Forecasting the success of megaprojects with Judgmental Methods

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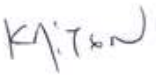
Signature of candidate:  Date: 10 June 2021

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To: Aleka

Disclaimer

Opinions expressed are solely my own and do not express the views or opinions of my current or past employers.

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Forecasting the success of Megaprojects with Judgmental Methods

Extended Abstract

Forecasting the success of megaprojects is a very difficult and important task because of the complexity of such projects, as well as the large capital investment that is required for the completion of these projects. In the current climate and crisis due to the global pandemic of COVID-19, it is becoming even more important to be able to forecast to some extent the evolution and success of such large projects, as these are meant to be the ones that will drive the countries and respective economies from the ground; and will pave the long-term future in all critical sectors from energy and telecommunications to transport, logistics, and defence. In this thesis, project s*uccess* is defined across all dimensions of the project triangle: time, money, and scope; thus, the extent to which the project finishes on time, on budget, and the anticipated socioeconomic benefits achieved, quantify the success of a megaproject, or any project for that matter.

One could argue that forecasting is not needed in the context of project management. The arguments follow the line that the master Gantt chart of the tasks, person-hours, procedures and operations run through the project, plus the respective Bill of Materials (inclusive of the lead times to acquire these materials too) should suffice for a very accurate estimation of the duration and cost of a project.

However, If that was simply the case, then every project would finish on time and on budget – but this is far from true as the numerous examples attest: HS2, Channel Tunnel, large IT public projects in the NHS, the very COVID-19 vaccination project to name a few. Furthermore, this estimation/prediction is not actually a true forecast - it is merely a calculation assuming every single operation will start and finish on time.

This calculation indeed varies rarely and seriously underestimates the true uncertainty in operations within a project - and life in general, and as such true a-priori forecasts are needed. Especially for megaprojects forecasts are even more essential and important, given that there is no prior experience for most of the sub-projects and operations involved in the project, on top of some technologies that are not mature enough on the time of the project conceptualisation in order to guarantee successful completion on time. That also renders quantitative methods - that require past data to work and train efficiently, very hard to apply in this context.

To that end, in this research, a qualitative methodological approach is employed and the use of judgmental forecasting methods for the tasks prompted. In order to collect empirical data and provide respective evidence, we have designed and run three sets of judgmental forecasting experiments. The target dependent variable is the forecasting performance of the participants/subjects, and the independent/treatment variable is the judgmental forecasting method used. In some of these experiments, we do control for the level of expertise when the group is not homogeneous for that aspect.

In the first experiment, the participants forecast for one megaproject ('space exploration') with Unaided Judgment (UJ), Structured Analogies (SA) and Interaction Groups (IG) with IG showing the best results since IG>SA>SA (where > is noting statistically significant better accuracy). In the second experiment, we use a different megaproject ('a major recreational facility in the very centre of a major cosmopolis') and see the success in many dimensions separately: first in terms of excesses in the budget and the duration of the project.

Furthermore, the participants forecast the extent to which the socio-economic benefits are realised. I do analyse three different stakeholder perspectives: that of the a) project manager, b) funder(s), and c) the public. I do control for two levels of expertise – novices, and semi-experts, and the participants use UJ, SA, IG and Delphi (D) as well, resulting in favour of the group forecasting methods versus the individual ones, highlighting the benefits of pooling expertise and analogous past information, as IG>D>SA>UJ. In the third and final experiment, I qualitatively explore the use of scenarios in forecasting the success of megaprojects. Using the first megaproject again ('space exploration'), we draw insights from requesting three scenarios from the participants (baseline, worst-case, best-case).

Finally, combining the results of the three experiments, I propose a new theoretical construct, a new judgmental forecasting method, a 360-degree method using both the past (analogies) and the future (scenarios) in order to forecast from the present for the future: Structured Analogies aNd Scenarios (SANS).

Keywords: Judgemental Forecasting; Megaprojects; Uncertainty; Structured Analogies; Interaction Groups; Delphi; Scenarios;

Forecasting the success of Megaprojects with Judgmental Methods

Abstract

Forecasting the success of megaprojects is a very difficult and important task because of the complexity of such projects, as well as the large capital investment that is required for the completion of these projects. One could argue that forecasting is not needed in this context: the master Gantt chart of the tasks with assigned person-hours plus the respective Bill of Materials should suffice for an accurate estimation of the duration and cost of a project. If that was the case then every project would finish on time and on budget – but this is far from true as the numerous examples attest: HS2, Channel Tunnel, major IT public projects in NHS, to name a few. In this research, we employ judgmental forecasting methods to predict the success of megaprojects in as series of forecasting experiments. In the first experiment, the participants forecast for one megaproject ('space exploration') with Unaided Judgment (UJ), Structured Analogies (SA) and Interaction Groups (IG) with IG showing the best results since IG>SA>SA. In the second experiment, we use a second megaproject ('a major recreational facility in the very city centre of a major cosmopolis') and see separately the success in terms of excesses in the budget and the duration of the project. Furthermore, the participants forecast the extent to which the socio-economic benefits are realised. We do analyse three different stakeholder perspectives: that of the a) project manager, b) funder(s), and c) the public. We do control for two levels of expertise – novices, and semi-experts, and the participants use UJ, SA, IG and Delphi (D) as well, resulting IG>D>SA>UJ. In the third and final experiment, we qualitatively explore the use of scenarios in forecasting the success of megaprojects.

Key words: Judgemental Forecasting; Megaprojects; Structured Analogies; Group Forecasting; Scenarios;

List of abbreviations

AE: Absolute Error

BCS: Best-case scenario

BLS: Base-line scenario

BOM: Bill of Materials

D: Delphi

Gantt: Gannt Chart

D: Delphi

MAE: Mean Absolute Error

SA: Structured Analogies

S: Scenarios

s-SA: semi-Structured Analogies

UJ: Unaided Judgement

WCS: Worst-case scenario

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1. Introduction

In this chapter,

I relay my motivation for this thesis, my interest in projects and especially megaprojects, and the respective techniques to forecast these, in essence contributing to the body of literature on project management. I further present the research aim for this dissertation as well as the respective objectives and, consequently, the main research question. I also discuss the contributions to knowledge, theory, as well as practice from this thesis and conclude the chapter by presenting the structure of this monograph.

1.1 Project management and Megaprojects

The plurality of the field of Project Management

The field of project management has gained lots of interest, especially in the last few decades, with researchers arguing that there is a need for further project management research (Narayanan et al., 2019; Parvan et al., 2015; Liu, 2015; Hazir, 2015; Hall, 2012; Kolltveit et al., 2007). Project management deals with a remarkably broad range of issues within an organisation or a company; from the strategy, the events, the financial aspects, the technology, the contracts, the planning, the emergency response - like the case of the 2020-2021 global COVID-19 pandemic, the environment and much more. In other words, as Meredith and Mantel (2011) put it, *project management is applicable in any context;* and in the current circumstances - and the global pandemic at its forte - as timely and important as ever.

Organisations' development depends on project management practices and can benefit from these (Wang et al., 2017). Maylor (2003) state that the project management approach has changed in recent years and a less traditional approach is seen the project management as an essential part of achieving the strategic objectives and recognising the vital role of the project managers and the characteristics that this position requires.

Moreover, project management requires certain structures in the decision-making process which, in times of uncertainty and threats like the periods of economic crisis, these structures go under high pressure making the business environment more complicated (Rosenthal et al., 1989). Martens and Carvahlo (2016) emphasise that the national business environment defines the success of any project.

In this thesis, the adopted position is that project s*uccess* is defined across all dimensions of the project triangle: time, money, and scope; thus, the extent to which the project finishes on time, on budget, and the anticipated socioeconomic benefits achieved, quantify the success of a megaproject, or any project for that matter.

