gets rapture from building monuments to themselves and for their causes, and from the visibility, this generates with the public and media. The delight businesspeople and trade unions get from making lots of money and jobs off megaprojects, including money made for contractors, workers in construction and transportation, consultants, bankers, investors, landowners, lawyers, and developers. The pleasure designers and people who love good design get from building and using something very large that is also iconic and beautiful, such as the Golden Gate Bridge.

Although there are many motivations behind the initiation of megaprojects, there are also hesitations to engage in megaprojects construction due to some factors that may lead to their failures. The reason for some of these failures will be discussed further in the next section.

2.4. The Four Main Reasons that may lead to Megaproject Failures

Although megaproject shows certain characteristics of resilience it is more likely to encounter failure. Herewith, we summarize some of the main factors that may contribute to megaproject failure.

2.4.1. Decision-Making Behavior

There are many studies on decision making and their effect on the execution of projects and even more particular interest in the investigation about the success and failures in megaprojects. Denicol, Davies & Krystallis (2020) in their review of 86 literature on the causes and cures of megaproject failure found out among other reasons that the behaviors in the front-end and during the execution phase are associated with poor performance in decision making (Denicol, et al., 2020). This view is also echoed by Merrow (2011) that, one of the “success factors” might be detailed front-end engineering and design (FEED) or the early engagement of external stakeholders. This decision at the front-end stage which includes the process of initiation and planning phases of a megaproject has a very strong potential to influence the consequent stages and the ability to achieve a successful project output and outcomes. Flyvbjerg (2014) noted two examples of prominent poor decision making from executives as below:

- (1) Managers overestimating the benefit and underestimating the cost;
- (2) Executives and sometimes politicians strategically misrepresenting the truth to serve their interests.

2.4.2. Leadership and Capable Teams

Denicol, Davies & Krystallis (2020) defines leadership and capable teams as the relationships among project team members, individual competencies, required skills, and organizational capabilities that contribute to the performance of megaprojects. One of the main sources of poor performance which are associated with project leadership is an inadequate definition of the project scope, roles and responsibility, and project culture which then leads to misalignment of the megaproject objectives. Such kind of environment will promote a dysfunctional structure that will encourage behaviors driven to attend to individual goals rather than the collective vision and objectives. The two most predominant solutions to this challenge are:

- (1) The need for project champions, dedicated leaders who are committed to the success of the project
- (2) Using competent managers.

2.4.3. Complex Interfaces

The megaproject is complicated because it requires bringing together independent multi-disciplinary teams, materials, systems, budgets, and schedules for a determinate amount of time. The nature of construction is such that there are many uncontrolled variables, further complicating the process. In the act of bringing multi-organizational teams and complicated materials together, several interfaces, or interactions, are temporarily created (Daniels, et al., 2014). Pavitt and Gibb describe three general types of interfaces that exist in a construction project, including physical, contractual, and organizational interfaces (Pavitt & Gibb, 2003).

Interface management is then simply the idea of organizing a complex project into definable interface points and managing all communication, responsibilities, and coordination associated with these interdependent parts. While other management models like lean and agile project management have been known to provide some success in complex interface management (Daniels, et al., 2014), recent authors have argued that collaborative project delivery models (PDM), such as institutionalized partnering through the establishment of routines represent a key means of improving complex interface management (Bygballe & Sward, 2019; Jergeas & Lynch, 2015).

2.4.4. Supply Chain Integration and Coordination

These factors refer to the mechanism used by the different types of organizations like the sponsors, clients, main contractors, and sub-contractors. Denicol, Davies & Krystallis (2020) defines the three main concepts in this theme are;

- (1) Program management: associated with systems, procedures, and tools to monitor, control, consolidate, optimize, and achieve benefits from several individual interrelated projects.
- (2) Commercial relationships: linked to the establishment of formal relationships with the organizations delivering projects and subprojects, as well as the management of those interfaces throughout several phases of the project; and
- (3) Systems integration: related to the technical and managerial capabilities required to integrate several components produced by different parties to deliver an operational asset to the client.

2.5. Managing Megaproject

2.5.1. The Method of Fast-Tracking

In the project management field, triple constraints refer to cost, time, and scope that project managers and their team by using methods are struggling to meet effectively. Project managers always wish for sufficient time given for each task to meet the Triple Constraints. However, due to increased competition in today's business market, companies are forced to use something called fast-tracking or crashing. By applying the fast-tracking approach, project managers are pressured to perform the activity in a shorter period which ultimately introduces products and services to market within shorter intervals. Strong forms of fast-tracking or aggressive scheduling are becoming increasingly common especially in construction projects where the project management team is struggling with tight schedules, tight budgets, and the client is seeking the quicker start of operation (Ibbs, et al., 1998).

One of the impacts of using fast-tracking methods is to impose on the project some risks that stem from overlapping between planning, design, and construction phases so that one begins before the previous phase is completed or frozen. There is a high risk of lack of information (uncertainty) when the design work is performed in parallel with the construction stage. Any changes or decision which results in the construction of a package after completion of the construction phase cannot be reversed without incurring substantial costs. According to Ibbs (Ibbs, et al 1998), *“many industry observers believe that such scheduling may actually incur more changes, leading to delays and increased costs of change”*.

In general, utilizing fast-tracking or crashing concepts, schedule compression, accelerating or overlapping project delivery systems can positively impact on achieving the project objectives, but sometimes it may result in unexpected outcomes. However, these unexpected outcomes can be avoided by setting realistic goals and avoiding aggressive overlapping, planning properly and realistically, deploying an experienced and knowledgeable project team, learning from previous similar projects, and establishing effective project coordination and communication system. Nevertheless, some of the projects' characteristics such as expected duration, complexity, project organization maturity level, and project team competency are key factors that may increase the variances of the projects' outcomes (Alhomadi, et al., 2011).

2.5.2. Program Management Office (PMO)

PMI defines a program as related projects, subsidiary programs, and program activities managed in a coordinated manner to obtain benefits not available from managing them individually (Project Management Institute, 2017). PMI also defines *Program Management Office (PMO) as a management*

structure that standardizes the program-related governance processes and facilitates the sharing of resources, methodologies, tools, and techniques. A PMO facilitates the governance practices (Project Management Institute, 2017). A PMO is usually staffed with professional expertise, highly trained, senior project managers to assure the program governance practices. A PMO member provides oversight, support, and decision-making capability to the program (Project Management Institute, 2017).

PMOs have a range of functions and the services they often offer depending on the maturity of the department and the skill levels of the people working in the PMO. PMOs generally concentrate on project management functions and centralize expertise around them.

The environment and dynamic of a PMO have a huge influence on designing and developing a PMO. For example, organizations pursuing exceptionally large, complicated, or complex programs may establish multiple PMOs, each of which may be dedicated solely to the conduct of one or more critical organizational programs. The establishment of a PMO in an organization structure seems to influence the success and is seen as a critical success factor (Spalek, 2014). Fernandes, Ward & Araujo (2014) also argued that the development of standardized structures to manage projects such as PMO or similar structures will improve performance and hence the value of the organization (Fernandes, et al., 2014). It is imperative to study the structures of the type of PMO to implement in megaprojects since this project type as noted earlier has a unique characteristic that may not be found in any other project done before. Therefore, designing a PMO type is a real challenge to the organizations and it is depending on many factors such as the maturity level of organization and complexity of programs. The topic of design a PMO type is out of scope of this study, however requires a further study. Many companies are being encouraged to implement PMO without a clear definition of what this may entail (Aubry, et al., 2010), without clear objectives for implementation, functions, and responsibilities within the organization (Andersen, et al., 2007). This is in contrast to the definition of PMO by the Project management Institute.

2.6. The preliminary research framework

Table 3 summarizes the key challenges associated with the planning phase and the major mechanisms of investigation for tackling these challenges. This framework is used to guide the overarching research process.

Table 3: Preliminary Research Framework

KEY CHALLENGES ASSOCIATED WITH THE PLANNING OF MEAGA PROJECTS	MAJOR MECHANISMS/ASPECTS
TASK COMPLEXITY	Organizational planning, design planning, work preparation, site installation, construction management (Brockman & Girmscheid, 2007)
TASK UNCERTAINTY	Technological novelty, flexibility, system complexity (Denicol, et al., 2020 ; Pedwell, et al., 1998)
INCENTIVE	Technological, Political, Economic, and Aesthetic drivers (Flyvbjerg, 2014 ; World Bank, 2011)
MANAGERIAL FACTOR	Decision making, leadership (Denicol, et al., 2020 ; Flyvbjerg, 2014)
WHETHER RIGHT METHODS ARE IN PLACE	Fast tracking, program management, PMO (Alcabes, 1973 ; Ibbs, et al., 1998 ; Project Management Institute, 2017)

3. Methodology

This chapter explains the methodology, the research methods, and the analysis methods utilized for this study. The chapter starts with explaining our research approach, the research design, a critical discussion on the advantages and disadvantages of our chosen research tools. Then it is followed by discussing the chosen method's ability to produce valid results, meeting the aims and objectives set for this study. It further elaborates on how we intend to meet the research goals. Finally, we conclude with the ethical considerations and research limitations.

3.1. Research Approach

This thesis utilizes a case study research strategy, with inductive reasoning (for exploratory purpose and given the nature of our research problem does not stem from a hypothesis). A pragmatic research approach is also adopted in operationization of the study.

To begin with, we approached the case with an exploratory mindset and inductive reasoning. One of the primary advantages of using a case study approach is that it allows for the use of empirical research that primarily uses contextual rich data from a bounded real-world setting to investigate a focused phenomenon (Yin, 2009; Barret, et al., 2011). The flexibility in a case study approach has the potential to provide bases for future research especially when findings in the case study provides new dimensions during a comparative overview of what is previously known theoretically or from literature review (Welch, et al., 2012; Goffin, et al., 2019). A case study approach permits the investigation of otherwise impractical or unmeasurable attributes or situations and gives the researcher the possibility to provide a descriptive factual interpretation of the information collected (McLeod, 2019). Therefore, for this research we define the *Research approach* as the general plan for the steps we will take to answer the research problem (Saunders, et al., 2009) which involves searching and identifying a suitable case study that fits all the definitions of megaprojects.

The research approach is carried by three steps: 1) first we conducted literature review on both theoretical concepts on megaprojects and project management in general; we also include and previous studies about the research phenomenon, including several special issues on megaproject management published in top project management journals; 2) second we conducted a case study by using qualitative research methods to collect empirical evidences that answer to our research questions; 3) we used qualitative case analysis methods, such as pattern matching and inductive reasoning to identify patterns in our findings as well as supports in the literature. Our analysis was conducted in an iterative process between the theoretical concept and the data collected, where we went back and forth to compare our

empirical findings to the literature and vice versa. This means the analysis took place throughout the study as we attempted to retheorize the existing literature.

3.2. Research Design

The chosen research design is exploratory research. According to Ghauri & Gronhaug (2010), the flexibility of this research design helps us to examine the case study. As one of the advantages of exploratory research, we aim to theorize through observation, collecting information, and constructing explanations (Ghauri & Gronhaug, 2010).

We used a combination of primary data and secondary data in this study. When primary data was not available we added secondary data to compensate and add insights to our research questions. The primary data are consisting of interviews with subject matter experts such as project managers, senior engineers, and senior planners whereas secondary data came from other published sources.

All interviews took place at a distance with different approaches due to the 2020 Covid-19 pandemic. Conducting all interviews on-site in each office would have entailed large resource costs as the respondents are deployed in different parts of the country. Moreover, the Covid-19 pandemic has further made it difficult for us to conduct on-site interviews for health reasons and following the Swedish Public Health Agency's recommendations, after which telephone interviews and interviews through Zoom and Skype have been beneficial and better suited. The benefit of telephone interviews is that it saves researchers time and money. A potential disadvantage is that the interviewee's body language cannot be seen, which can be important when asking a certain question (Bryman & Bell, 2011).

However, the majority of the conversations were conducted via the computer program Zoom, which enables video conversations where the interviewee's body language and mind games can also be identified. All the interviews were transcribed for data analysis.

3.3. Research Methods

As qualitative data and field-based construction and analysis are composed in this case study, we utilized a combination of methods to collect and analyze data. Since one of the authors has worked in the case study project, field observations and analysis of texts were used to collect first-hand information in a natural setting (Ghauri & Gronhaug, 2010).

Our intent of using the qualitative research method with the case study is to understand the underlying question of reality and also to further develop the theory behind the question. We employed the use of

semi-structured interviews for responders that will agree to personal interviews and will use a semi-structured questionnaire for responders that opted for a written response. According to (Ghauri, et al., 2020) semi-structured interviews allow the informants to freely talk about their experiences and their actions in terms of providing their experiences of what worked well and what didn't go well and also provide additional strategies of how to resolve the problems. The semi-structured interview technique also provides a foundation for the interviewee to give a repertoire of possibilities. It is sufficiently structured to address specific topics related to the phenomenon of study while leaving space for participants to offer new meanings to the study focus (Galletta & Cross, 2013). The use of a semi-structured interview/questionnaire will help us gain the advantage of both the structured and unstructured interviews in the sense that that, it allows us to dictate the directions of the interviews and allows the interviewees to provide sufficient information to present an in-depth picture of their answers (Keller & Conradin, 2020). One of the challenges of semi-structured interviews as with any unstructured interview is to make the result reliable since personal bias from individual experience. This is the reason the researchers have taken time to structure the interview questions and conducted an adequate number of interviews so that these challenges could be mitigated (Galletta & Cross, 2013).