Periods of crisis and the importance projects

According to Hruzova and Thornton (2011), projects still exist during an economic crisis; the issue that rises is a noticeable gap in both literature and in the knowledge on how project management has been affected during these periods. Furthermore, organisations are usually not prepared to deal with a crisis (Fainshmidta et al. 2017); however, they still have to manage and survive an economic crisis (Grewal and Tansuhaj, 2001). Especially the really large projects - called hereafter *megaprojects*[1], where commitment for a long term has been established, are the ones that need to continue under any circumstances; and thus attest further for the timeliness of this research in the light of the ongoing global crisis.

Given the current global economic, healthcare, and supply chain management crisis due to COVID-19 (Nikolopoulos et al. 2022; Nikolopoulos et al. 2021), and the number of megaprojects that are stalling and need to be progressing, this stretches further motivation to research megaprojects, and especially forecasting models that can give use good estimates of the potential success of such large projects (Petropoulos et al., 2020). To that end judgmental forecasting methods (Nikolopoulos et al., 2015) may seem a better choice for the task, as megaprojects are usually one-off projects, where past data are not available, and the utilisation of experts and their opinions is necessary.

Forecasting in Project Management

Forecasting in project management is a difficult task (Homer, 2007). Especially forecasting in the context of megaprojects is a very difficult and important task because of the complexity of such projects, as well as the large capital investment that is required for the completion of these projects. In the current climate and crisis due to the global pandemic of COVID-19, it is becoming even more important to be able to forecast to some extent the evolution and success of such large projects, as these are meant to be the ones that will drive the countries and respective economies from the ground; and will pave the long-term future in all

[1]The term will be formally defined in chapter 2 in the literature review section

critical sectors from energy and telecommunications, to transport, logistics, and defence.

One could argue that forecasting is not needed in this context: that of projects in general. One could argue that the master Gantt chart of the tasks, person-hours, procedures, and operations run through the project, plus the respective Bill of Materials (inclusive of the lead times to acquire these materials too) should suffice for a very accurate estimation of the duration and cost of a project (PMBOK, 2004). If that was the case, then every project would finish on time and on budget – but this is far from true as the numerous examples attest: HS2, Channel Tunnel, most IT public projects in NHS, to name a few.

For example HS2's costs and potential delays are running out of control, warn MPs in UK (https://www.theguardian.com/uk-news/2020/may/17/hs2-costs-and-potential-delays-are-out-of-control-warn-mps) and state that "The department and HS2 appear to have been blindsided by contact with reality – when phase one started moving through parliament, the predicted costs of necessary commitments to the communities affected have **exploded from £245m to £1.2bn**.". Furthermore in a very well know megaproject taught in most Business schools around the globe, the Eurotunnel (Channel Tunnel), by the time tunnel opened in May 1994, it **was one year behind schedule and £2bn ($3.6bn) over budget**. ('How Eurotunnel went so wrong' http://news.bbc.co.uk/1/hi/business/4088868.stm). If it was about just counting how long each operation will last and how many bags of cement will be needed, then none of these excesses would have happened. Thus, a true forecast better always be in place before the project starts.

Furthermore, this aforementioned estimate is not actually a true forecast - it is merely a calculation assuming every single operation will start and finish on time. This happens rarely; in fact, it underestimates the true uncertainty in operations and life in general, and as such true a-priori forecasts are needed.

In this calculation, the bill of materials (BOM, PMBOK 2004) is used that is merely a comprehensive inventory of the raw materials, assemblies, parts and components, and respective quantities needed to manufacture and construct a

product or complete a service or operation. It is essentially the complete list of all the items that are required to build a product.

While the Gantt is a chart (PMBOK, 2004), commonly used in project management, as a very popular way of showing activities/processes/operations/tasks/ or events displayed against time. But this all assumes perfect knowledge of the future and seriously underestimate how things evolve in a real project where delays surface at each and every instance and in this context time is money, and delays are projects going over budget.

Thus, a true forecast primarily based on the nature and type of the project is essential: a forecast on the potential excess of budget, excess of project duration, and missing key targets given the (challenging) nature of the endeavour in hand. This should be done in parallel, complementing, and not substituting any calculations done base on the Gantt charts of the megaproject.

1.2 Forecasting the success of megaprojects

Forecasting the success of Megaprojects is a tricky task, both given the nature of these projects and also that success has many facets as already elaborated in the previous section. Forecasting, for example, the socio-economic impact of projects like Olympic games or space exploration is a very difficult but also extremely important task, not only for the resources allocated in such projects but predominantly for the great expectations around them.

Flyvbjerg et al. (2014) argue vividly how difficult it is to forecast the success of such major projects. They claim that:

> *"Large capital investments that are completed on schedule and within their budgets are probably the exception rather than the rule—and even when completed many fail to meet expected revenues. Executives often blame project underperformance on foreseeable complexities and uncertainties having to do with the scope of and demand for the project, the technology or project location, or even stakeholder opposition. No doubt, all of these factors*

at one time or another contribute to cost overruns, benefit shortfalls, and delays."

Turner and Zolin (2012) even claim that we cannot properly define what success is – or what it will be when the Megaprojects target are materialised to some extent. They argue that we need reliable scales in order to predict multiple perspectives by multiple stakeholders over multiple time frames – so definitely a very difficult long-term problem.

This could be done via a set of leading performance indicators that will enable managers of Megaprojects to forecast during project execution how various stakeholders will perceive success months or even years into the operation. Megaprojects have many stakeholders who have different objectives for the project, its output, and the business objectives they will deliver.

The output of a megaproject may impact further than the initial scope, and the project's benefits can last for a lifetime, if not decades. It is interesting to see how different stakeholders perceive success and how this is changing over time

Megaprojects most of the time run for the first time on such a scale, and there is no previous experience or data per se exist on the expectations around the duration, budget, and potential socio-economics impact to be achieved. Thus quantitative methods are not the initial choice of weapons in our forecasting arsenal there, and we rely on experts and judgmental forecasting for the aforementioned challenging task.

1.3 Research Aim and Objectives

The aim of this thesis is to:

> *Explore and identify the best methods for forecasting the success of megaprojects*.

This aim inevitably leads to the following specific objectives:

a) Explore the variety of forecasting methods that could be used in the field of project management.
b) Explore the variety of forecasting methods that could be used in the context of megaprojects.
c) Investigate if judgmental methods - that require no hard data - might be more appropriate in this context.
d) Investigate the role of expertise and stakeholders on the derived forecasts.

This research journey is captured in figure 1 where the areas that I will be exploring are presented in a mind map/Venn diagram and the gap that I aim to cover is on the "potential use of judgmental forecasting methods for forecasting the success of megaprojects".

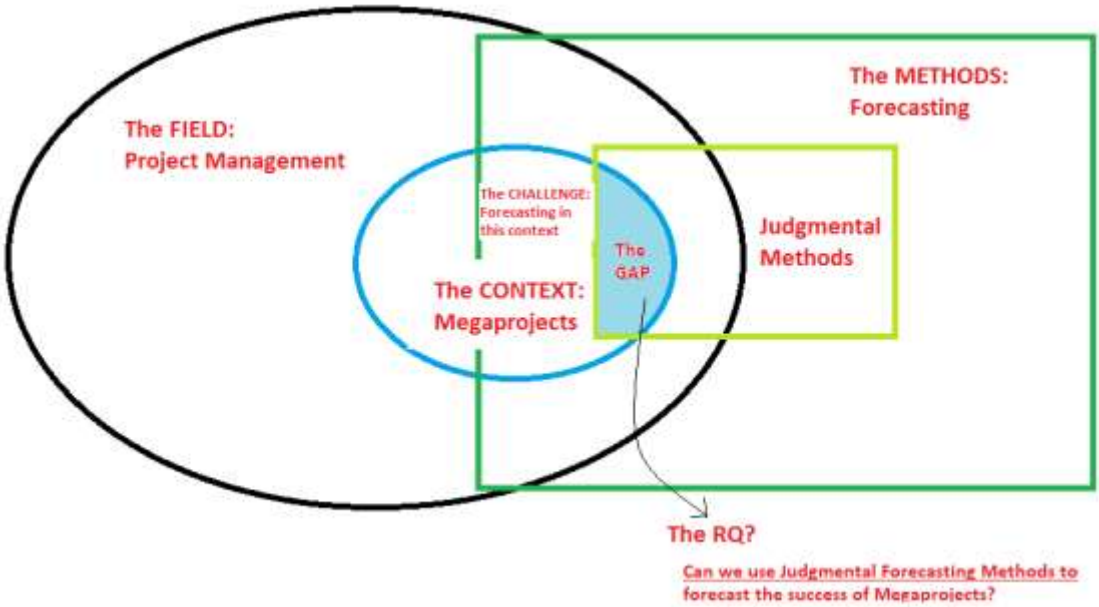

Figure 1.1 Research journey during this Thesis

Given the introduction as mentioned above, and motivation, the main research question for this study, that will be reconfirmed after a thorough literature review in the next chapter, is:

> *"Which judgmental forecasting methods can we employ in order to get the best possible forecasts for the potential success of megaprojects?"*

This research would explore and try to shed light more specifically to the following sub-research questions:

a. Which judgmental methods forecast better the success of megaprojects?

b. How this success is perceived by different stakeholders: the project manager, the funders, the public?

c. How important is the experience and expertise of the forecasters?

In the course of this thesis, I will be evaluating the performances of mainstream and very promising judgmental forecasting methods of Unaided Judgment (UJ), Structured Analogies (SA) and semi-Structured Analogies (s-SA) as well as Interaction Groups (IG), Delphi (D) and Scenarios (S) in forecasting the impact of such projects.

The reason and academic motivation for the experimentation and evaluation of the relative performance of the aforementioned judgmental methods come from a series of studies in the broader field of structured judgmental forecasting methods: Savio and Nikolopoulos (2009, 2010, 2013) evaluation of s-SA and SA versus UJ for individual forecasters – in a very difficult forecasting problem; and Nikolopoulos et al. (2015) that extend the scope of such endeavours via including groups judgmental forecasts with IGs and Delphi approaches.

1.4 Contribution to the knowledge

The main focus of this research as is pictured earlier in this chapter is to explore the forecasting challenges when assessing the potential success of megaprojects; this is an area where both theory and practice have not provided many advances but, more fundamentally, where empirical evidence is quite scarce (Wang et al. 2017; Saunders et al., 2012; Cicmil et al. 2006). Neither in practice nor in theory, the fundamental things as what constitutes project success and failure have been answered. Prabhakar (2008) discusses the different positions the researcher support about what makes a project successful or not.

1.5 Contribution to the theory

"Theory without empirical evidence to test it is simply a story" (Alberts, 2011, p. 36). And in a PhD journey adding to the body of theory on a specific domain is essential.

My theoretical contribution will be dual:

a) responding to the call Cicmil (2006), Winter et al. (2006), among others, my research will provide concrete empirical evidence of the variety of forecasting methods used in project management for megaprojects. The focus will be given to judgmental forecasting methods, as argued in the previous paragraph. This will also be further contributing to the body of empirical literature on project management.

b) the ongoing and developing literature in forecasting and management science, and especially the one in judgmental versus statistical methods as elaborated in Lawrence et al. (2006), or the more recent one of Arvan et al. (2019).

1.6 Contribution to practice

On a more practical aspect and with impact at mind, this research will give the opportunity to those practitioners working in project management, especially for megaprojects, to understand better the challenges they might have to face in their projects and use the appropriate range of forecasting methods and tools in order to estimate the potential success of their projects.

Research has been done mainly in the theoretical approach of the techniques used in project management. To that end, Wang et al. (2017), Ika (2009), and Cicmil (2006), among other researchers, suggest that further research should be focused on real projects as lots have been researched from a more theoretical perspective and thus the case used in our judgmental experiments will be real megaprojects disguised sufficiently.

1.7 Structure of the thesis

The rest of the thesis is structured as follows:

- Chapter 2 provides the relevant literature review.
- Chapter 3 presents an introduction to methodological approaches and the one I selected for my research.
- Chapter 4 details the data collected through the experiments performed and the respective analysis: in the first experiment, forecasting for the first megaproject (Megaproject1: on space exploration) with UJ, SA and IG; in the second experiment, forecasting for the second megaproject (Megaproject2: on a major recreational facility) with UJ, SA, D and IG, with participants of two different levels of expertise: novices, and semi-experts; and in the third experiment, forecasting for the first megaproject with Scenarios (S).
- Chapter 5 presents my reflection and discussion of the previous set of results chapters, resulting in a new proposition, a new forecasting method entitles SANS: Structured Analogies and Scenarios. It further closes my research investigation via presenting the main conclusion, drawbacks and limitations, and a roadmap for future research

2. Literature Review

In this chapter,

I convey my critical approach to the literature review in the field of project management in general, and that of forecasting within that body of literature, especially in the context of megaprojects. I further focus on the qualitative approaches per se, most notably judgmental forecasting techniques both individual (structured analogies) as well as group ones (Delphi and Interaction Groups). The chapter concludes with the research gaps in the literature and the natural formation of my research questions. Given the qualitative nature of this endeavour, I do not form formal hypotheses rather than loose research questions; this is consistent with similar social sciences quests.

LITERATURE REVIEW

In order for the reader to be able to visualise the process followed in this non-systematic literature review, the following mindmap depicts the path followed and respective areas covered on my way towards identifying the gaps in the contemporary literature:

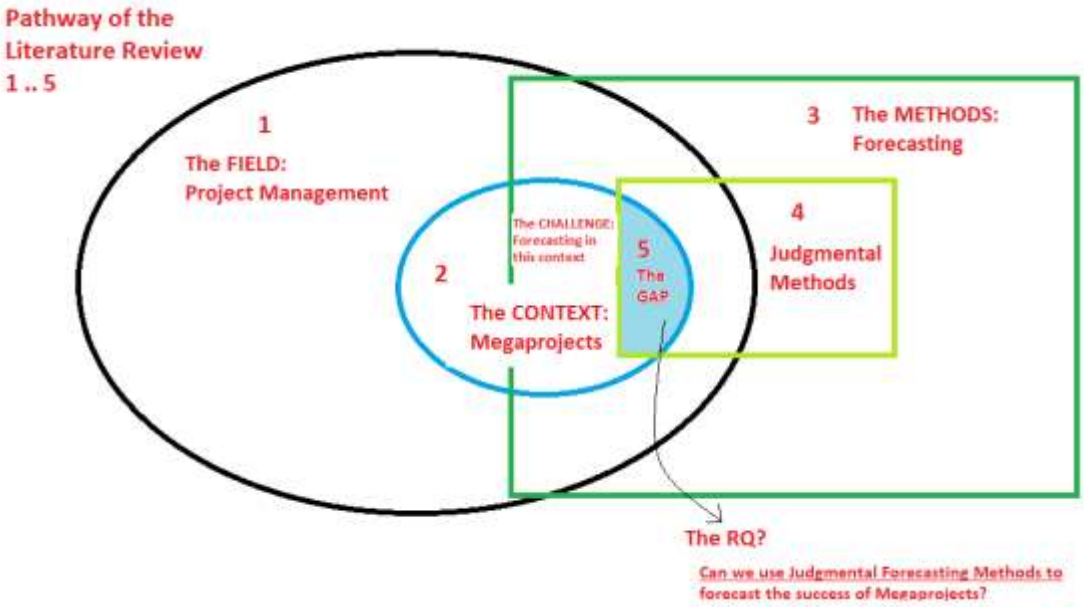

Figure 2.1 Mindmap of the adopted lieterature review pathway

PART I. THE FIELD: PROJECT MANAGEMENT

2.1 What is a project and what is Project Management

There is a continuous discussion among researchers (Maylor, 2017), what kind of elements constitute a project, and, if project management is an academic discipline or is an area that practitioners mainly have to deal with it. Thus, on the project management literature front, a project is a given, plannable and unique task, limited in time, complex in its implementation and subject to evaluation, (Packendorff, 1995). For Harvard Business Review Staff (2016), a project is the entire process that needs to be followed, in order to solve a problem that has been identified and needs to be addressed. Nevertheless, Geraldi and Soderlund (2017) state that project management is a series of elements -processes, tools, techniques and concepts- in order to manage a project.