3.3.1. Sampling Procedure

The sampling choices were selected in such a way that the researchers will get a deeper understanding and a true representation of the phenomenon that is being studied (Carlsen & Glenton, 2011). To achieve this, the researchers developed the following criteria for the sampling.

- A. The sample must be chosen in such a way that is conceptually driven by the theoretical framework.
- B. The sample must have a minimum of 10 years of work experience in managing megaproject or large-scale projects so that rich data can be collected.
- C. The samples must come from diverse backgrounds or departments so that a true population representation of the case study can be achieved and bias associated with the unique experience can be eliminated.
- D. The sample must have a good command of English language proficiency.

To fulfill these criteria, the researchers have chosen a purposive sample where the participant has the characteristic which is desired. This was made easy because one of the researchers worked previously on the case study. The result from this sampling process can be seen in Table 3 where the 8 interviewees have a total of over 150 years of working experience in the related field.

3.3.2. Interview Questions Development

Since a qualitative research method has been selected for this thesis, we developed our interview questions based on descriptive questions. We also designed the questions based on the known characteristic of the megaproject, elements of megaproject planning and management, and literature study. We also reviewed the most common challenging areas in managing megaprojects and designed the interview questions accordingly. The interview questions have been evolved based on inputs received from the previous interviewees. Moreover, the interviewee's background experience and their current position were two pivotal factors that were used to discuss more the related subjects.

Before conducting the interview, we distributed the interview questions to the interviewees in advance to give them some time to review the questions and put their thoughts together. We also checked with the interviewee's time availability to set a duration for the interview. During the interviews, we started by explaining the purpose of the interview, addressed terms of confidentiality, and allowed the interviewee to clarify any doubts about the interview questions and process.

3.3.3. Data & Collection

The interviews were carried out exclusively through the Zoom portal and Google Meet with some of these recorded with the approval of the interviewee. A total of 8 interviews were conducted with people from diverse backgrounds and experiences as seen in Table 4. Most of the interviews lasted 2 hours and some were needed to be rescheduled as additional time was needed. The interviews were semi-structured and there was a great deal of flexibility as most of the interviewees wanted to be detailed with their responses. Similar interview questions were provided to all interviewees but there were many follow-up questions due to the nature of their responses on critical issues. The interviews came from different companies which have been anonymously presented as A, B, C, and D. Since three megaprojects (A, B and C) share similar characteristics: a) all are greenfield infrastructure projects; b) all 'mega' by nature; c) all located in Scandinavia, we treat them in a collective manner and refer them as our 'green field infrastructure megaprojects'.

Table 4: Interviewees information

Interviewee code	Position	Years of experience in management	Megaproject-related experience
Interviewee 1	Planning Supervisor / Project A	>30 years	Deep expertise in project planning and resource management with Swedish Transportation Administration. Lead planner for decommissioning of KVV6 coal power plant
Interviewee 2	Project Director / Project B	>30 years	Directs multinational EPC projects in the power section and across Scandinavia and the Middle East
Interviewee 3	Electrical Design Manager / Project C	>20 years	Electric design manager on the largest Electric Vehicle battery manufacturing startup plant ever built in Europe. Lead electric power plant design across Scandinavia and the UK
Interviewee 4	Director of Interface Management and Risk / Project C	>15 years	Interface management on the largest Electric Vehicle battery manufacturing startup plant ever built in Europe. Project manager of Oil & Gas JV projects (mostly with Shell) with multiple international Stakeholders
Interviewee 5	Electrical Design Project Manager / Project C	>10 years	Planning manager on the largest Electric Vehicle battery manufacturing startup plant ever built in Europe
Interviewee 6	Project Manager / Project D	>10 years	Have a Ph.D. in Project Management. Managed project/program activities of integrated product team (IPT) for development, delivery, and integration of the complex systems (hardware/software) of multi-billion dollar complex TF-X project
Interviewee 7	Business Unit Manager / Project C	>23 years	Building manager on the largest Electric Vehicle battery manufacturing startup plant ever built in Europe
Interviewee 8	Lead Project Planner / Project C	>16 years	He has worked for almost 7 years on three major projects including one and a half years in the case study project.

3.3.4. Data Analysis

The data collected was quite massive and to make sense of this, they were first manually transcribed from the audio recording into a format that would be easily understood and compared (See appendix 8.2). The researchers then employed data reduction techniques as noted by (Ghauri, et al., 2020) which involves the process of selecting, focusing, simplifying, abstracting, and transforming the data that appear in the transcriptions. We then dived into these simplified data by manually reading multiple times

to search for similar phrases, recurring themes and created different first-order codes that are relative to the themes (Nag & Gioia, 2012) so that comparative overviews of the different interviewees can be displayed. For example, we have found many aspects of inter-relationship challenges which were coded under communication importance, cross-cultural relationship, and contractor collaboration. We also used Naomi Quinn's review of her own thirty years of qualitative research (Quinn, 2005) where she said to look for lines of reason, keywords, and metaphors in the interview data. We emphasized finding meanings embedded in the interviews.

Gioia's methods (Corley & Gioia, 2004; Gioia et al., 2012; Nag & Gioia, 2012) was used to guide the overall data analysis. Thus, we have developed first-order codes based on the interviewees' account – the empirical data; second order themes by linking to our theoretical framework and concepts; and an aggregation analysis for conceptualization. Table 5 illustrates our first-order analysis results.

Table 5: Identified themes connected to previous findings and representative quotes

Themes	First-Order codes	Representative Evidences
Uncertainty	Changes	<p>Interview 1: We estimated the soil property during the planning and in the excavation time, found out that the texture was different, and have to reduce the speed of the excavator leading to delays in the schedule.</p> <p>Interview 3: Too many changes are involved because multiple firms were used during the basic design phase, and they spend entire time and resources correcting this.</p> <p>Interview 4: Handling product development cycle changes and project development cycle is a program management issue. This is even difficult for a greenfield project (large-scale EV battery startup) where the project is defined without knowing what the final product will be (product is evolving with the project development). There are lots of risks and uncertainty associated with such a project, but such management does have a high-risk appetite than risk-averse. A PMO is a key to managing such kind of megaproject which involves both product development and project development. It will help with uncertainty and the complex interface associated with a start-up megaproject. This PMO should be a directing one that has the right to make a decision relevant to the product development and project execution. They can be structured in such a way that the PMO is separate for the product development and the project development and then integrated at the upper management section.</p>
	Fast-tracking	<p>Interview 3: Overlapping between different gates also brings uncertainty. For instance, the basic design is not fully completed before moving to the next stage and that means the design input. Moreover, if there are large changes, for instance, the air compressors become much larger than needed, then they need a bigger building.</p> <p>Interview 4: In my experience, fast-tracking creates so much risk, uncertainty, and exponential increase when changes occur that affect interfaces.</p> <p>Interview 6: Fast-tracking causes lots of grey areas due to poor scope planning and too many assumptions leading to a much wider delay.</p> <p>Interview 8: The fast-tracking approach has been used carelessly without considering the associated risks and even sometimes jeopardizes the</p>

Complex interface and integration	Ambiguity	<p>deliverables deadlines, mainly by making mistakes and then fixing it and consequently missing the target dates.</p> <p>Interview 4: If you don't know what you will deliver, it becomes very difficult to deliver it. Without an adequate scope of work and adequate front-end loading, you will always struggle with the right strategy to deliver the project.</p> <p>Interview 6: The customer wanted to design an aircraft that has never been built before and his requirements were unclear resulting in different interpretations</p>
	Oversight Office	Interview 1: It is important to have an independent person who has oversight functions between the parties of the interfaces.
	Aligned with all parties	<p>Interview 2: The project's objectives must be aligned with all the parties to the different interfaces.</p> <p>Interview 3: Poor design coordination between the contractors could be a real issue if this is not managed in the time schedule and they are not aligned.</p>
	Managing all interfaces	<p>Interview 1: The best way to manage complex interfaces is to use a multiple milestones strategy. This involves setting milestones between the parties involved in those interfaces where information or services are to be shared. These milestones should be documented and there has to be an oversight from the stakeholders.</p> <p>Interview 2: A PMO with limited duties will not be effective in managing complex interfaces. It should be capable of advising, directing, and working together in the execution of projects.</p> <p>Interview 4: It is important to use an experienced resource to manage the interface and it has to be in a form of an organizational structure like PMO.</p> <p>Interview 7: We do have a meeting once a week for all contractors involves in the building. This building site is split into 4 areas. Each area does have a meeting every more before they start working and are represented by the head of the contractors.</p> <p>Interview 8: One possible issue is related to the hand-over process and any possible delay that will make the successor contractor file a claim against the predecessor contractor (the employer). This issue is mostly caused by poorly defined interface management both in the time plan and process.</p>
	Coordination	<p>Interview 3: It is important to use one firm to do all the basic design to facilitate the better flow of information to different sub-contractors.</p> <p>Interview 8: Disconnection issue and lack of coordination between the project design engineer, construction engineer, and commission is crucial. In megaprojects, this becomes even more problematic due to the magnitude of the project and the high complexity.</p>

We also found new features which were not mentioned in previous studies as summarized in Tables 6 and 7.

Table 6: New-found identified themes and representative quotes

Themes	First-Order Codes	Representative Evidences
Resource availability	More resource on feed stage	<p>Interview 1: The more money and time you spend on the pre-work, the easier the project becomes. My point is that things are not done properly in the pre-work stage, and we end up doing most of the redesigning during the execution stage.</p> <p>Interview 5: To have a bigger organization planner earlier in the project so that any shortfall can be escalated earlier in the project.</p> <p>Interview 6: Adding more resources to the scheduling unit will solve some of the problems of managing complex interfaces.</p> <p>Interview 8: The employer should have started the planning of the execution phase much earlier, maybe one year before the current date because of the complexity of the project from an interface and integration point of view.</p>
	Schedule procrastination	<p>Interview 1: An overlooked point that causes megaproject delays is procrastination. Most megaproject duration can take up to 10 years and people do lose a sense of urgency at the earlier stage, believing they have much time. This leads to lots of procrastination of duties and leads to more delay at the end. It is important to allocate some resources earlier to these activities and then set an intermediate goal to monitor their performance. This will help minimize the problem.</p>
	Adding more experienced resources	<p>Interview 3: One of the ways to deal with uncertainty is to man up the resources with highly experienced people in the early phase of the project to reduce uncertainty.</p> <p>Interview 4: Adding more experienced resources during front-end loading will mitigate some risk but this depends on the maturity of the project. On a start-up (which involves both product and project development) where products are changing, this will be difficult.</p> <p>Interview 6: If given the authority to do something different that will bring success to the megaproject, I will spend more resources on competent people.</p>
Inter-relation management	Importance of Communication	<p>Interview 3: In a large start-up megaproject that involves many stakeholders and people from diverse backgrounds, communication will be a key issue and if not properly organized, will lead to schedule delay. It is important to map the flow of information properly throughout the life cycle of the project. For example, the company is ordering a lot of steel earlier in the project since the contractor has demanded so much which later led to an inventory problem.</p> <p>Interview 8: Everyone needs to use only one planning source to communicate with. Otherwise, the integrity of the time plan will be jeopardized. Therefore, there should be only one common language of planning to communicate.</p>
	Lack of cross-cultural relationship	<p>Interview 5: "We are working with many people from different countries. It's a lot of cultures and one needs to adapt to these people so that you can get the best performance.</p>

Coordination	<p>Interview 7: It's a lot of new people in the building with many different customers and lots of coordination challenges.</p> <p>Interview 8: it is crucial to coordinate the people who work on the site especially when there are plenty of workers who are supposed to work in a tiny place with a high probability of happening conflicts.</p>
Collaboration	<p>Interview 1: Most government projects are executed with a very tight budget that makes contractors very transactional (deliver the project with minimum cost) as possible and less collaboration with other contractors.</p> <p>Interview 4: In Sweden, there is less collaboration between contractors as compared with international projects. The contractor mentality is to see conflicts as somebody else problem.</p>

Further, we have aggregated some of the findings into two dimensions that address the planning challenges of megaprojects namely: Multifaceted challenges and Intermediate milestones concept. See Figure 4 below.

The first dimension is labelled as *Multifaceted challenges* characterizes the challenges that the managers being faced. It emphasizes not only those challenges that are related to their field of expertise but other issues related to the inter-relationships due to the characteristics of megaprojects such as uncertainty, complex interfaces and integration, ambiguity, and cross-cultural environments which are elevated in a megaproject complex environment. The second dimension is referred as *intermediate milestone*. We use this term to address *an* important concept that has multiple outcomes. It can be used to expedite the exchange of information along with the complex interfaces which will help parties that are involved in the interfaces to plan ahead of time and reduce the risk associated with assumptions. Intermediate milestone is also important for mitigating challenges resulting from schedule procrastination. This means schedules that come much later in the megaproject could be started earlier in small steps which will also reduce the possibility of delays.