According to Pinto and Kharbanda (1995), Tavares (2002) and Krahn (2006), project management is a fast-growing discipline with considerable impact on other fields as well. Munns and Bjeirmi's (1996) perception is as the achievement of a specific objective constitutes the project when the series of activities and tasks to complete it, is the project management. Moreover, Alias et al. (2014), defined the projects as a series of activities that should be followed in order to reach a specific objective, which a company has set earlier. Alias et al. (2014) adds that most of the projects demand project management to some extent. Muller and Jugdev (2012) acknowledge the contribution of the three "giants" Pinto, Slevin and Prescott, to the field of project management and their work as a dominant component to the continuous development of the area.

Lister (2014) states that everyone is a project manager to a different extent even without realising this; people do have to deal with a number of projects in their everyday life – from having to finish a task, organising a gathering and many more set duties. Furthermore, according to Carden and Egan (2008), the literature in the discipline is limited to the traditional areas of project management.

Project management's roots could be found in the engineering field (Geraldi and Soderlund, 2017) that has changed in recent years; Maylor (2003:6) state: *"Recently the nature of project management has changed".* Kwak and Anbari (2009) cite that project management has been expended in several areas and has been increasing the interest of diverse organisations, and companies non-traditional project management areas have been arising in the discipline (Kerzner, 2001; Carden and Egan, 2008).

2.2 The Development of Project Management

From Maylor's point of view, the development of project management can be broadly divided into three stages as follows:

Stage 1: Pre-1950s

The development of the project management (PM) as we see it today didn't exist earlier than the 1950s. Nevertheless, projects were undertaken before 1950s, but PM as a discipline wasn't generally accepted and there weren't defined methods (Maylor, 2017).

Stage 2: 1950s

During the 1950s, formal tools and techniques were developed to help manage large, complex projects that were uncertain or risky (Maylor, 2017).

Stage 3: 1990s

In the third stage – after 1990s – a new approach of project management emphasises on the strategic role of projects; particularly on the processes that the results of the project should meet the customer's satisfaction. The role of the project managers is evident in this stage as he is the key component between the objectives and the delivery of the project. *Project managers become project integrators* (Maylor, 2017).

Nevertheless, Carden and Egan (2008) analyse the articles that outline historical perspectives of project management and they identify four key periods:

The emergence period:

The emergence period is referred in the early of 1900s during which project management was established as an orderly work-related framework and was provided as a tactical and strategic approach to chart and implement projects (Carden and Egan, 2008). Furthermore, Packendorff (1995) stress that project management started as an organised, work-related approach in the early 1900s and the reason behind this was mainly the need to have a tool to plan and manage a project; Henry L. Gantt developed the Gantt chart in 1910.

The refinement period:

During the refinement period - the 1950s, project management became more theoretically and mathematically oriented, adding refined algorithms and project-planning techniques. For Packendorff (1995), during the same period – 1950s, it was the time when the project management entered a new era.

The human resource period:

During, human resource period - in the 1960s, project management emphasises on the effectiveness of the individuals, the teams and the organisation on the process. According to Packendorff (1995), the focus was given to the resources and managerial concerns in the context of organisational projects.

The performance period:

Lastly et al. (2008) state that the performance period indicates the project management as known today. Recently there is an increasing focus on the dynamic contexts that are often technology-driven and involve sophisticated support tools. Even so, the project management discipline continues to grow and as Carden and Egan (2008) state that this performance-oriented era remains a major focus as some of the focus shifted from humans as inputs and processors of projects to project outcomes.

2.3 The Project Management Knowledge Base

In the Project Management area, there are two main institutions that constitute the unique idea of Bodies of Knowledge; the APM and the PMI body. Both bodies' presence and input in the discipline is notable as they are allied with project management professional qualifications.

The Project Environment

Studies of communication in and around projects have generally concluded that project effectiveness is strongly correlated to the quantity of communication in the project organisation and the quality of the communication with the project environment *(Packendorff, 1995).* However, Krahn (2006) support that there are several factors – such as the type of project being managed, the specific project's characteristics, the business environment, the characteristics of the team and many more – that influence and impact on the project environment.

Project manager

Project managers play a crucial role in all kinds of projects and influence projects' success (Jalochaa et al., 2014). Kerzner (2001) supports that the project manager's role is to mainly coordinate and combine activities across multiple operations. Particular project manager's techniques for a successful project have been seen mainly in areas of planning and control time, cost and quality. (Pandya, 2014; Munns and Bjeirmi, 1996).

Since the very first periods of project management development Gaddis (1959) state that in the project leadership literature, it is acknowledged that the project manager's skills follow between corporate management and project specialists. The demanding business environment needs people to lead a project not just to manage it (Dubois, 2015) and as Eweje et al. (2012) argue, successful project management involves powerful leadership. This latter demand brings a huge challenge for the organisations; they have to operate in a very complex and uncertain environment (Mason, 2007) and as Lloyd-Walker and Walker (2011) stress, it is vital for project leadership to adapt to the needs of the 21st century.

Researchers (Badewi, 2015; Mir and Pinnington, 2014; Munns and Bjeirmi, 1996) agree that project success and project management success are two separate features and, as such, should be considered. Nevertheless, Kaiser et al. (2015) state that however, it is allied to the final outcome of the project and very often, unsuccessful management reach a successful project and vice versa (Munns and Bjeirmi, 1996). Moreover, Alias et al. (2014) argue that the project manager and the success of the project are closely linked with the project manager as the most critical part of the project success.

2.4 Public Value Management

Talbot (2009) claims that public value management is where many scholars believe the future of any social sciences field lies. Essentially public value management is seen as an integration of ideas around efficiency and performance with broader considerations about the role of public project and process managers. In order to create public value, we need operational capacity, a clear target to create something of value and political will, continuity, and sustainability (Moore, 1995). Effectively public value management can be seen as New Public Management with the added factors and respective emphasis of feasibility and value creation.

PART II. THE CONTEXT: MEGAPROJECTS

2.5 Megaprojects

Megaprojects are temporary projects characterised by large investment commitment, enormous organisational complexity, having a long-lasting impact on the environment, the economy, and society (Sanderson, 2012). The US Department of Transportation defines megaprojects as projects with at least a budget of USD 1 billion (Capka, 2006). In EU countries, the International Project Management Association (IPMA) (2011) describe EUR 1 billion as the threshold defining megaprojects across all industries.

Megaprojects include power plant, oil and gas extraction and processing projects, transport projects (such as highways and tunnels, bridges, railways, seaports) and even creative/cultural events such as the Olympics (Mišić and Radujković, 2015).

This project form is sometimes labelled as megaprojects (Flyvbjerg et al., 2003); the service-led project (Alderman, et al., 2005); large capital projects (Bekker and Steyn, 2007); or the large engineering projects (Miller and Lessard, 2000).

2.6 Successful Megaprojects

Megaprojects are significant activities characterised by a multi-organisation structure, which produces highly visible infrastructure or asset with very crucial social impacts (Aaltonen, 2011). Indeed, the world needs megaprojects especially those that deliver social and economic goods that are lacking and create economic growth (Flyvbjerg et al., 2003). Typical features of megaprojects include some or all the following. Delivering a substantial piece of physical infrastructure with a life expectancy that spans across decades; main contractor or group of contractors are privately owned and financed; the contractor could retain an ownership stake in the project, and the client is often a government or public sector organisation (Sanderson, 2012).

However, megaprojects are heavily laced with extreme human and technical complexities making their delivery and implementation difficult and often unsuccessful (Alfalla-Luque et al., 2015; Brooks, 2015; Merrow, 1988). This is

largely due to the challenge of managing megaprojects, including extreme complexity, increased risk, tight budget and deadlines, lofty ideals (Fiori and Kovaka, 2005). Due to the possibility and consequences of megaproject failure (Mišić and Radujković, 2015), forecasting the outcomes of megaprojects is becoming of growing importance. In particular, it is crucial to identify and assess the risks and uncertainties as well as other factors that contribute to disappointing outcomes of megaprojects in order to mitigate them (Ansar, Flyvbjerg, Budzier and Lunn, 2014; Flyvbjerg et al., 2003; Miller and Lessard, 2007).

Literature reviews in forecasting in megaprojects are scarce. However, there are a few themes that have emerged in the extant literature as characteristics of megaprojects that should be skilfully managed to provide a guideline for the successful planning and construction of megaprojects (Fiori and Kovaka, 2005; Sanderson, 2012).

2.7 Front-end considerations

The decisions that are taken at the very early stages of megaproject development are of great importance since megaprojects involve substantial financial investments and commitment, and starting a wide set of socioeconomic effects. Scholars (such as Flyvbjerg, 2005; Miller and Hobbs, 2005) have emphasised the importance of a comprehensive, complex and expensive front-end as this impacts the outcomes megaprojects above and beyond the management of engineering, procurement and construction stage. Front-end considerations for megaprojects is described as an iterative, complex, non-linear and time-bound process in which the megaproject is formed, tested, challenged and reformed in a series of episodes, where unanticipated risks and issues emerge in successions and must be managed (Miller and Lessard, 2000). Failure to account for unforeseen events frequently lead to cost overruns (Flyvbjerg et al., 2003).

2.8 Risk management

Risk management is a mandatory part of megaprojects and it plays a crucial role in determining the success of megaprojects. It can help project managers anticipate factors that cause project delays and failure (Alfalla-Luque et al., 2015). In fact, assessing risks in the early stages could help determine whether the megaproject should be developed or not. A study by PMI in 2015 reveals that one of the major causes of megaproject failures is the fact that in 30% of the cases examined, opportunities and risks were not properly defined. Furthermore, Merrow (2011) suggested that it is important to carry out an engineering and risk analysis before commencing megaprojects as doing this is likely to validate project timelines and reduce costs by up to 20 per cent. However, studies that focus on risk management in megaprojects are just emerging (Alfalla-Luque et al., 2015).

2.9 The role of stakeholders

Stakeholders are individuals, groups, or institutions with an interest in the project, whose influence can affect the outcome of the project (Alfalla-Luque et al., 2015). Stakeholders can be internal or external (Winch, 2010). Internal stakeholders have a legal contract with the client and can be considered to those who surround the client on the demand side and the supply side. External stakeholders are the public and private actors. The public actors include government bodies and regulatory agencies, while the private actors are the local residents, landowners, environmentalists, and archaeologists. In most cases, the internal stakeholders tend to be in support of the project while the external stakeholders tend to be in support, against, or indifferent about the project (Takim, 2009).

For the reason that megaprojects are owned by multiple stakeholders who may have varying perceptions of success and project expectations (Kardes, Ozturk, Cavusgil & Cavudgil, 2013), the key issues of governance arrangements and risk/reward allocation must be explicitly considered to maintain the cooperation of all stakeholders as the projects develop. Therefore, project managers need to carefully consider the complexity of the megaproject and determine the right mix of abilities and stakeholders to be integrated into the team (Armstrong and Green, 2018). These experts must work together to create comprehensive and practical

approaches to how the team would function and how to react to contingencies (Garemo, Matzinger, and Palter, 2015).

According to the World Bank Global Development Finance report (2007), cited in (Vassallo et al., 2011), two criteria should be considered when allocating risks. Firstly, risk should be borne by the stakeholder who is best to bear the outcome of the risk, and secondly, the stakeholder who will be best to handle the risk at least cost should bear the risk. At the same time, risk allocation should be based on a balance of stakeholder's interests and the liabilities associated to megaproject risks should be distributed in proportion to prospective gain or loss (Khazaeni et al., 2012).

The social, legal and economic situation of a county greatly influences how risks are allocated. These factors must be carefully considered as improper risk allocation to either the public or the private stakeholder can result in a lack of financial feasibility for the megaproject (Vassallo et al., 2011).

2.10 Governance

Governance in project management is a growing field with a lot of promise (Alfalla-Luque et al., 2015; Pitsis et al., 2014). Governance refers to how individuals, groups, organisations, societies, nation-states are held accountable for outcomes and ethical behaviours (Clegg et al., 2002). In relation to megaprojects, although a high degree of flexibility is needed to accommodate uncertainties and ambiguities, there is still a need for governance and change control with unplanned change requests (Gil and Tether, 2011). The governance of megaprojects must be able to hire and retain human capital that is skilled in all technicalities of the project and flexible to adapt to emerging changes in the project environment (Pitsis et al., 2014).

Although the literature often considers governance issues as dynamic, (Miller and Hobbs, 2005), it is imperative that governance of megaprojects are dynamic to ensure alignment with both strategic objectives as well as changing contexts of action which may constantly reform these objectives (Pitsis et al., 2014). As a result, leaders of megaprojects are encouraged to ensure that not only is the

project dynamic but that their leadership approach is also dynamic (Meskendahl, 2010).

2.11 Complexities

Amongst other projects, megaprojects have the most dynamism, ambiguity, complexity, external influences, time, complex structures, and uncertainty (Kardes et al., 2013). Megaprojects can take several decades from initiation to completion. During this period, there are changes to the economy, laws and regulations and political system (Capka, 2006).

Also contributing to the complexity of megaprojects are factors including the large scale, long time span, multiplicity of technological disciplines, the number of participants, multi-nationality, the interests of stakeholders, sponsor interest, escalating costs over time, country risk, uncertainty, and high levels of public attention or political interest (Van Marrewijk et al., 2008). Due to the conflicting interests of all stakeholders, further complexities are added to the development of megaprojects (Kardes et al., 2013).

There is no integrated framework for managing complexities in megaprojects (Alfalla-Luque et al., 2015). However, they are some methods offered in the literature on how to deal with complexities. Vidal et al. (2011) propose using an Analytical Hierarchy Process. Bosch-Rekveldt et al. (2011) suggested the Technological, Organisational and Environmental Framework. Two concepts of project complexities are generally acknowledged: structural complexity (organisational and technological), with associated differentiation and interdependencies (Baccarini, 1996) and uncertainty (Williams, 2007).

Dealing effectively with the challenge of complexity in megaprojects is difficult and requires management interventions beyond the scope of simple analytical approaches. Thamhain (2013) suggests an interaction of people, work environments and work processes. In addition, communication and collaboration among all stakeholders are considered important condition for early risk detection and effective risk management in complex project situations.

2.12 Sustainability and environment

For megaprojects to be successful, environmental risks must be identified and managed. Environmental risks that could affect revenue are classified into clients' risks, society risks and society risks (Irimia-Dieguez and Afonso, 2012). Customers buy the product or service, users are the people who use the product or service, and society benefits from the social profitability of the project. In relation to the customers, there could be demand risks that threaten sales volumes such as inflation, price trends and range.

In addition, there is the possibility of market risks including variations in customer requirements and even the existence of a market. There is also a consideration for whether the megaproject provides the expected benefits to the society and the negative impact megaprojects may have in the local area such as environmental risks and resource depletion (Kroeger and Simonovic, 1997).

Thus, assessment of sustainability becomes important in the development of megaprojects. However, there is no methodological description as it is an evolving area. Simply put, it is any process that directs decision-making towards sustainability (Bond and Morrison-Saunders, 2011). Therefore, social, health and environmental impact assessments could be considered as forms of sustainability assessment (Pope et al., 2013). More research is needed in this area in regards to megaprojects for a holistic understanding of how sustainability measures affect the planning and performance of megaprojects (Alfalla-Luque et al., 2015).

2.13 Time and cost

Time and cost are the major areas in which megaprojects often go off the rails as project managers are constantly under pressure to deliver in less time and at a lower cost while they may also be facing challenges of poorly defined requirements, and in some cases lack of access to specialist resources (Garemo, et al., 2015). This makes the issue of meticulous planning very important to forecast the outcomes of megaprojects as well as the actual outcomes of the megaproject.