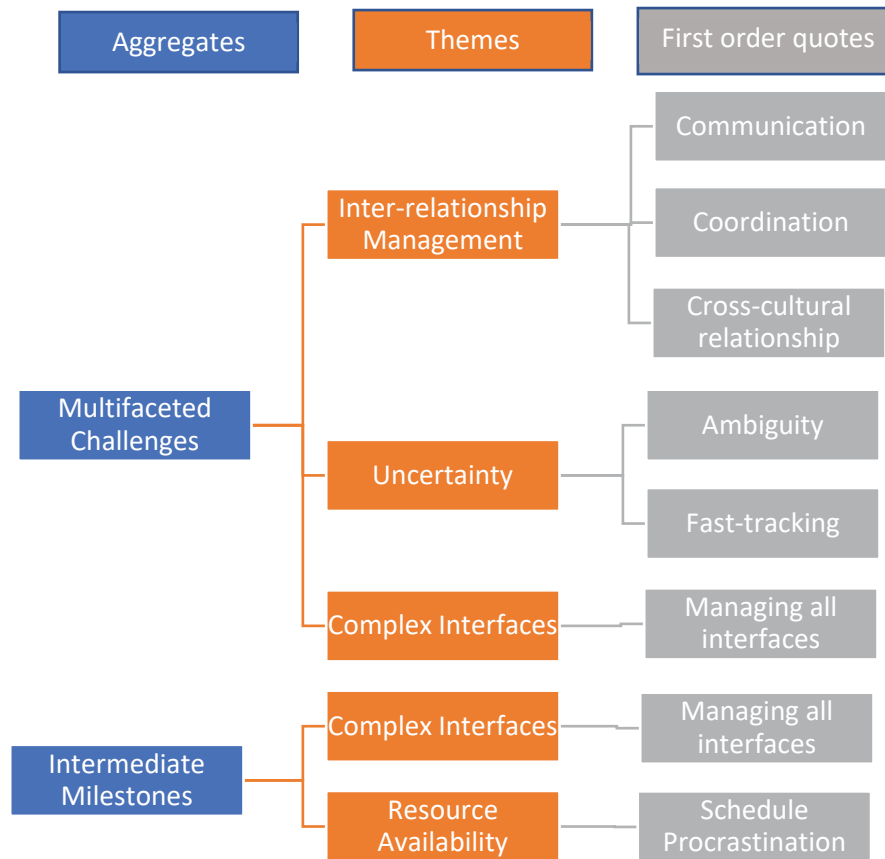


Figure 4: Relationship between First order quotes, Themes, and Aggregates

3.4. Trustworthiness

This research involves using a megaproject as a case study. This megaproject fulfills most of the characteristics to be considered a megaproject. The megaproject constitutes the development of a blueprint for next-generation lithium-ion battery manufacturing that is fundamentally different from conventional battery production facilities.

The Interview was conducted with people who have firsthand information about the project. We have limited the interview to people who will be in the position to experience the type of information that we need for the qualitative analysis. The includes departmental managers who are involved in the day-to-day management, head of Engineering teams who will be informed about necessary design changes, finance managers, field support managers, and contracting staff.

The findings from the qualitative data were based solely on the interview participant responses and were presented in a manner that is not skewed. The researchers have made sure that any potential biases or personal motivation were eliminated from the report.

3.5. Ethical Considerations

Denscombe (2010) stated that “*no one should suffer as a result of participation in a research*” as a core principle of his research ethics (Denscombe, 2010). Bryman and Bell states four ethical concerns that we will take into consideration when performing the research (Bryman & Bell, 2011);

- Whether there is harm to participants.
- Whether there is a lack of informed consent.
- Whether there is an invasion of privacy.
- Whether deception is involved.

We have taken some details consideration of the megaproject and provided the following guarantee to our interviewee:

- Participants will be anonymous.
- Data will be treated as confidential.
- The participant will be informed about the nature of the research and their involvement.
- The participants will voluntarily consent to be interviewed.

The interviewee was notified that the thesis work will remain at the BTH University, and their consent will be sought after before any publication outside the boundaries of the university.

3.6. Limitations

This study has several limitations. We faced some challenges to deal with during this thesis with such a comprehensive research topic, limited time, finding the right people to interview with, isolated, with limited possibilities to discuss with peers face-to-face.

Firstly, it is due to time constraint which determines the choice of more efficient methods, such as case interviews, as opposed to questionnaires and focus groups. The time constraint also led to the limited sample size (8) as most potential participants decline to respond due to reasons of the NDA signed with the case study project and that the case study project is still ongoing. Secondly, no site-visitation was conducted since we are in a pandemic situation. Site visitation would have given us the first experience to observe how the multidisciplinary environment is playing with the case study and the opportunity to interview some of the field employees. Finally, most of the respondent which has been used comes from one of the researchers who was formally working on the case study. These respondents are working on only a section of the megaproject case study which means their views will be biased towards their

experience on the unit. This shows that this research work might have the potential of not representing the whole sample in the case study.

All interviews took place at a distance with different approaches due to the outbreak of the 2021 Covid-19 pandemic. Conducting all on-site interviews in each office would have entailed large resource costs as the respondents are deployed in different parts of the country. The Covid-19 pandemic has further made it difficult for us to conduct on-site interviews for health reasons and following the Swedish Public Health Agency's recommendations, after which telephone interviews and interviews through Zoom and Skype have been beneficial and better suited. The benefit of telephone interviews is that it saves researchers time and money. A potential disadvantage is that the interviewee's body language cannot be seen, which can be important when asking a certain question (Bryman & Bell, 2011).

4. The Case of the lithium-ion battery megaproject

In this chapter, we present our main case study and the findings in four themes: inter-relation management, uncertainty, complex interfaces and integration, and resource availability.

4.1. A Brief Overview of the Lithium-ion Battery Factory Megaproject

A main case study is conducted within a megaproject that started to construct a series of lithium-ion battery factories to supply the automotive industry with electric vehicle batteries. This megaproject is considered to be one of the biggest industrial projects in Scandinavia. This megaproject has a diversity of product delivery and is a process-driven project where the scope of the project includes civil work (physical facilities), electrical installation (transformers, switchgear, cables, lights, etc.), mechanical installation (heat, ventilation, air-condition), process equipment, and many others. This megaproject is a combination of the systems managed as a program that is broken down into several individual projects with individual systems and interconnections between them. Figure 5 demonstrates how the organization has set up a structure to achieve strategic organization's objectives.

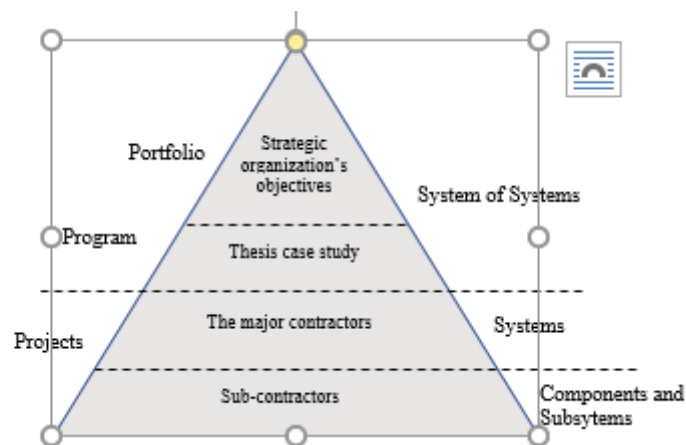


Figure 5: Managing projects in the case study's organization

Because of diversity in both product and project levels, it requires assembling project teams using members of the organization/contractors/sub-contractors from different functions. It also requires multidisciplinary inputs from many organizations.

This megaproject is built by international construction joint ventures (ICJVs) which makes it even more complex than the organization of a single contractor or a client. There is also task complexity which refers to the density of activities in a time/space segment with interrelationships (interfaces) between different contractors such as civil and electrical contractors or mechanical and process contractors. Since

the number of interfaces is numerous, a change on one subject will have repercussions for many others. Moreover, as the technology in this project has not been used before and project knowledge is low, it causes more uncertainty in the project organization.

Finally, because of the FEED approach applied in this project, the degree of uncertainty intensifies during the execution of the project. By considering the interrelatedness, and consequential impact of a decision field, managing the project in extreme uncertainty is a key element to the success of this project. All the above characteristics of this project have made us see this project as an interesting project to study.

4.2. The Perceived Challenges by the Managers

This section presents the important findings of the study and shows some of the challenges experienced by managers in the execution of megaprojects. Some additional factors that can create uncertainty in megaproject and possible remedies were also described.

4.2.1. Inter-Relation Management in Megaprojects

Four different aspects of relationship challenges were brought to the spotlight where it seems that inter-relationship management is crucial for the success of megaprojects. This includes communication structure, cross-cultural communication, coordination, and collaborative work.

To begin with, having a better **communication structure** is paramount to the relationship of these different stakeholders, as noted by Interviewee 3:

In a large start-up megaproject that involves many stakeholders and people from diverse backgrounds, communication will be a key issue and if not properly organized, will lead to schedule delays.

Interviewee 3 went further to describe this communication problem as one of the main challenges encountered in a startup megaproject where experience is lacking. The ability of the managers to effectively communicate to people with different cultural backgrounds should not be underestimated according to Interviewee 5. He went further and talked about the difficulty to motivate field workers from Eastern European contractors to provide a better performance and there need to consider training in **cross-cultural communication**.

Managing inter-relations also means **coordination** of different contractors working at the same time in the same location and the challenges involved in managing this without interference on their work schedule, as noted by Interviewee 7.

It is a lot of new people in the building with many different customers and lots of coordination challenges.

Also, Interviewee 8 has a similar opinion in regards to coordination as he noted:

The failure to develop an integrated time plan with resource loaded could cause some issues in terms of resource conflicts when they are supposed to work in a tiny space at the same time without proper coordination.

He added:

Disconnection issue and lack of coordination between the project design engineer, construction engineer, and commission is crucial. In megaprojects, this becomes even more problematic due to the magnitude of the project and the high complexity.

Interviewee 1 also lamented the transactional project delivery mentality with projects in Sweden. Most large-scale projects are sponsored by the government where the budget is always tight. This leads contractors to try to deliver the project with less cost as much as possible and sometimes quality might be affected. Interviewee 4 acknowledges that based on his experience, there seems to be a less **collaborative** effort in Sweden as compared to companies in the UK. He said as follows:

In Sweden, there is less collaboration between contractors as compared with international projects. The contractor mentality is to see conflicts as somebody else problem.

Clearly, all these challenges are associated with the characteristics of megaprojects being large-scale and complex projects. More relevantly, the challenges stem from the involvement of multiple stakeholders and contractors. These contractors can potentially come from different regions which will pose inter-relationship problems between the different parties involved in the project.

4.2.2. Uncertainty

There were 4 different aspects where uncertainty can come to the megaproject. Interviewee 1 described **changes** that come from making assumptions during the initial phase (like basic engineering). He gave an example in the excavation of underground railway construction of finding out during the soil property turns out to be much different than what was anticipated in the basic design. These findings lead to a reduction in the excavation speed, and which eventually caused delays in the project. He provided a solution of creating more resources to dig and record the soil properties during the initial stage.

Managers also face challenges from handling changes resulting from multiple companies being involved during the basic design phase as quoted by Interviewee 3.

Too many changes are involved because multiple firms were used during the basic design face and they spend entire time and resources correcting this.

She also recommended using one company during the basics so that one source of information can be flowing to all the companies involved in the detailed design. Uncertainty also arises from changes in contractors which brings in many new people during the project. Sometimes, we do not know what to expect from these new people, explained Interviewee 7.

The other source which creates uncertainty in the project is **fast-tracking**. Interviewee 3 noted how the overlapping of different gates in the battery startup megaproject has created so much uncertainty and provided an example of a fast-tracked building for a compressor. The compressor was then changed due to an increase in the demand capacity which ultimately means they will need a larger building. Fast-tracking does lead to an exponential increase in cost as noted by Interviewee 4.

In my experience, fast-tracking creates so much risk, uncertainty and even leads to an exponential increase in cost when there is a change that affects multiple interfaces.

Fast-tracking creates lots of grey areas in the project according to Interviewee 7. The reason is that there is poor scope planning in the basic design assumption, and this normally leads to a much wider schedule delay than the intending schedule expedition it was intended for.

Ambiguity is a huge factor that creates uncertainty in megaprojects. “If you do not know what to deliver, then it becomes very difficult to deliver the project.” quoted Interviewee 4. When a project is not adequately scoped and the front-end loading is not properly carried out, it will make it difficult to find the correct strategy and manpower to deliver the project. Improper scope definition is a vital source of controversy among contractors and brings uncertainty. Interviewee 6 explained that,

In most cases, the scope of work is not clear on the interfaces leading to many different interpretations from the contractors.

The overall project objectives must be clear to all the contractors involved in delivering the project according to Interviewee 2. In most cases, different contractors might have their objectives, and this could be a challenge because expectations from performances will be different across these contractors.

4.2.3. Complex Interfaces and Integration

The best way to manage complex interfaces is to use a multiple milestones strategy, quoted Interviewee 1. This involves setting milestones between the parties involved in those interfaces where information or services are to be shared. These milestones should be documented and there must be an **oversight** in the form of an independent office and should come from the stakeholders. This oversight office must have the responsibility of making sure that this documented milestone is implemented. Interviewee 1 went further to talk about his current project where a team of grey hair specialists provides a supportive function to program managers that oversee these interfaces. In his own words, he concluded “you will not find a group that has an experience better than this team”.

The parties involved in the interfaces must have the same objectives which should resonate with the overall megaproject objects, noted Interviewee 2.

*The best way to manage complex interfaces is to **align** the overall objectives of the project to all the parties involved in the interfaces.*

The objectives must be clear and defined, hence the reason why it is important to have a structure like PMO. This PMO should not have a limited duty. In a complex large-scale project like the startup battery project, they should be capable of advising, directing, and working together in the execution of projects concluded Interviewee 2. Interviewee 6 lamented the challenges that they were faced in a project from having an unskilled PMO. This leads to the PMO functioning as more of a monitoring service instead of the supportive service that was expected.