In a review of studies that have focused on risk, uncertainty and governance in megaprojects, Sanderson (2012) demonstrated that stakeholders (typically politicians and contractors) often engage in rent-seeking behaviours just to get

projects approved and to win contracts. This behaviour could be in the form of systematically under-estimating project costs, over-estimating project benefits and being over-optimistic with project scheduling (Kahneman and Lovallo, 2003). Garemo et al. (2015) posit that such projects are doomed to fail from the outset.

In fact, these wrong estimates are believed to be intentional and not due to poor technical skills and inadequate data. Rather, they are dishonest tactics to make projects appear attractive and to get projects started (Flyvbjerg et al., 2003). Due to the great expectations of megaprojects to deliver social good, such projects could get approvals. However, given the lengthy period to implement megaprojects, there is usually a lack of accountability as initial project promoters (politicians) may no longer be in office. It is also the case that contractual penalties for producing over-optimistic tenders are often low in comparison to the potential profits involved (Davidson and Huot, 1989; Wachs, 1990).

Therefore, Flyvbjerg et al. (2003) recommend that it is important for project managers to gather information about the economic and social priorities and then use this information to determine what projects are best suited to deliver them. This process should involve engaging in detailed analyses and accurate information about the cost and benefits of the project. In particular, it is recommended that to avoid rent-seeking behaviours, and to increase transparency and accuracy of time and cost forecasts, forecasts should be subjected to thorough assessment and criticisms (Flyvbjerg et al., 2014).

Further, Garemo et al. (2015) suggested that top leaders should consider offering incentives (financial and non-financial rewards) for project champions whose estimates are accurate and levy penalties for forecasts that are seriously misleading, including financial obligations to pay for project overruns or dismissal.

2.14 Public Value as the ultimate objective of megaprojects

The role of Public Value Management (PVM) is to advance public values above and beyond the expected norms (Stoker, 2006), and as such PVM highlights the importance to be able to implement value from individual actions. The basic idea of adding public value via making sure that policy objectives are achieved while at

the same time improving public policy operations is compatible with the main take of this research thesis (Pitts, 2007; Talbot, 2009), especially in the context of megaproject that very often are the key drivers of public value. PVM requires governments to base decisions on forecasts. Impact Assessment (IA) may be performed as well – but not instead (European Commission, 2009) and it has to be mentioned that IA is considered a costly and resource-intensive methodology (Savio and Nikolopoulos, 2010, 2013), thus forecasting maybe a far better way to go. The selection of a specific forecasting model depends on the availability of data (De Gooijer and Hyndman, 2006; Savio and Nikolopoulos, 2009).

Although Cost-Benefit Analysis (CBA) is a useful tool, it is limited because it only evaluates policies in terms of economic efficiency (Maas, 1966; Simpson and Walker, 1987). Both IA and CBA are tools that can be used after a specific policy implementation has been decided upon (Savio and Nikolopoulos, 2013). As a result, they are not used in the preliminary screening of alternative policy implementations, which leads to space for simple and fast forecasting approaches that estimate the effectiveness of policies that may be implemented. Consequently, those forecasts might be used to select which alternative to implement, and then IA or CBA would be employed.

PART III. THE METHODS: FORECASTING

2.15 Quantitative forecasting methods

De Gooijer and Hyndman (2006) offer an extensive review of the progress of time series forecasting from 1981 to 2006. This review reports the progress seen for each individual family of models: exponential smoothing, ARIMA, ARCH, etc. Quantitative forecasting methods can be divided into time series and causal. Causal models are based on the causal relationships between the dependent variable and independent variables that are assumed to exist. Thus, these latter models need information about the domain. Time series models however do not need such information as they take more of a 'black box' approach to the system (Savio, 2010; Makridakis et al., 1998).

The performance of time series models is assessed via empirical forecasting competitions (Makridakis and Hibon, 1979; Makridakis et al. 1982; Makridakis et al. 1993; Makridakis and Hibon, 2000; Makridakis et al. 2018, Makridakis et al. 2020a; Makridakis et al. 2020b; Makridakis et al. 2020c; Makridakis et al. 2021), For the performance of causal models, Armstrong (1986) and Fildes (1985), come to differing conclusions. Armstrong (1986) argues that explanatory models will forecast well when three conditions are met:

- the causal relationship between variables can be estimated accurately,
- the causal variables change significantly over time, and
- this latter change can be predicted accurately.

Fildes (1985) on the other hand, concluded that, no matter what the horizon, causal methods performed better than extrapolative ones. Allen and Fildes (2001) revisited this research question and provided evidence that the causal methods are more accurate than time series ones about as often for the short term as for the long term.

A solution in order to combine the strength of causal and time series models is via combining. The idea of combining methods is not new (Reid, 1968; Bates and Granger, 1969) and has been proven very successful in the biggest forecasting competition ever with 100000 time series (Makridakis et al. 2020a; Makridakis et al. 2020b).

2.16 Judgmental Forecasting Methods

Judgmental forecasting has seen great attention over the years (Armstrong, 1986; Goodwin and Wright,1993; Makridakis and Gaba , 1998). Lawrence et al. (2006) reviewed extensively the literature on judgmental approaches published between 1981 and 2006. Researchers over the years gradually understood the benefits of the latter methods, however, they do come with a series of biases. Judgmental forecasting uses qualitative past data but also forecasters' subjective information acquired via experience and training. Judgmental forecasting is also used in the absence (or limited) of numerical data was (Makridakis and Gaba, 1998; Makridakis et al., 2009). Judgmental approaches are popular as they can forecast irregular changes (Savio,2010).

2.16.1 Judgmental Forecasting, Analogies, and Structured Analogies

Green and Armstrong (2007b) conducted an extensive review of the performance of analogies in forecasting and found very little evidence. Nonetheless, some studies do exist, with differing levels of success. Kokinov (2003) conclude that human behaviour can be explained by assuming decisions are made by using past analogies. The use of analogies for economic and business forecasting dates back to the 1930s (Goldfarb et al., 2005).

It is also used in the context of software development project management. Outcomes and costs of past projects can be retrieved from historical databases and used to predict the cost of future projects (Angelis and Stamelos, 2000). Heemstra (1992) finds that the majority of organisations who forecast the cost of

software projects did so by using analogies for their target case. Forecasting by analogy has also been popular in the area of technology (Schnaars, 2009), where the idea is that similar technologies are diffusing in a similar fashion. Easingwood (1989) looked at predicting the diffusion of a new product, and through comparisons and analogies, estimates and forecasts about a new product's diffusion can be derived. Analogies have also been used in scenario planning (Dortmans and Eiffe, 2004).

Green and Armstrong (2007b) propose that analogies show that they can improve the accuracy of judgmental methods as long as them use din a structured way and often with the use of a facilitator/administrator. The claim analogies will be useful mainly in the presence of

- Low level of quantitative data
- High uncertainty

Lee, Goodwin, Fildes, Nikolopoulos, and Lawrence, (2007) and Green and Armstrong (2007b) propose that forecasters require support when using analogies and provide recommendations on structuring them. Green and Armstrong (2007b) stronly believed that the structuring of the use of analogies will improve accuracy and propose a formal method for using analogies which minimises the biases caused by a human interface. They propose the method of Structured analogies (SA) that has five steps:

- *Description of the target situation*
- *Selection of experts*
- *The experts each identify and describe analogies*
- *The experts each rate the similarity of the situations*
- *Derivation of the forecasts*

Savio (2010) and Savio and Nikolopoulos in a series of studies (2009, 2010, 2013) extended further the idea of structured analogies via proposing the Semi-structured analogies (s-SA) where a facilitator is not necessarily needed as the experts provide analogies and forecasts at the same time. Savio and Nikolopoulos evaluated s-SA and SA versus UJ for individual forecasters – in a very difficult forecasting problem; and Nikolopoulos et al. (2015) extended the scope of such endeavours via including groups judgmental forecasts with IGs and Delphi approaches. Litsiou et al in 2019 used the same methods successfully in the context of project management too.

2.17 Expert Judgment

An expert is an individual with appropriate (to the task) training and experience. But how can an expert be identified? Many studies attempt to define the properties of experts (Johnson, 1983; Shanteau, 1987; Shanteau et al., 2002). The latter authors argue that if there is some external criterion against which experts judgments could be compared, one could simply call everyone whose answers come within a certain range of this criterion, is an expert (Savio, 2010). They also go further and identify experts based on nine criteria:

- *Experience*
- *Certification*
- *Social acclamation*
- *Consistency*
- *Reliability*
- *Consensus*

- *Discrimination ability*
- *Knowledge tests*
- *Creation of experts* (through extensive training)

PART IV. THE CHALLENGE: FORECASTING IN THIS CONTEXT IN THIS FIELD

2.18 Forecasting in project management

Forecasting in the context of megaproject is a young but promising field. However, there are techniques that have been used to forecast projects in the field of project management.

Forecasting is vital in project management for predicting the actual duration and cost of a project in progress accurately. As stated by Batselier and Vanhoucke (2015), earned value management (EVM) is the most singular used and best performing methodology for obtaining a project's actual duration and cost forecasts. The EVM technique is deemed a feasible and valued basis for forecasting the duration and cost of a project. Various novel EVM- based time forecasting approaches has been developed in recent years and these techniques can be categorised into deterministic and probabilistic approaches (Barraza, Back, αnd Mata, 2004). Deterministic approaches yield a point estimate of the eventual project duration, whereas probabilistic techniques provide confidence intervals and/or distributions of possible durations (Batselier and Vanhoucke 2015).

Even though EVM methodology is widely acclaimed as useful and reliable for evaluating the current cost performance of a project; and forecasting its actual cost, the time dimension EVM, only got the requisite boost after Lipke (2003) introduced an extension concept known as earned schedule (ES). Various forecasting approaches have also emerged over time but largely as an extension to EVM (Kim and Reinschmidt, 2010; Lipke, 2011; Elshaer, 2013; Khamooshi and Golafshani, 2014; Mortaji et al., 2014; Baqerin et al., 2015; Chen et al., 2016).

Anbari (2003) proposed the planned value method (PVM), whereas Jacob and Kane (2004) developed earned duration method (EDM). Elshaer (2013) developed an approach which integrates activity sensitivity information in ESM time forecasting to calculate project duration forecasts comparable to Lipke (2011) which are both extensions of the traditional ESM (Earned Schedule Method).

Conversely, Khamooshi and Golafshani (2014) developed an approach which though sprung from ESM had a different definition of the key metrics. They proposed earned duration management (EDMt), which instead of using cost-based metrics calculates schedule performance from time-based. They opined that using ESM for time forecasting could yet produce ambiguous results as the method continuously uses costs as a proxy to measure schedule performance.

Thus, ES is calculated based on EV and PV values, which are both expressed in cost units). They, therefore, developed the technique replacing the ES metric by earned duration ED(t) which is calculated as the projection of the total earned duration on the total planned duration based on metrics, expressed in time units instead of the projection of EV on PV, yielding ES. Studies on EVM forecasting accuracy by Batselier and Vanhoucke, (2015) and Vanhoucke and Vandevoorde, (2007) have however found ESM to be dominant over PVM and EDM.

Batselier and Vanhoucke (2015) in their study titled Improving project forecast accuracy, integrated the earned value management (EVM) methodology with the exponential smoothing forecasting approach to propose XSM (eXponential Smoothing-based Method). Rationalising the use of the exponential smoothing technique, they implied that since the data collected during a project represent a time series, exponential smoothing which is applied to any time series, can therefore be utilised to forecast a project duration and cost. The forecasting approach developed by Batselier and Vanhoucke (2015) for both project duration and cost is also an extension of the established EVM and earned schedule (ES) cost and time forecasting methods.

The approach requires only one smoothing parameter to calculate the enhanced EVM performance factor which can be adjusted during the project's growth based on information about past performance and/or anticipated management actions. The XSM is built by integrating the known EVM metrics into the exponential smoothing formulas. Batselier and Vanhoucke (2015) additionally emphasised that XSM demonstrates a significant improvement in overall performance compared to the most accurate project forecasting methods proposed by previous research.

They further argue that the XSM can be applied in both a static and a dynamic way. The static approach chooses the model's parameters before the project begins and remains constant throughout the project duration. Additionally, Batselier and Vanhoucke (2015) compared the forecast accuracies of the static and the dynamic approach of the XSM with the accuracies of the most known and best performing EVM forecasting methods for both time and cost. They found XSM could potentially produce forecasts that are on average 14.8% more accurate than the best EVM time forecasting methods and 25.1% more accurate compared to the best EVM cost forecasting method.

2.19 Forecasting the outcomes of megaprojects.

Having found that qualitative models or models that best fit past data may not be the best methods to predict future outcomes, judgemental forecasting methods are increasingly being recognised as advantageous over other forecasting approaches such as multiple regression, data mining, neural nets, and big data analytics approaches (Armstrong and Green, 2018; Lawrence et al., 2006). The capability to modify human judgements particularly makes this method more likely to produce improved forecasts (Makridakis and Gaba, 1998). Furthermore, judgemental forecasts are prescribed in situations that are suitable for the characteristics of megaprojects. For example, Makridakis, Gaba and Hogarth (2009) suggested that judgemental forecasting are suitable where there are scarce quantitative data and where the level of uncertainty is very high. Similarly, O'connor and Lawrence, (1998) suggested judgemental forecasting where expert knowledge is believed to be needed to improve forecasting accuracy. Judgemental methods are quick to use and typically inexpensive (Makridakis et al., 1998). However, selecting the best judgemental method may be contingent on the requirements of the forecasting situation (Meyer and Booker, 2001).

Unaided forecasting (where individuals are not provided with any form of guidance about forecasting) is the standard benchmark of judgemental forecasting (Green and Armstrong, 2007).

However, it is not without flaws which have prompted academic researchers to suggest using structured judgemental forecasting methods or tools to predict the outcome of projects over less structured methods (Armstrong, 1986; 2001; Nikolopoulos et al., 2015). Although unaided judgement can provide useful information, this method of forecasting produces inaccurate forecasts as the forecasters may not always be able to recall analogous cases correctly (Green, 2002; Lee et al., 2007).

Therefore, the adoption of structured approaches to judgemental forecasting is considered a way to overcome the limitations of unaided judgement and fully utilise expert judgement (Green and Armstrong, 2007a). Taking this up a notch, Armstrong and Green, (2018) demonstrated that incorporating evidence-based methods are more useful in processing complex information reliably. Similarly, Green and Armstrong, (2004) suggested that an expert's understanding of their own analogies may help them to provide accurate forecasts.

Specifically, there is evidence to show that structured analogies and interaction groups provided more accurate forecast than unaided judgement up to about 54% when the necessary conditions of forecasting are met (Nikolopoulos et al., 2015). These requirements and conditions including but not limited to the employment of experts from diverse backgrounds, using more related analogies, engaging experts with a high level of experience, and encouraging the interaction of experts are contained in the checklist for forecasting methods and principles checklist proposed by Armstrong and Green (2018).

Nikolopoulos et al. (2015) reported that errors from structured analogies are less compared to unaided judgement. Moreover, an analysis across ten comparative tests from three studies show an average 40% reduction in the error of forecasts made using structured analogies (Armstrong and Green, 2018). Nevertheless, the success of judgemental forecasting methods also rests upon careful examination and management of the strengths and weaknesses of the methods chosen (Lawrence et al., 2006; Parackal, Goodwin and O'Connor, 2007).

The Delphi method is a multiple-round survey in which experts participate anonymously to provide their forecasts and feedback (Rowe and Wright, 2001).