There must be a coordination effort among the contractors on the interfaces. It is the responsibility of the managers involves in these interfaces to manage this coordination effort so that information and document can be exchange in a timely manner as explained by interview 3.

Poor design coordination between the contractors involved in the different interfaces could be a real challenge if these interfaces are not managed with the proper time schedule and aligned with the overall planning.

Managers should also avoid design or activities that increase the complexity of the interfaces. It will be better to use one engineering company during the basic engineering phase so that there is one source of information going to the contractors in the subsequent stages. This will help reduce the complexity of the interfaces.

Interface management requires expertise. It is not only important to use more resources, but these resources should have the experience required to **manage** these interfaces. This resource must be in an organizational structure like PMO according to Interviewee 4.

It is important to use an experienced resource to manage the interface and it must be in a form of an organizational structure like PMO.

One of the best practices to manage complex interfaces and integration is to integrate and consolidate all time schedules into one master time plan with clearly defined interfaces and real data quoted Interviewee 8. This should be incorporated by a clearly defined interface document where each party knows exactly what requirements should be fulfilled and what type of deliverables should be expected during the hand-over process.

4.2.4. Resource Availability

The limited resource was a resounding concern with most of the interviewees and some of them traced back the challenges which are found on the detailed engineering and production stage stem from the resource used during the FEED stage. For instance, Interviewee 1 quoted,

*“The **more money** and time you spend on the pre-work, the easier the project becomes; my point is that things are not done properly on the pre-work stage and we end up doing most of the redesigning during the execution stage”.*

Interviewee 5 speaking from a scheduling engineer perspective, lamented the poor planning done during the early stage of the EV battery manufacturing startup project. He recommended that the organization should have used **more resources** in the earlier stage in the megaproject so that any shortfall can be escalated earlier or resolved much earlier. Correcting this shortfall does take time and more and causes schedule overruns. Interviewee 6 added that if more resources are used during the initial scheduling phase, some of the problems encountered with managing complex interfaces will be mitigated.

Interviewee 3 acknowledged the benefit of using more resources in the earlier stage in the project but added that the quality of the resource is also of high paramount. A highly **experienced resource** in the early phase of the megaproject (especially with the EV battery startup with unique technology) will help reduce the uncertainty that is seen on the other stage in the project. Interviewee 4 also corroborated the idea of using the experienced resource as seen in his quotation below.

Adding more experienced resources during front-end loading will mitigate some risk but this depends on the maturity of the project. On a start-up (which involves both product and project development) where products are changing, this will be difficult.

He added that an experienced resource in the initial stage will create a better execution plan to manage the interface and Risk. When asked to mention what he would have done differently if given the authority so that the megaprojects will be successful, Interviewee says “spend more money on competent people.” The competence in the management team and that of the contractors are low sometimes. This is relative to both technical and megaproject management within Sweden. It is more found within the construction sector also. In general, the contracting and consulting structure within Sweden is not so competent to run a megaproject. There is a lack of EPC big enough to carry such megaproject and this poses lots of challenges to the startup megaproject like the EV battery manufacturing plant.

Interviewee 8 sees the resource availability topic from a different angle. Since his expertise is related to project planning, he highlighted the importance of having enough competent planners to be assigned to the megaproject. He quoted that:

In such a megaproject, where there are too much data incorporated into the time plan, it requires more people to maintain these inputs in the time plan. However, when the location of the project site is not attracting people, then it gets very hard to find competent resources to do the job.

5. Discussion

In this chapter we go back to the literature and make a comparison between what we found about megaprojects and what the literature says about it, to see if there is any discrepancy in between. We start with presenting a summary of the findings, elaborating additional features of megaprojects that were not fully elaborated in the extant literature, and move to our discussion on the challenges in managing megaprojects.

5.1. A Summary of the findings

Megaprojects are large-scale complex projects that involve multiple stakeholders. These stakeholders can come from different sectors (both public and private) and multiple countries. In the case studies, the stakeholders came from different countries which present an inter-relationship management challenge for the managers namely: communication structure, cross-cultural communication, coordination, and collaborative work.

Uncertainty is one of the critical characteristics of a megaproject that poses challenges to managers. This uncertainty was found to come from three different areas namely: first is changes that normally come from assumptions that are taken during the conceptual stage. The difficulty is because of the complex interfaces involve with megaprojects, the extend of these changes is difficult to predict. The second is fast-tracking which is intended to expedite activities in the project. Tracking is a two-edge sword which when not properly implemented, will cause delay, and exponentially increases in cost. The third is ambiguity resulting from improper scope definition. This normally leads to unclear requirements and many contractual challenges for the managers.

Managing complex interfaces by only one organization (the employer) is a cumbersome task. That is why the setting of milestones among the parties in the interface with an oversight office like PMO will help mitigate some of these challenges. Also getting the interest of contractors involves in these interfaces to be aligned with the objectives of the overall project is paramount to the success of the project. Other managers recommend designing the interface to be as simple as possible so that information will flow faster.

There is no project with unlimited resources. Managers always face resource limitations and proper allocation of these limited resources is key to performance. Most managers recommend using more resources on the initial stage, for instance during the front-end loading to mitigate some of the challenges experienced in the later stage of the project.

The semi-structured interview also lead to the extension of our research framework with the inclusion of new megaproject characteristics as shown below (Table 7).

Table 7: Revised Research Framework

KEY CHALLENGES ASSOCIATED WITH THE PLANNING OF MEAGA PROJECTS	MAJOR MECHANISMS/ASPECTS
TASK COMPLEXITY	Organizational planning, design planning, work preparation, site installation, construction management (Brockman & Girmscheid, 2007)
TASK UNCERTAINTY	Technological novelty, flexibility, system complexity (Denicol, et al., 2020; Pedwell, et al., 1998)
INCENTIVE	Technological, Political, Economic, and Aesthetic drivers (Flyvbjerg, 2014; World Bank, 2011)
MANAGERIAL FACTOR	Decision making, leadership (Denicol, et al., 2020; Flyvbjerg, 2014)
WHETHER RIGHT METHODS ARE IN PLACE	Fast tracking, program management, PMO (Alcabes, 1973; Ibbs, et al., 1998; Project Management Institute, 2017)
AGGREGATE FINDINGS	Multi-faceted challenges, Intermediate Milestone

5.2. Beyond the Listed Characteristics: emerging new features

Based on the case study, we have found some interesting aspects that could be added to the list of characteristics previously presented in Table 1. These features are schedule procrastination and megaproject duration, mixing up product development life cycle with project development life cycle, mega cross-cultural effect, and the correct mapping of information flow.

5.2.1. Schedule Procrastination and Megaproject Duration

Megaprojects are large-scale projects that normally take extensive time to plan and execute. The theoretical framework noted that among other different characteristics that megaprojects do take a decade or more to plan, design, finance, and build (Skyes, 1998; Flyvbjerg, 2014). This duration is mostly perceived by the stakeholders to be more than the necessary time needed to execute the project. Interview 1 noted that in large-scale projects that take more than a decade to complete, it is difficult to get the stakeholders to focus without losing the sense of urgency.

Interviewee 1 quote: *An overlooked point that causes megaproject delays is procrastination. Most megaproject duration can take up to 10 years and people do lose a sense of urgency at the earlier stage, believing they have much time.*

Project scope and duration are normally planned during the earlier phase of the megaproject and some activities have adequate time for completion. It is normal not to prioritize these activities that have more time to execute but that brings lots the possibility that these activities could be ignored until when it becomes necessary.

This view of schedule procrastination in megaproject by Interviewee 1 is a factor that is not mentioned in literature and has the potential to cause more delays in the execution of the project. Interviewee 1 suggested that stakeholders can mitigate these problems by setting intermediate goals or milestones that must be completed. These intermediate milestones will not only solution for the short-term target but also help to keep the long-term target in focus. These intermediate goals must be agreed upon and implemented in the overall schedule of the project.

5.2.2. Confusing Product Development Life Cycle with the Project Development Life Cycle

In some megaproject cases, especially when the product is still evolving and the project final deliverable is not still clear, confusion between product development life cycle and project development life cycles is inevitable. According to Interviewee 4, this is even difficult for a greenfield project (large-scale EV battery startup) where the project is defined without knowing what the final product will be. In these cases, it is difficult to distinguish two budgets and maintain the costs for each life cycle. This is a program management issue.

In this sense, a PMO is a key to managing such kind of megaproject which involves both product development and project development. It will help with uncertainty and the complex interface associated with a start-up megaproject. This PMO should be a directing one that has the right to make decisions that are relevant to the product development and project execution. They can be structured in such a way that the PMO is separate for the product development and the project development and then integrated at the upper management section, added Interviewee 4.

5.2.3. Mega Cross-Cultural Effect

As noted in the theoretical framework, megaprojects are vast, complex ventures that may potentially involve stakeholders from public and private sectors (Flyvbjerg, 2014) which can also come from foreign investment. For instance, one of the major investors on the lithium-ion battery megaproject located in Scandinavia is from Germany. Interviewee 5 also talked about the challenge managers faced working in an environment with multiple peoples or organizations and the difficulty to motivate people from Eastern Europe to provide better performance.

Interview 5 quotes. *We are working with many people from different countries. It is a lot of cultures and one needs to adapt to these people so that you can get the best performance.*

Each organization does have its unique cultures that might be different from other organization's cultures and working together may be difficult. This also can be said of people who comes from different areas or nationality that have different cultures. The managers should be well informed and if possible, should seek additional courses that improve their knowledge on how to manage these types of environments.

5.2.4. Incorrect Mapping of Information Flow

In megaprojects, it is crucial to develop and map the right flow information process throughout the project life cycle from the design phase to the construction phase. There should be known who is driving the whole construction work. Is it the civil constructor who should determine how the layout of the building should be? Or is it the mechanical design team that can determine what kind of utilities must be deployed?

For example, Interviewee 3 mentioned that the company is ordering a lot of steel earlier in the project since the contractor has demanded so much. Since there is always an inventory problem at the site in large-size projects, inventorying a huge amount of steel will add more problems to the existing ones. In the main case study project, which is a process-oriented project, the design process contractor must feed other contractors (with inputs from process design) such as civil, structural, architectural, mechanical, electrical, and piping contractor and mandate important details like the layout of the utilities, design of transformers, power of compressors, the thickness of walls, etc.

Table 8 provides a summary of these newly identified challenges described above.

Table 8: New Features in Megaproject Management

New features in megaproject management	Proposed solution
Schedule procrastination and megaproject duration	Defining and setting intermediate milestones
Mixing up two distinguished concepts of project development life cycle and product development life cycle	Distinguishing between two different concepts by setting an individual budget on each concept and maintaining the costs
Mega cross-cultural effect	Training people especially managers to be aware of cross-cultural differences and improving their cross-cultural management skills
Incorrect mapping of information flow	Investigating and developing the correct information flow through process mapping analysis

5.3. Managerial Challenges

We have identified three key managerial challenges based on our findings; inappropriate front-end stage, inadequate PMO implementation to manage complexity and uncertainty in the megaproject, and lack of synergy with partners involved in the megaproject. Accordingly, we also develop three propositions in these managerial challenges. Propositions is another way of contributing to a theoretical concept (Cornelissan, 2017) and our own case provides better understanding of megaprojects. We suggest further studies shall be carried on testing these propositions.

5.3.1. Inappropriate Front-end Stage

Interviewee 4 quote: *Adding more experienced resources during front-end loading will mitigate some risk but this depends on the maturity of the project. On a start-up (which involves both product and project development) where products are changing, this will be difficult.*

The front-end stage comprises the initiation and planning phase of the megaproject. The decision taken at this stage will determine the scope of the megaproject, the governance, the procurement, and the project delivery strategies. The contribution of our theoretical framework identifies these decisions as the main cause of megaproject failures (Merrow, 2011; Denicol, et al., 2020). This view was corroborated in our main case study findings by Interviewee 4 when he declared that the megaproject was not adequately scoped leading to wrong contracting and manpower strategy which then influences subsequent stages in the megaproject. Interviewees 1 recommend using more resources in the initial stage to help eliminate some challenges face in the subsequent stage:

Interviewee 1 quote: *The more money and time you spend on the pre-work, the easier the project becomes. My point is that things are not done properly on the pre-work stage and we end up doing most of the redesigning during the execution stage.*

Interviewees 3, 5 & 8 also corroborated this view saying that some of the challenges they faced in the execution and construction stage of the megaprojects came from either limited resources or inexperienced resources used during the initial stage of the megaproject. This discussion brings us to an adage which says “a work well begun is half done” which then leads us to the proposition:

Proposition 1: If more time and competent managers are used during the front-end stage in the megaproject, there will be a higher chance of success in the megaproject.

5.3.2. Managing Complexity and Uncertainty in Megaprojects through the Implementation of PMO

A PMO is usually staffed with professional expertise, highly trained, senior project managers to assure the program governance practices (Project Management Institute, 2017). It is an office that provides guidelines on how to deal with issues related to uncertainty and how complex interfaces are to be managed. In one of our findings (from Interviewee 7), the PMO in that case study was staffed with less competent members leading to difficulties in its implementation. In his view, the PMO was just a reporting office where you provide the status of your work. They do not provide any direction, guidance, or support which then echoed the findings of Aubry et al (2010) and Andersen et al (2007) that many companies are being encouraged to implement PMO without a clear definition of what this entails and without clear objectives for implementations, functions, and responsibilities within the organization.

Interview 7 quotes: *The PMO I have experience in a project is just the reporting office that takes information to the steering committee. It was difficult to work with them because they were not technically inclined. They take no decision and provide no support. They just ask you to provide your status in Primavera⁴ so that it can be submitted to the steering committee.*

According to PMI, PMO acts as a management structure that standardizes the program-related governance processes and facilitates the sharing of resources, methodologies, tools, and techniques (Project Management Institute, 2017). This management structure was lacking in our case study by Interviewee 2 where he described that the PMI in his organization is a “one-man” where he provides all the supporting functions due to his vast experience in managing projects.

Interviewee 2 quote: *In my previous experience, PMO did not exist. So, I was acting like the one-man PMO since everyone comes to me for support due to my experience.*

This one-man PMO will not provide the performance level required in our main megaproject case study of the construction of an EV battery manufacturing plant where there is a presence of multidisciplinary environment and a unique technology is employed. The unique technology brings additional uncertainty to the project and having a group of professional expertise, highly trained, senior project managers working as an oversight office in the governance of the megaproject will provide better performance.

⁴ A project planning tool that is widely used by project planner, project managers, and project resource managers in project organizations to manage time, cost, and resources.

This will agree with what Interviewees 1 and 4 proposed to have an oversight office to manage the complex interfaces.

A PMO when properly implemented will be a resource to managing the complex interfaces associated with megaproject by collecting information from the multiple stakeholders, analyzing this information as a unit, and project-related support which will be in alignment with the overall strategic objectives or interest of the owners. This agrees with what Interviewees 1 and 4 proposed to have an oversight office to manage the complex interfaces. Their expertise in executing different projects will help manage the risk and uncertainty that are associated with megaprojects.

Some of the interviewees have highlighted the importance of coordination, collaboration, and communication in a megaproject. Interviewee 8 quoted that building a common language that helps everyone understand, share information, and integrates different components and is crucial to the success of a megaproject. Also, Interviewee 5 highlighted the important role of coordination and collaboration between different disciplines/contractors who shared some interfaces to yield a high pace of the construction works in the case study project. Moreover, in the literature review, one of the most important functions of a PMO is to ensure a proper project communication plan is developed, documented, and updated accordingly and finally shared with all within the project organization (Project Management Institute, 2013). This brings us to our second proposition that;

Proposition 2: A PMO when properly implemented with competent professionals will provide better performance to managing the uncertainty and complex interfaces associated with megaprojects.

5.3.3. Routinized Meetings Help Create a Synergy of Different Partners in Megaprojects.

Managers are faced with the daunting challenge of managing megaproject complexity, especially across multiple interfaces. These interfaces can be in the form of different stakeholders and contractors having to work in the same location and at the same time. Interviewee 7 in his solution to managing these interfaces elaborated the importance of having a routine meeting among all the stakeholders that are involved in that interface. In the case study, there were daily meetings among the field technicians of the different contractors in the morning whereas the managers meet every Monday morning. During these meetings, schedules are discussed, queries are presented and discussed, and most importantly an alignment of the project objectives. Interviewee 7 strongly believes that these routine meetings mitigated most of the risk and improved collaboration between the contractors involved in the interfaces.

Interviewee 7 quoted: *We do have a meeting once a week for all contractors involves in the building to discussed changes and collaboration. This building site is split into 4 areas. Each area does have a meeting every more before they start working and are represented by the head of the contractors.*

This view corroborates the finding of Bygballe and Sward (2019) that collaborative project delivery models such as institutionalized partnering through the establishment of routines represent a key means of improving large construction project performance. Jergeas & Lynch (2014) also echoed the findings in the case study that alliancing between stakeholders involves in the interfaces does minimize risk and creates an environment where trust, teamwork, and innovation will excel.

Proposition 3: The routinized meetings between stakeholders will mitigate some risk associated with complex interfaces and improves the coordination of changes.

6. Conclusions

This thesis aimed to explore some of the unique characteristics of megaprojects that create uncertainty and failures and to find possible solutions that mitigate these challenges. This was investigated by building a theoretical framework from previous research and then using a case study to compare these theories with the current practice.

In our case study, we conducted a qualitative case study within a megaproject. We found factors like change, fast-tracking, and ambiguity to be the main sources of uncertainty in megaprojects and unique challenges from schedule procrastination with respect to megaprojects duration, confusion between product and project development, resource availability, and lack of proper flow of information. Our literature review of some main causes of megaproject failures corroborated some findings in our cases study, for instance; inexperienced/limited resource in the initial stage or inappropriate front-end stage being a source of failure for subsequent stages in megaproject (Morrow, 2011; Denicol, et al., 2020), inadequate implementation of PMO leading to poor performances (Aubry, et al., 2010; Andersen, et al., 2007) and using the routinized meeting to create synergy between the partners involved in megaproject delivery.

6.1. Answer to the research question “How to cope with uncertainty and complex interfaces in a megaproject?”

Uncertainty and complex interface are key phenomena that are known to affect the performance of megaprojects. They create considerable challenges for managers in the execution of megaprojects and require a great deal of experience in managing their risk. Some of the causes of these uncertainty and complex interfaces can be traced to early decisions that were taken in the initial phase of the projects. To answer the research question clearly, we are stating that a structured PMO (made from multidisciplinary professional experts) with standardized program-related functions and responsibilities like governance process, resource allocation, oversight, communication, coordination, and collaboration will help the program management team mitigate uncertainty and complexity associated megaprojects. To further support our answers, we found out from our research that if competent resources and time are used during the front-end loading in megaprojects, risk, and uncertainty associated with the megaproject will be better managed.

6.2. Thesis Contribution

This thesis contributes to the literature of project management especially in relation to megaprojects in the following ways:

- a) It sheds light on the importance of inter-relation management in a megaproject. Arguably, inter-relation management is important for any project, yet our research suggests that inter-relation management can be a crucial factor determining the success of a megaproject. This is because megaproject does not only mean size but factors such as cross-cultural relationships, communication are now also having a mega effect.
- b) We add to the literature by expanding the list of megaproject characteristics such as schedule procrastination, mega cross-cultural effect, correct mapping of information flow processes, and mistaken product development cycle with the project development cycle.
- c) It also contributes to the literature on the concept of using an intermediate milestone strategy in mitigating challenges from complex interfaces and schedule procrastination.

6.3. Recommendations for further research directions

This research work was faced with a time constraint that has limited the use of efficient methods of investigations, limited sample size, and lack of site visitation. We nevertheless came to three key conclusions which have been developed into propositions are based on our study to advancing our understanding of managerial challenges. These propositions are vital element which can be used to create constructs in further studies (Cornelissan, 2017). They are:

Proposition 1

If more time and competent managers are used during the front-end stage in the megaproject, there will be a higher chance of success in the megaproject.

Proposition 2

A PMO when properly implemented with competent professionals will provide better performance to managing the uncertainty and complex interfaces associated with megaprojects.

Proposition 3

The routinized meetings between stakeholders will mitigate some risks associated with complex interfaces and improves the coordination of changes.

6.4. Ethical and Societal Implications

In a project management environment, compromising ethical lines to bring the project on track is perpetual. The bigger the megaproject, the more opportunities pass up for people or organizations to compromise. Even though PMI has provided Code of Ethics to guide project managers to ethical project management and decision making, there is still a high possibility to face difficult ethical decisions from time to time (Project Management Institute, 2004). Some of the ethical lines that are addressed in this research are but are not limited to responsibility and conflict of interests. These ethical lines can be crossed by the project manager or any project team member to compromise in an effort to bring the project in on time and on budget.

A project's success or failure is ethically one of the main responsibilities of a program manager. However, it does not mean that she or he "alone" is deemed to take the whole responsibility. It is the project organization's job to assign responsibility where necessary to be able to hold others accountable from point of view of a very important aspect of influencing project outcomes and learning from them.

In a complex megaproject with numerous interfaces and involved large numbers of outside contractors and subcontractors, there is a great tendency to flinch from responsibility if the interface qualities fail to pass. Or as mentioned earlier, for cases where cost is involved, people always look to the company's interest first.

According to Arman Köklü, project director, GE Power, Zürich, Switzerland, *"there is a project anywhere in the world that doesn't have a social impact"* (Pulse of the Profession, 2020). This is even more tangible in megaprojects where their objectives are providing essential infrastructure, improving public health and safety, and creating massive new jobs. This echoes by the PMI Future 50 leader saying that *"All projects have an impact on the world—that's one of the main reasons why we execute them."* (Pulse of the Profession, 2020). On the other hand, there is a common belief among project promoters, their planners, and managers that society benefits from megaprojects which might lead to justification in "cooking" costs and benefits to help projects initiated (Flyvbjerg, 2014).

6.5. Managerial Implications

- a) The need to improve their cross-cultural management skills, especially for field engineering managers that will be faced with the day-to-day managing of field technicians from different organizations or countries.
- b) The need for stakeholders to make a standardized PMO a must in megaproject management as this will be effective in managing the complex interface and multidisciplinary environments.

- c) Managers should consider investing in competent and skilled employees especially during the conceptual and initial stage in megaproject as this will help with mitigating problems seen in subsequent stages.
- d) Managers should allocate more resources in the initial stage of a megaproject so that risk associated with assumptions could be mitigated.

7. Bibliography

- Alcabes, J., 1973. Fast-track scheduling. *Project Management Quarterly*, 4(3), p. 15.
- Alhomadi, A., Dehghan, R. & Ruwanpura, J. Y., 2011. The Predictability of Fast-Track Projects. *Procedia Engineering*, Volume 14, pp. 1966-1972.
- American Psychological Association, 2010. *Publication Manual of the American Psychological Association*. 6th ed. ed. Washington, D.C.: American Psychological Association.
- Andersen, B., Henriksen, B. & Aarseth, W., 2007. Benchmarking of Project Management Office Establishment: Extracting Best Practices. *Journal of Management in Engineering*, Volume 23, pp. 97-104.
- Anon., 2008. Best project management and systems engineering practices in pre-acquisition practices in the federal intelligence and defense agencies.. *Project Management Journal*, 39(1), pp. 59-71.
- Anton, B. & Sjöberg, V., 2016. *Managing a megaproject as a program: A case study from an internal communication perspective*, s.l.: Chalmers University of Technology.
- Aubry, M., Hobbs, B., Muller, R. & Blomquist, T., 2010. Identifying Forces Driving PMO. *Project Management Journal*, 41(4), pp. 30-45.
- Aziz, L., 2009. *Building a cathedral: project architecture and the PMO*. North America, Orlando, FL. Newtown Square, PA, Paper presented at PMI® Global Congress 2009: Project Management Institute..
- Barret, M., Choi, T. Y. & Li, M., 2011. Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations Management*, 29(4), pp. 329-342.
- Barshop, P., 2003. *Best practice pays off*, s.l.: European Chemical News.
- Bosch-Rekveltdt, M. et al., 2011. Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework. *International Journal of Management Reviews*, 29(6), pp. 728-739.
- Brockman, C. & Girmscheid, G., 2007. *Complexity of Megaprojects*, s.l.: CIB World Building Congress.

- Bryman, A. & Bell, E., 2011. *Ethics in business research*. 3rd ed. Oxford: Oxford University Press.
- Bygballe, L. & Sward, A., 2019. Collaborative Project Delivery Models and the Role of Routines in Institutionalizing Partnering. *Project Management Journal*, 50(2), pp. 161-176.
- Cantarelli, C. C., Flyvbjerg, B. & Buhl, S. L., 2012. Geographical variation in project cost performance: the Netherlands versus worldwide. *Journal of Transport Geography*, Volume 24, pp. 324-331.
- Carlsen, B. & Glenton, C., 2011. What about N? A methodological study of sample-size reporting in focus group studies. *BMC Medical Research Methodology*, 11(26).
- Chapman, R. J., 2016. A framework for examining the dimensions and characteristics of complexity inherent within rail megaprojects. *International Journal of Project Management*, 34(6), pp. 937-956.
- CII, 1999. Project Delivery System Selection Workbook. In: Second, ed. *Construction Industry Institute*. Austin: Construction Industry Institute, pp. IR133-2.
- CII, 2003. Owner's Tool for Project Delivery and Contract Strategy Selection. In: S. Edition, ed. *Construction Industry Institute*. Austin: Construction Industry Institute, pp. RS 165-2.
- Cornelissan, J., 2017. Editor's comments: developing propositions, a process model, or a typology? addressing the challenges of writing theory without a boilerplate. *Academy of Management Review*, 42(1), pp. 1-9.
- D. Baccarini, 1996. The concept of project complexity—a review. *International Journal of Project Management*, 14(4), pp. 201-204.
- Daniels, C., Farnsworth, C. B. & Weidman, J., 2014. *Interface Management on Megaprojects: A Case Study*. Provo, Uta, Brigham Young University.
- Denicol, J., Davies, A. & Krystallis, I., 2020. What Are the Causes and Cures of Poor Megaproject Performance?: A Systematic Literature Review and Research Agenda.. *Project Management Journal*, Volume 51, pp. 328-345.
- Denscombe, M., 2010. *The Good Research Guide for small-scale social research projects*. 4th ed. New York: Mc Graw Hill Open University Press.
- Engwall, M., 2002. The Futile Dream of the Perfect Goal. *Beyond Project Management: New Perspectives on the Temporary Permanent Dilemma*, pp. 261-277.

- Eriksson, T. A. S., 2016. Design Organisation - Client-Consultant Coordination in a Large Infrastructure Project. *Chalmers University of Technology*.
- Fazio, P., Moselhi, O., Thberge, S. & Revay, S., 1988. Design impact of construction fast-track. *Journal of Construction Management and Economics*, 6(3), pp. 195-208.
- Fernandes, G., Ward, S. & Araujo, M., 2014. Developing a Framework for Embedding Useful Project Management Improvement Initiatives in Organizations. *Project Management Journal*, 45(4), pp. 81-108.
- Flyvbjerg, B., 2007. Policy and Planning for Large-Infrastructure Projects: Problems, Causes, Cures. *Environment and Planning B Planning and Design*, 34(4), pp. 578-597.
- Flyvbjerg, B., 2014. What You Should Know About Megaprojects and Why: An Overview. *Project Management Journal*, 45(2), pp. 6-19.
- Flyvbjerg, B., Bruzelius, N. & Rothengatter, W., 2003. *Megaprojects and Risks: An Anatomy of Ambition*. Cambridge: Cambridge University Press.
- Flyvbjerg, B., Skamris, M., Holm & Buhl, S., 2002. Underestimating Costs in Public Works Projects: Error or Lie?. *Journal of the American Planning Association*, 68(3), pp. 279-295.
- Froud, J., 2003. The Private Finance Initiative: risk, uncertainty and the state. *Accounting, Organizations and Society*, Volume 28, pp. 567-589.
- G.Locatelli, P.Littau, N.J.Brookes & M.Mancinid, 2014. Project characteristics enabling the success of megaprojects: an empirical investigation in the energy sector. *Procedia - Social and Behavioral Sciences*, Volume 119, pp. 625-634.
- Galletta, A. & Cross, W. E., 2013. *Mastering the Semi-Structured Interview and Beyond : From Research Design to Analysis and Publication*. New York: New York University Press.
- Ghauri, P. & Gronhaug, K., 2010. *Research Method in Business Studies*. 4th ed. London: Pearson.
- Ghauri, P., Grønhaug, K. & Strange, R., 2020. *Research Methods in Business Studies*. 5th ed. Cambridge: Cambridge University Press.
- Goffin, K., Åhlström, P., Bianchi, M. & Richtnér, A., 2019. Perspective: State-of-the-Art: The Quality of Case Study Research in Innovation Management. *Journal of Product Innovation Management*, 36(5).

Greiman, V. A., 2013. *Megaproject Management: Lessons on Risk and Project Management from the Big Dig*. New Jersey: John Wiley & Sons.

Grun, O., 2004. *Taming giant projects: Management of multi-organization enterprises*. Berlin: Springer.

Ibbs, C. W., Lee, S. A. & Li, M. I., 1998. Fast-tracking's impact on project change. *Project Management Journal*, 29(4), pp. 35-41.

IBM Global Business Services, 2021. *Capitalizing on Complexity: Insights from the Global Chief Executive Officer Study*. [Online]
Available at: http://www-304.ibm.com/businesscenter/cpe/download0/200422/ceostudy_2010.pdf
[Accessed 22 April 2021].

Invernizzi, D. C., Locatelli, G. & Brookes, N., 2018. A methodology based on benchmarking to learn across megaprojects: The case of nuclear decommissioning. *International Journal of Managing Projects in Business*, 11(1), p. 18.

J. Brookes, N. & Locatelli, G., 2015. Power plants as megaprojects: Using empirics to shape policy, planning, and construction management. *Utilities Policy*, Volume 36, pp. 57-66.

Jergeas, G. & Lynch, R. P., 2015. *Future Pathway for Industrial Mega-Project Delivery*, Alberta: GO Productivity.

Johansen, A., Zidane, Y. J.-T. & Ekambaram, A., 2013. Megaprojects-Challenges and Lessons Learned. *Social and Behavioral Sciences*, Volume 74, pp. 349-357.

Keller, S. & Conradin, K., 2020. *Semi-Structured Interviews*. [Online]
Available at: <https://sswm.info/planning-and-programming/decision-making/gathering-ideas/semi-structured-interviews>
[Accessed 09 07 2021].

Klakegg, O. J., 2017. Project delivery models — situational or fixed design?. *2017 12th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT)*, pp. 202-206.

Klein, G. & Aubry, M., 2017. From the Editors: Introducing the Special Issue on Megaprojects—“Symbolic and Sublime”. *Project Management Journal*, 48(6), pp. 3-4.

- Kumaraswamy, M., Wong, K. W. K. & Chung, J., 2017. Focusing megaproject strategies on sustainable best value of stakeholders. *Built Environment Project and Asset Management; Bingley*, 7(4), pp. 441-455.
- Lahdenperä, P., 2012. Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery. *Construction Management and Economics*, 30(1), p. 579.
- Linehan, C. & Kavanagh, D., 2004. *From project ontologies to communities of virtue*. Bristol, University of Western England.
- Little, R. G., 2011. The Emerging Role of Public-Private Partnerships in Megaproject Delivery. *Public Works Management & Policy*, 16(3), pp. 240-249.
- Loch, C. & Terweisch, C., 1998. Communication and uncertainty in concurrent engineering.. *Journal of Management Science*, 44(8), p. 1032.
- Mann, A. & Banerjee, T., 2011. Institutions and Megaprojects: The Case of Delhi Metro Rail. *Environment and Urbanization ASIA*, 2(1).
- Marrewijk, A. V., 2007. Managing project culture: The case of Environ Megaproject. *International Journal of project management*, 25(3), pp. 290-299.
- McLeod, S. A., 2019. *Case study method*. [Online]
Available at: <https://www.simplypsychology.org/case-study.html>
[Accessed 04 07 2021].
- Mendel, G., 2012. Keep in simple? A case study into the advantages and disadvantages of reducing complexity in mega project planning. *International Journal of project management*, 30(7), pp. 781-790.
- Morrow, E. W., 2011. *Industrial Megaprojects—Concepts, Strategies and Practices for Success*. Hoboken: John Wiley & Sons.
- Miller, J. B., Garvin, M. J., Ibbs, C. W. & Mahoney, S. E., 2002. Toward a New Paradigm: Simultaneous Use of Multiple Project Delivery Methods. *Journal of Management in Engineering*, 13(3), pp. 58-67.

- Miller, R. & D. R., L., 2001. *The Strategic Management of Large Engineering Projects: Shaping Institutions, Risks, and Governance*. Cambridge, MA: The MIT Press.
- Miller, R. & Hobbs, B., 2005. Governance regimes for large complex projects. *Project Management Journal*, 36(3), pp. 42-50.
- Mirza, E. & Ehsan, N., 2017. Quantification of project execution complexity and its effect on performance of infrastructure development projects. *Engineering Management Journal*, 29(2), pp. 108-123.
- Morris, P. & G. H., H., 1987. *The anatomy of major projects*. Chichester: John Wiley and Sons.
- Mysore, K., Kirytopoulos, K., Ahn, S. & Ma, T., 2020. Adversarial factors in multi-stakeholders' engagement of global-IT projects. *International Journal of Managing Projects in Business*, 14(2), pp. 445-471.
- Nag, R. & Gioia, D., 2012. From common to uncommon knowledge: Foundation of firm-specific use of knowledge as a resource. *The Academy of Management Journal*, 55(2), pp. 421-457.
- Naomi, B. & Locatelli, G., 2015. Power plants as megaprojects: Using empirics to shape policy, planning, and construction management. *Utilities Policy*, Volume 36, pp. 57-66.
- Olaniran, J., Olatunji, O. A. & Edwards, D. J., 2015. Cost overruns in hydrocarbon megaprojects: a critical review and implications for research. *Project Management Journal*, 46(6), pp. 126-138.
- Park, M., 1999. *Robust control of cost impact on fast-tracking building construction projects.*, s.l.: Department of Civil and Environmental Engineering, Massachusetts Institute of Technology.
- Pavitt, T. & Gibb, A., 2003. Interface Management within Construction: In Particular, Building Facade. *Journal of Construction Engineering and Management*, 129(1), pp. 8-15.
- Pedwell, K., T Hartman, F. & Jergeas, G., 1998. Project capital cost risks and contracting strategies.. *Journal of Cost Engineering*, Volume 1, p. 37.
- Perminova, O., Gustafsson, M. & Wikström, K., 2008. Defining uncertainty in projects: a new perspective. *International Journal of Project Management*, 28(1), pp. 73-79.
- PM Solutions, 2014. *The State of the Project Management Office (PMO)*, s.l.: pmsolutions research.

Priemus, H., Bosch-Rekveltdt, M. & Giezen, M., 2013. *Dealing with the complexity, uncertainties and risk of megaprojects: redundancy, resilience and adaptivity*. UK, Edward Elgar Publishing.

Project Management Institute, 2004. *A guide to the project management body of knowledge: PMBOK guide*. Third ed. s.l.:Project Management Institute Inc..

Project Management Institute, 2013. *Organizational Project Management Maturity Model (OMP3)*. 3rd ed. s.l.:Knowledge Foundation.

Project Management Institute, 2013. *PMO Frameworks*. s.l.:Project Management Institute.

Project Management Institute, 2017. *The Standard for Program Management*. 4th ed. s.l.:Project Management Institute.

Pulse of the Profession, 2020. *Why Social Impact Matters: Delivering Meaningful Change Through Projects*, s.l.: Project Management Institute.

Qazi, A., Quigley, J., Dickson, A. & Kirytopoulos, K., 2016. Project complexity and risk management (ProCRiM): Towards modelling project complexity driven risk paths in construction projects. *International Journal of Project Management*, 34(7), pp. 1183-1193.

Quinn, N., 2005. *Finding Culture in Talk: A Collection of Methods*. 1 ed. New York: Palgrave Macmillan US.

Saunders, M., Lewis, P. & Thornhill, A., 2009. *Research Methods for Business Students*. New York: Pearson.

Senescu, R., Aranda-Mena, G. & Haymaker, J., 2012. Relationships between project complexity and communication. *Journal of Management in Engineering*, 29(2), pp. 183-197.

Spalek, S., 2014. *Success factors in project management. Literature review*. Valencia, Paper presented at the 8th International Technology, Education and Development Conference INTED2014.

Sun, J. & Zhang, P., 2011. Owner organization design for mega industrial construction projects. *International Journal of project management*, Volume 29, pp. 828-833.

Sykes, A., 1998. Megaprojects: Grand Schemes Needs Oversight, Ample Funding. *Forum for Applied Research and Public Policy*, 13(1), pp. 61-75.

- Thamhain, H. J., 2005. *management of technology- managing effectively in technology-intensive organizations*. 2nd ed. New Jersey: John Wiley & Sons.
- Vidal, L. A. & Marle, F., 2008. Understanding project complexity: Implications on project management. *Kybernetes Emerald Insight*, 37(8), pp. 1094-1110.
- Vidal, L.-A., Marle, F. & Jean-ClaudeBocquet, 2011. Measuring project complexity using the Analytic Hierarchy Process. *International Journal of Project Management*, 29(6), pp. 718-727.
- Vukomanović, M. et al., 2021. Trust and Governance in Megaprojects. *International Journal of Project Management* , 39(4), pp. 321-416.
- Welch, C., Plakoyiannaki, E., Piehhari, R. & Paavilainen-Mäntymäki, E., 2012. Legitimizing diverse uses for qualitative research: a rhetorical analysis of two management journals. *International Journal of Management Reviews*, 15(2), pp. 245-264.
- Whyte, J., 2019. How Digital Information Transforms Project Delivery Models. *Project Management Journal*, 50(2), pp. 177-194.
- Williams, T. et al., 2010. *Early warning signs in complex projects*, Washington DC.: Project Management Institute.
- Williams, T. M., 1999. The need for new paradigms of complex projects. *International Journal of Project Management*, 17(5), pp. 269-273.
- Williams, T. M., 2005. Assessing andmoving on from the dominant project management discourse in the light of project overruns. *IEEE Transactions on Engineering Management*, 52(4), pp. 497-508.
- Williams, T., Vo, H., Edkins, A. & Samset, K., 2019. *A Systematic Literature Review: The Front End of Projects*, s.l.: Project Management Institute.
- World Bank, 2011. *World Bank Annual Report 2011*, Washington DC: World Bank.
- Yin, R., 2009. *Case study research, design and methods*. 5th ed. London, UK: Sage Publications.

8. Appendix

8.1. Interview Questions⁵

1. Pick three below characteristics of a megaproject that may cause major delays on the project delivery date!
 - a) Size
 - b) Duration
 - c) Uncertainty
 - d) Ambiguity
 - e) Complex interfaces & integration
 - f) Cross-functional environment
 - g) Multidisciplinary works
 - h) Diversity of product through the project life cycle
 - i) Significant political and external influence
2. What is your opinion regarding the biggest risks that make the project failed which are not listed above? (Free text)
3. Do you have ever experience working within PMO (Project/Program Management Office) framework? Do you have a PMO in your current project?
4. How well the PMO has been established in your organization?
5. How do you think your organization is managing the front-end development approach throughout the project?
6. How do you think your organization is managing a cross-functional environment
7. How do you think your organization is managing complex interfaces & integration
8. How do you think your organization is managing multidisciplinary works
9. How is the maturity of your organization to deal with change and uncertainty?
10. What is your opinion about the proactivity level of the project management team in your project to deal with uncertainty? (Free text)
11. What are the most important elements that are missing in your project to make the project succeed? (Free text, for example, good leadership, well-established instructions, etc.)
12. Have you ever been involved in a megaproject? If yes, please name a few of them.
13. Why would you consider this project a “megaproject”?
14. What is the uniqueness of this megaproject?
15. Were both public and private involved in this project?
16. What were/are your duty/duties in this megaproject?

⁵ There was a great deal of flexibility with the questioning and some interviewees where asked follow-up question based on their response.

17. In your view, will you consider this megaproject complex?
18. What special characteristic made you consider this complex?
19. In your opinion, what is the best way to approach megaproject complexity?
20. Was there a standardized project delivery model used in this project or was this model specific to the project?
21. How will you describe the relationship between the different parties in the PDM? Adversarial, transactional, or collaborative?
22. Would you agree that the complexity in the project makes these relationships more challenging?
23. How were risks managed by this project delivery model?
24. Was any form of fast-tracking of some activities or the construction carried out in a complete sequential manner?
25. Fast-tracking is generally assumed to be beneficial when expediting some activities. Would you agree to this statement?
26. What challenges did you encounter in activities that were fast-tracked?
27. How did these units relate in time of changes caused by problems of fast-tracking?
28. In your own opinion, what best delivery model will bring the best result for this project?

8.2. Summary of interviews

8.2.1. Interview with Interviewee I (Planning Supervisor)

Question 1: Characteristics that are more important in megaproject challenge:

1st Schedule Procrastination with respect to timeframe: An overlooked point that causes megaproject delays is procrastination. Most megaproject duration can take up to 10 years and people do lose a sense of urgency at the earlier stage, believing they have much time. This leads to lots of procrastination of duties and leads to more delay at the end. Using intermediate goals will solve this problem.

2nd No uncertainty works during megaproject planning. In most times when the project scheduling is done at the beginning of the project, there is no uncertainty planning for scheduling and by the time this is realized, it is too late in the project and causes extensive delays.

3rd Improper risk management. Most of the risk management is done in an excel sheet and not properly implemented. People think that just keeping money aside for risk management will solve the problem but, money is not infinite and thus leads to further cost and schedule overruns.

Question 2: Is there a designated Risk manager in the project?

Yes, but these managers are mostly not focusing on the risk that applies with time but just the risk that applies with activities and finance. In the previous project, the risk analysis was done every 6 months and was done both on-time scheduling and on uncertainty using the Monte Carlo method. This makes the project be completed on time.

Question 3: Example of uncertainty:

During the planning of excavation of a tunnel, some assumption was made of the types of soil properties base on the previous data and the estimated excavation time and machine speed are planned. If we find a strong deviation to the soil texture, this will lead to a wrong estimation and there will be considerable changes in the time plan.

Question 4: How do you solve this risk and uncertainty in scheduling?

The use of risk money and contingency planning for uncertainty. But there the challenge we face is that the money is consumed very early in the project. Most of the major project is run by the government and some rules apply that are different from private stakeholders. For instance, the funding is allocated during the tenure of the politician and if there is a new government, funding can be stopped due to different interests. Also, the government's ideology is that you cannot buy the best contractor but rather the one with the best price which makes project delivery difficult. They also use buffers when scheduling and constantly changing the planned date if a new challenge is encountered along the way.

Question 5: Have you experienced PMO in your organization?

No Standardized PMO; There is no standard PMO in the project which was executed but there is a sort of supporting function that is mostly provided by the experienced head of the department. There is no template or structure to this type of supporting function. It's a group of senior employees that work beside the program managers.

Question 6: How is the maturity of this team that provides support to the program managers?

They are the best within the organization as they are made up of the most experienced employees in all disciplines, have been in the business for a long time, and mostly have grey hairs.

Question 7: What type of functions do they have?

They only assist the program managers and do not take any decisions. It is a supportive function, and they only take notes of all the support they provide. The program and project managers do take the decision.

Question 8: How do you manage the interface between the multidisciplinary environments? How does this experienced team support such an interface?

Documented Milestones: The best way to manage complex interfaces is to use a multiple milestones strategy. This involves setting milestones between the parties involved in those interfaces where information or services are to be shared. These milestones should be documented and there must be an oversight from the stakeholders.

Question 9: How do you manage the changes that are related to these interfaces?

Every change is done through a change control board (CCB). It must be identified and documented. The change also must be decided by the management. The CCB is a decision list that will follow all the changes, when it happens, who did the change, and who is responsible for the changes.

Question 10: In your opinion, how best do you think uncertainty can be mitigated or eliminated?

Uncertainty from Complex Technology: Uncertainty from complex technology will be mitigated if more resources are employed during the FEED stage, especially during the pre-work stage.

Question 11: How do you manage fast-tracking and gates overlapped in projects?

Most of the projects I have experienced are not done with fast-tracking and specific gates are delivered before the other gates start. One of the critical challenges we face is that the time between the different gates start-up is too short and we mostly faced material delivery shortfall that leads to much wider delays.

Question 12: How is the relationship between different contractors within project delivery?

Project delivery Model: In Sweden, the government is mostly the measure stakeholders in megaproject and the relationship between the different parties to the project delivery is strongly transactional. This means the cost is very essential and sometimes quality is being sacrificed.

In most cases, the budget is designed on a yearly-basis even though the project is running for multiple years. That makes contractors focus only on short-term planning as they are many uncertainty-related challenges to plan for multiple years not knowing if the budget will come in the future.

8.2.2. Interview with Interviewee 2 (Project Director)

Question 1: Characteristics that are more important in megaproject challenge:

The interviewee has chosen three major characteristics of a megaproject as complex interface and integration, cross-functional environment, and multidisciplinary works. He believes that unclear interfaces will most likely lead to the failure of the project. He thinks that a technical project manager can manage interfaces and coordinate between the employer and contractors. As an example, the interviewee mentioned the coordination between the turbine supplier and the instrument supplier which they were missing coordination. Here a PM steps in by started having regular basis meetings between different parties and defining clearly the requirements between interfaces and make sure these requirements will be fulfilled when an interface has been delivered.

Question 2: Have you experienced PMO in your organization?

Regarding the PMO subject, the interviewee mentioned three different types of PMO including directive, supportive, and controller type from his point of view. However, in his previous projects, a PMO didn't exist and I was acting as the one-man PMO because of my vast experience. The interviewee in his role as project director had the authority to make a decision, but sometimes he was forced to anchor the decision into the steering committee, and then the head of the steering committee as the main sponsor made a decision accordingly. This step must be taken even in the presence of a supportive PMO for example.

According to the interviewee, a PMO can get total authority to manage the project from time-wise, financial-wise, or any other aspect from the sponsor or head of the organization. Therefore, the less authority, the less added value by PMO. The most effective PMO is the one with strong authority where they can make a decision that would be beneficial to the project. Depending on how a PMO organization has been structured, the responsibility of PMO must be adopted. According to the interviewee, a project planner, a cost controller can also be part of a PMO.

As a program manager, first, you should establish a PMO where you can define your immediate resources. A PMO should have a strategic structure that is aligned with the organizational strategy. The major risks in the project are related to the execution stage. According to the interviewee, the majority of over cost is related to the execution phase.

Question 3: How do you manage fast-tracking and gates overlapped in projects?

Regarding the fast-tracking issue, the interview uses the example of a software development project approach that deploys the agile technique to deal with uncertainty caused by the fast-tracking method.

8.2.3. Interview with Interviewee 3 (Electrical Design Manager)

Question 1: Characteristics that are more important in megaproject challenge:

Three major characteristics of a megaproject that could make delays in a megaproject: Uncertainty, complex interfaces and integration, and multidisciplinary works

Question 2: Example of uncertainty:

Examples of uncertainty: if the design input is uncertain when the design is issued, then the design input is changing or the beginning of the design input is not 100% completed.

According to the interviewee, overlapping between different gates also brings uncertainty. For instance, the basic design is not fully completed before moving to the next stage and that meant the design input. Moreover, if there are large changes, for instance, the air compressors become much larger than needed, then they need a bigger building.

Her organization was a start-up company and it is still a very young company when it comes to the process. No one fully understands how the process is working and that is back to the design inputs. They do understand when the design is fully done.

Another issue is related to the flow of information (inputs). In some cases, the company is ordering a lot of steel earlier in the project since the contractor has demanded so much. That is not normally doing in process-oriented projects where the design process and layout should mandate the civil design based on the process utility layout (inputs). When the design process is completed, the allocation of utilities will be known, and based on that, the civil design will be completed.

Question 3: If given the opportunity, what would you have done differently to make the startup project work well?

One of the most important success factors of a megaproject could be related to choosing one good engineering company to do the basic design. By having ideally one company, it would be possible to have one integrated schedule for the whole different disciplines (civil, structural, architectural, mechanical, electrical, and piping). This could make it much easier to do a coordination job between different contractors with multidisciplinary works within the execution of the project. Another advantage of having one company is that the quality of the basic design would be much better and harmonized among different disciplines. That also makes a much stronger start of detail design and a lot of problems related to the integration would have been removed.

In some cases, for example, the civil contractor had completed the detailed design even before MEP (Mechanical, Electrical, and Piping) basic design is completed.

Question 4: How mature is your organization in regards to dealing with change and uncertainty?

One of the ways to deal with uncertainty is to man up the resources with highly experienced people in the early phase of the project to reduce the uncertainty that could appear during the execution of the project and increase the quality of design in the project, but in some cases, it is difficult for the contractor company to scale up the resources to cope with the huge amount of demands from the client.

Question 5: Are they routine coordination between contractors?

Poor design coordination between the contractors could be a real issue if this is not managed in the time schedule and they are not aligned.

8.2.4. Interview with Interviewee 4 (Director of Interface Management and Risk)

Question 1: What are the megaproject challenges that caused the delay?

Ambiguity, Complex Interface & Integration, and Multidisciplinary work.

Ambiguity: Size and duration will not be a huge issue with delivery if the project is adequately scoped and defined. For Ambiguity, if you do not know what to deliver, then it becomes very difficult to deliver the project. Without adequately scoped work, without proper front-end loading, you will not get the proper strategy to deliver the project at the right time and cost. This will negatively affect manpower and delivery strategy.

Complex Interface and Integration go hand with Ambiguity. If the project is not adequately scoped, the contracting strategy which is very influential on the interfaces will be affected and will lead to much wider failure.

All megaproject involves Multidisciplinary work and if this is split according to a different discipline, the interface will be difficult to manage and hence the reason why it is important to design the project to implement Multidisciplinary work.

Question 2: What are the other challenges that are within a startup megaproject?

In a large capital Oil and Gas Project where there is the maturity of the project which will be combined with the cost and risk schedule analysis. The main challenge that causes delays in the startup project like the one I am currently involved in is managing a megaproject like an Agile way. By this is using small incremental changes all the way through the project and by the time you get to the production stage, the cost has run into exponential increments. The recommendation will be to adequately scope the project by completing the basic design where the front-end loading will be fully carried out before the detailed work is started.

Competence of project management team in Sweden.: The competence in the management team and that of the contractors are low sometimes. This is relative to both technical and megaproject management within Sweden. It is more found within the construction sector also. In general, the contracting and consulting structure within Sweden is not so competent to run a megaproject. There is a lack of EPC big enough to carry such megaproject and this poses lots of challenges to the startup megaproject like the EV battery manufacturing plant.

Question 3: What is an example of uncertainty?

Using the oil-well test data done in the feed stage to design a downstream facility can lead to considerable risk if the data is different like the viscosity of the oil-gas interface.

Question 3: Will manning the project with more experience resources in the beginning help mitigate some of the risk associated with the startup project?

It is a tradeoff between time and experience. Putting more time and having more experience manpower resource still need to make sure that the front-end loading is still adequate and that the team (involving the owners) have the right experience. In my opinion, I will go for more skilled resources during the conceptual stage because if this is properly done to fill in most of the design gaps that will be encounter during the subsequent stage of the project, then most of the risk will be mitigated.

Question 4: How should product development and project development be handled within a startup megaproject?

It is a program management issue. This is even difficult for a greenfield project (large-scale EV battery startup) where the project is defined without knowing what the final product will be. There are lots of risks and uncertainty associated with such a project, but such management does have a high-risk appetite than risk-averse. In Oil and Gas megaprojects where there is a huge consequence of change, they rarely used stage-gate overlapped but in a startup company, they do. A PMO is a key to managing such kind of megaproject which involves both product development and project development. It will help with

uncertainty and the complex interface associated with a start-up megaproject. This PMO should be a directing one that has the right to make a decision relevant to the product development and project execution. They can be structured in such a way that the PMO is separate for the product development and the project development and then integrated at the upper management section.

Question 5: Do you think it is essential to implement this PMO at the early stage of the project or during the project execution stage?

The PMO should always be there with the organization from the beginning but this also depends on the maturity of the company and the type of megaproject.

Question 6: How is your experience with PMO in Sweden?

PMO is not quite common but does exist to some extent. There is a company that has a similar idea and create functions that serve similar as a PMO but do lack proper documentation and guideline for implementation. The teams that form the PMO are a smaller subset of the board. It is a flat organization team that can quickly escalate issues to the owners for the decision to be implemented at a faster rate.

Question 7: How are the complex interface and integration being managed in the current startup megaproject you are involved in?

Seen poor implementation. Recommend using experienced resources to manage all interfaces. Using a PMO or better project organization structure.

Question 8: In your opinion, how can we best manage the uncertainty that comes from complex technology like the EV startup?

Adding more experience resources during front-end loading will mitigate some risk but this depends on the maturity of the project. On a start-up company (which involves both product and project development) where products are changing, this will be difficult, and the organization must be prepared to accept some certain level of risk or uncertainty. They should buy in more expertise which will enable them to manage more risk.

Question 9: How is the best way to manage risk associated with a startup company which is working with a unique technology like battery startup?

Using a scale-up approach will be best. This means starting with a small step like prototype testing to reduce the risk of testing at a larger scale. There might be difficulty in scaling it up for a complex startup

megaproject like the EV battery but with a proper PMO to oversee the development, it can be managed effectively.

Question 10: If given the opportunity, what would you have done differently to make the startup project work well?

Adding more time and quality resources, in the beginning, would have solved most of the challenges encountered in the production stage. There must be a proper design model at the beginning to make sure that things are done at the right time, rather than trying to do things all at once.

Question 11: How to manage changes that affect interfaces?

Having an adequate blanket or contracting structure that uses strategy and well-documented guidelines from the project execution plan will be key to manage the interfaces. The organization must plan and implement risk management associated with interface changes.

Question 12: How is Fast-Tracking implemented with your current project?

Has less experience with this but it creates so much risk, uncertainty, and an exponential increase in cost when changes occur in megaprojects

Question 13: How is cost associated with wrong info during fast-tracking activities is managed?

Typical in Sweden, it is more adversarial as the party seems to see this as somebody else problem.

Question 14: Are they routine collaborations between contractors?

In general, there is less collaboration with contractors in Sweden as compared with other countries

8.2.5. Interview with Interviewee 5 (Electrical Project Design Manager)

Question 1: What are the megaproject challenges that caused the delay?

The interviewee has been working as an electrical design manager for the last 10 years. He is currently working as a project management consultant for one of the contractors in the case study project. According to the interviewee, the size of the project, uncertainty, and complex interfaces and integration are the three most factors that could cause delay and overrun budget in the project. Deploying the new technology in this project could also make trouble to manage such a gigantic project.

He also highlighted the important role of coordination and collaboration between design subcontractors and construction contractors which can cause some risks because of the high pace of the project. He believes that in such a big project with high speed between design and construction, communication is very important. On the other hand, many people are preoccupied with many meetings that some of which are designed to communicate information and reduce the project speed from execution. To have communication up and running is very tricky and difficult in similar projects.

Question 2: How mature is your organization in regards to dealing with change and uncertainty?

Regarding change management, the interviewee stated that usually, the design team is working on-site but at the moment due to the Covid-19 issue, they are working from home and it makes it more difficult to manage changes under these circumstances. Meanwhile, the change process has been developed by defining certain steps to follow. He also emphasizes collaboration's importance in this project.

Regarding competent resources, the interviewee thinks that available resources are scarce in the country, and to be able to find the right people, it should have been planned in advance and started in a very early phase of the project.

This project requires a coordination job to manage the on-site interface between different contractors. As the interviewee said since the size of the project and the project's buildings are so big, coordination plays a key role and becomes even more crucial. But currently, coordination is only between two contractors and there is no coordination system in place at a higher level.

Question 3: What are the most important elements that are missing in your project in order to make the project succeed? (Free text, for example, good leadership, well-established instructions, etc.)

The interviewee has pointed out the importance of managing people with different cultural and social backgrounds. In some cases, it might lead to conflict if people management is not properly managed. Resource planning and knowing what people can do for the efficiency of the project is difficult as there are usually a big amount of people working on this kind of project.

8.2.6. Interview with Interviewee 6 (Project Manager)

Question 1: What are the megaproject challenges that caused the delay?

Complex Interface, Significant political & external influence, Competency of Project members, and Lack of well-defined roles and responsibilities of the project organization chart.

Question 2: Give an Example of uncertainty?

We received a megaproject to design a special Aircraft that has never been built before. The requirement from the customer was not clear. There was also a lack of defined roles and responsibilities of the project organization chart which leads to so many interdependencies in the interfaces. For instance, in the basic engineering phase, we end up having more than 5000 interface lines.

Question 3: What is your experience with PMO?

The PMO that I have experience in the project is just the reporting office that takes information to the steering committee. It was difficult to work with them because they were not technically inclined. They take no decision and provide no support. They just ask you to provide your status in Primavera so that it can be submitted to the steering committee.

Question 4: How was the uncertainty that comes from fast-tracking activities managed in the megaproject?

In the megaproject in which I was involved, this was poorly managed. We had 4 phases and the schedule was only done for the 1st phase which involves more than 5000 lines and was to be completed in 3.5 years. After 1.5 years, we then reschedule these activities again because of challenges caused by not having competent managers and too many assumptions made. These challenges resulted in lots of rework.

Question 5: How were changes that affect interfaces managed in this project?

In the beginning, we have faced too many challenges because of the interdependencies that were present in this project. For instance, a change in the dimension of one part of the Aircraft can affect so many other parts and can lead to considerable weight gain. Some of these changes could get detected much late in the stage. We did not have the right knowledge and tools necessary to manage these interface dependencies and this leads to many reworks. We did at a later stage using a tool called PLM (Project Lifecycle Management) which help us identify and optimized these interface dependencies. We then use a similar milestones strategy to manage these interfaces.

Question 6: How can you describe the collaborative efforts of different contractors when it comes to project delivery with complex interfaces?

Less collaborative and difficult relationship. The mentality is that I must protect my own company at all costs. There were so many grey areas from the scope that were not properly defined, and this leads to many different interpretations of the expectation. These grey areas caused a lot of delays.

Question 7: Can you say what you would have done in a different way to make the megaproject successful had you have the authority to make those decisions?

- Make the requirement clear: The customer did not know what they want. So I will make sure the requirement are clear and correctly defined before starting the project. This also includes making the benefit estimation to be clear.
- Employed competent people to manage the project. I mean spend more resources to employed competent people.
- A well-defined role and responsibilities of the Authorities.

8.2.7. Interview with Interviewee 7 (Business Unit Manager)

Question 1: How do you manage a cross-functional interface where you have a high density of working at the same time and the same location?

We do have a meeting once a week for all contractors involves in the building. This building site is split into 4 areas. Each area does have a meeting every more before they start working and are represented by the head of the contractors. That is how we do the coordination. We also face challenges sometimes because there are just too many people in the building all the time.

Question 2: Do you use a special tool (like Primavera) to manage the schedule or coordinate the activities for all these contractors?

We used a Microsoft Excel file to do that. We would like to use Primavera but not all the contractors can use this, and it will be difficult to synchronize the activities of all the contractors.

Question 3: Did you implement fast-tracking of activities?

Yes, we try as much to work with the design people but do not always have the information needed. We make assumptions and sometimes it works but other times it does, and we must do all the work again.

Question 4: How do you manage interfaces that have dependencies?

We have a technical meeting with the other contractors and set milestones like for instance, if 75% of the design work is done, then we proceed with the electrical installation work.

Question 5: How are changes that affect interfaces managed and especially where the cost is involved?

We are very good at the assumptions we do in electrical works. But for cases where cost is involved, sometimes the customer pays and sometimes they decline to pay. We just try to have a dialogue with the customer to resolve the issue. I must always look to my company's interest first in the negotiation is the reality.

8.2.8. Interview with Interviewee 8 (Lead Project Planner)

Question 1: What are the megaproject challenges that caused major delays?

The first one is the complexity. It is essentially due to the fact that those megaprojects are one of their kind and there is no blueprint. So, there is no backup on history on how to build it. You build the walls and you still don't know what the layout inside those walls is. It will cause the majority of delays. There is no way to avoid that.

The second one is the duration. Getting the plan within a short period is not achievable (the planned duration for the case study is about 15 months) even we have the blueprint, especially, when the fast-tracking approach has been chosen to execute the project. Where the major problem comes from in regards to those durations is that commercial is disconnected to the construction, because those people who sign the contract don't know how to build the construction.

The third one is the significant political and external influence if we take the case study example. This will come back to commercial as well. The company does not have money by themselves and they finance the project basically by lending money from sponsors. To get this money and to keep flowing the money into the project, they need to show some progress and achieve some milestones. That is when people start breaking the plan to focus on one area to achieve these milestones and let the money comes in and that is where most of the problems come as well. Then, the time plan becomes obsolete and no one starts to continue to follow it for this reason, because there is a work priority that is coming from the construction.

Question 2: What would you have done differently if you could do that?

I would have tried to incorporate the time plan with PMO. The first problem was that there was no official baseline approved and when there is no baseline if we are on a delay how do we know that? In some instances, delays are not caused by the contractor and then they are asking for mitigation. Mitigation is when the contractor is failed. But when you want to fix a delay that is caused by the employer, it is called acceleration which involves cost.

According to the interviewee, the employer should have started the planning of the execution phase much earlier, maybe during the FEED phase that usually takes around one year to complete for large-scale projects such as the case study project. To avoid significant changes during the construction phase, the client's project-specific requirements should be reflected properly during the FEED phase. However, there is usually close communication between the employer, the design engineering contractor, and the construction contractor to work up the project-specific requirements to compensate for the possible poor quality of the FEED phase.

In case of not using the FEED approach, it would be beneficial to start one year before the construction starting date because of the complexity of the project from an interface and integration point of view. He added that due to the poor project planning experience and knowledge of people who make the decision, some decision-making process speed was unnecessarily slow but avoidable. For instance, the employer was struggling for a long period to choose the right planning application (Primavera) and the reason for that might be related to the fact that they didn't have similar experience and knowledge about the time planning concept or project scheduling application or both.

Question 3, 4: Do you have ever experience working within PMO (Project/Program Management Office) framework? Do you have a PMO in your current project? How well the PMO has been established in your organization?

Yes, I worked on several projects that PMO has been established within the project organization. According to the interviewee, the employer is still missing a PMO in their organization. They misinterpret the PMO concept with the project management director where they call it a single-person PMO.

The employer failed to provide subcontractors with guidelines and instructions in regards to integrate and consolidate all time schedules into a master time schedule with clearly defined interfaces and real data. The failure to develop an integrated time plan with resource loaded could cause major issues in terms of resource conflicts when they are supposed to work in a tiny space at the same time without proper coordination.

Moreover, the workflow or the flow of resources through locations, and the resultant ability to control the hand-over between both locations and crews should be planned carefully in construction operations. For example, there is an additional risk that is related to the hand-over process and any possible delay that will make the successor contractor file a claim against the interface accountable (the employer). This issue is mostly caused by poorly defined interface management both in the time plan and process.

The interviewee thinks that the fast-tracking approach has been used carelessly without considering the associated risks and even sometimes jeopardizes the deliverables deadlines, mainly by making mistakes and then fixing it and consequently missing the target dates. In terms of having enough resources to manage the planning on both the employer and contractor sides, I strongly believe that there is a shortage. This issue becomes even more critical in a place where the fast-tracking approach has been deployed in the project that consequently requires maintaining a lot of changes within the project.

In the case study, on the contractor side, there were only two planners directly involved in the construction and one planner assigned to take care of the design part in particular. In such a megaproject, where there are too much data incorporated into the time plan, it requires more people to maintain these inputs in the time plan. Therefore, for such a big project, there should be at least two planners per block, one planner who understands how to build the plan, and one for helping out to manage all data that needs to be associated with. Then, the lead planner person for each block needs to go straight away to all those meetings such as design, change, and cost meetings and gathers input of the change while the second planner just maintains the plan as it is. It is not possible to go to a meeting and incorporate all the changes and maintain it at the same time. There would be too much works for one person. This leads to poor quality of the time plan and when the quality of the time plan is not sufficient, then people start losing trust in it. Then the time plan becomes a contractual document on the side while no one uses it. Generally, when the location of the project site is not attracting people, then it gets very hard to find competent resources to do the job.

The employer is not asking for a resource histogram/curve from the contractors and it means they cannot see the resource availability aligned with the activity time schedule. The current Covid-19 pandemic makes it even more crucial to demand resource graphs to plan and allocate the resources accordingly based on a prioritized plan.

There are numerous uncertainties and confusion among contractors related to the lack of project management support by a PMO. Some of these supports are but are not limited to developing the layout of each building to be used as a common reference by all contractors. Another example is related to developing physical progress methodology where both parties (employer and contractor) agree upon to measure the progress of the activity. This problem rolls up to misalignment on the progress on subsystem/area/room/building/project level. According to the interviewee, these topics should be managed by a centralized oversight entity within the employer organization.

Question 5: How do you think your organization is managing the front-end development approach throughout the project?

The problem with the case study is that the front-end development and fast-track approach are not working together.

Question 6, 7: How do you think your organization is managing complex interfaces & integration? How is the maturity of your organization to deal with change and uncertainty?

I use the Primavera application for planning. I make an extract from the plan for 2 and 4 weeks look ahead. I also use some kind of a visual tool that shows who is working what and where. The coordination is made via this visual method. Meanwhile, put the people responsible in front of their assigned work. Risks should be implemented and reflected in the time plan and a **Time Impact Analysis (TIA)** should be carried out to analyze the impact of change/uncertainty on the time plan.

In regards to managing risk and uncertainty, by having a commissioning plan and use it as a basis to build the time plan accordingly and make a priority list of the job based on that.

We need to write design requirements and in the meantime, we need to link design, procurement, and construction in the time schedule from day one. We cannot have the design going underway while the pipe is already there.

In megaprojects, it is not uncommon to see that PMs lose the helicopter perspective especially in absence of PMO, the communication becomes more problematic to manage than in regular projects. To address and continuously manage this issue, the communication within megaprojects should be managed simply by deploying one communication system. Everyone needs to use only one planning source to communicate during day-to-day meetings. Otherwise, the integrity of the time plan will be jeopardized. Therefore, finding and selecting the right alternative medium that fulfills the planning requirements and suits their purposes is critical for managers.

Disconnection issue and lack of coordination between the project design engineer, construction engineer, and commission is crucial. In megaprojects, this becomes even more problematic due to the magnitude of the project and the high complexity.