After each round, participants receive a report, including descriptive statistics of the forecasts provided. The Delphi method is concluded after a pre-agreed number of rounds or after the desired consensus level is reached by the forecasters. There are four key features of the 'Delphi' group process including anonymity, iteration, controlled feedback, and the statistical aggregation and presentation of group responses. Conversely, the Interaction Groups method suggests active interaction with a group of experts until a consensus forecast is reached through deliberation and discussion. The ability to pool information from these deliberations is a crucial factor that could make or mar the process.

This method is not without its flaws. Potential problems could arise from group biases introduced by the face-to-face contact of the experts, such as the 'central tendency' and the 'dominant personalities' effects (Van de Ven and Delbecq, 1971). Besides, group-based approaches tend to attract extra costs from multiple rounds in the Delphi setup or the need for meetings in the formulation of Interaction Groups. This fact renders these methods relatively more costly than other methods that group-based approaches are competing against and could be a potential disadvantage. Finally, there is mixed evidence about the forecasting potential of Interaction Groups (Armstrong, 2006; Boje and Murnighan, 1982; Graefe and Armstrong, 2011).

PART V. MIND THE GAP

2.20 Research Gaps

According to Hruzova and Thornton (2011) projects still exist during an economic crisis; this bring a noticeable gap in the literature on how project management is been affected during these periods, especially for the megaprojects, where commitment for a long term has been established, and are the ones that need to continue and be completed under any circumstances.

Given the current global economic, healthcare, and supply chain management crisis due to COVID-19 (Nikolopoulos et al. 2020), and the amount of megaprojects that are stalling and need to be progressing, makes all this a research gap that needs to be addressed immediately.

To that end, judgmental forecasting methods (Nikolopoulos et al., 2015) may seem a better choice for the task – a relatively under-researched area (Litsiou et al., 2020), as megaprojects are usually one-off projects, where past data are not available, and the utilisation of experts and their opinions is necessary.

2.21 Research Question(s)

Given the aforementioned research gap, the main research question for this study is:

> **Which judgmental forecasting methods can we employ in order to get the best possible forecasts for the potential success of megaprojects?**

This research would try to shed light on the following sub-research questions:

a. Which judgmental methods forecast better the success of megaprojects?

b. How this success is perceived by different stakeholders: the project manager, the funders, the public?

c. How important is the experience and expertise of the forecasters?

As we will be elaborate in the next chapter, these will be achieved through the empirical results provided by a series of controlled experiments; where participants with different levels of expertise will have to provide judgmental forecasts with a series of different forecasting methods, for three megaprojects: well disguised so the participants cannot know for what exactly they are forecasting, but with enough detail in order to complete the task.

3. Methodology

In this chapter,

I articulate my philosophical approach to the alternative route to scientific discovery via first illustrating clearly the advantages and disadvantages of respective dominant schools of thought including positivism, interpretivism and distinguish between quantitative, qualitative, inductive and deductive research. I devote a lot of time in conveying the benefits of employing Saunders' research onion, and conclude with my take on the most appropriate methodological approach for the set of research question in my thesis that is qualitative in nature, and thus the selection of <u>controlled experiments</u> (with subjects imposed on forecasting task with different forecasting methods) is perceived to be the most appropriate way for the quest in hand.

3.1 Introduction to "Methodology."

"What is this called science?" (Chalmers, 1982)

"Research methodology is a way to systematically solve the research problem" (Kothari, 2008:24). Hesse-Biber and Leave (2011) cite that methodology is the bridge that brings together the adopted philosophical stance and the methods used (tools and instruments) to collect data. The term "methodology" has been used in the management sciences extensively; however, different researchers have outlined several uses of methodology in the past (Lehaney and Vinten, 1994). Rajasekar et al. (2006) define methodology as the rational process that researchers follow to describe a research problem. Furthermore, Polychronakis (2011) argues that the term "methodology" is a blend word that is formed from a combination of two Greek words: "methodos" and "logos". "Methodos" refers to a systematic and particular procedure for achieving a pre-set aim, and "logos" is a term - among various meanings – describing the logic behind an argument. Leedy and Ormrod (2001:14) state that *"research methodology is the general approach the researcher takes in carrying out the research project"*. Moreover, Lehaney and Vinten (1994) argue that it is the synthesis of planning and drawing the process of conducting the research with the respective methods and techniques to address the research questions. In the same manner, for Lawrence Neuman (2014), methodology means to understand the entire research process and the philosophical assumptions, while methods are the specific techniques to gather data.

An experienced researcher should distinguish the terms "methodology" and "methods" and understand the difference between these two. Methodology refers to the philosophical discussion about the research approach that the researcher will adopt and, as Creswell (2007) states, the overall decision involves the plans and the procedures that the researcher sets to study a topic. On the other hand, the term "research methods" is used to describe the decisions involved in the

various methods available for data collection with the analysis and the interpretation of the findings.

Research methodology holds many dimensions aiming to set the rationale of the overall research approach (Kothari, 2008). This chapter examines the research principles of the study and discusses the reasoning of the research problem. It also presents the research decisions on the adopted philosophies, along with the justification of the selected approaches and techniques. The implemented approach on how the data has been analysed is also critically presented. Lastly, validity reliability and ethical considerations summarise the methodological approach.

The fundamentals of this study give emphasis on interpretivism, inductive and experimental research methodology as the critical element of this study. The methodological approach in this study is supported by Saunders' et al. (2015) research onion, in which the stages of the research philosophy are illustrated.

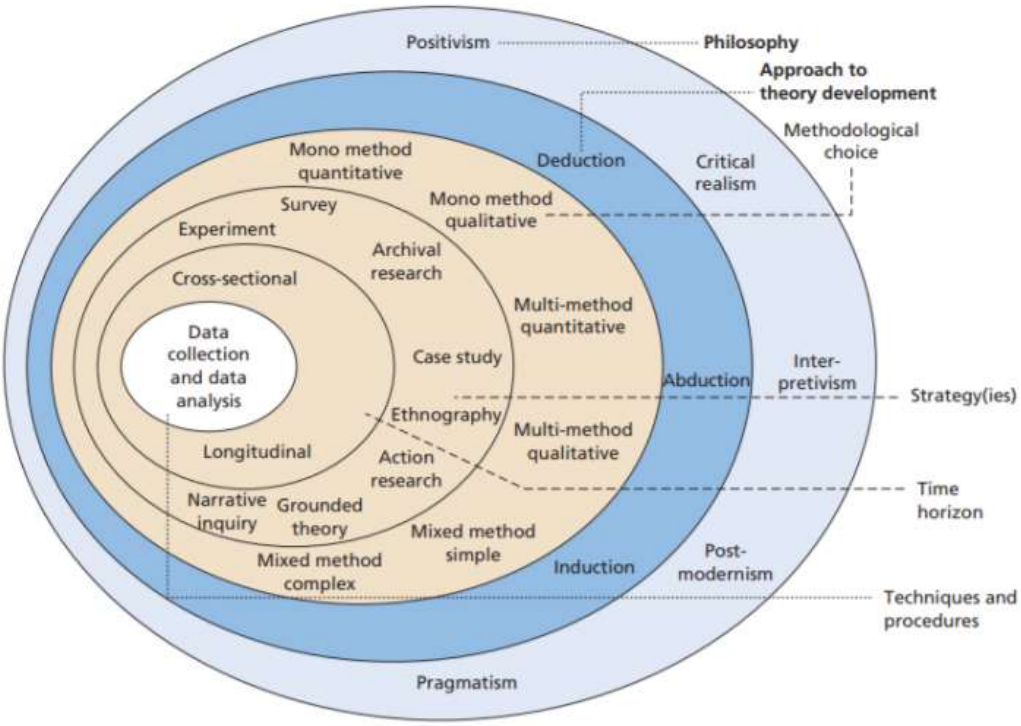

Figure 3.1 Research philosophy in the 'research onion'

(Source: Saunders et al., 2015, p. 124)

Easterby-Smith et al. (2015) state that every research design comes with a series of decision for the researcher in order to answer a particular research question and, they state:

> *A research design is a statement written, often before any data is collected, which explains and justifies what data is to be gathered, how and where from. It also needs to explain how the data will be analysed and how this will provide answers to the central questions of the research.*

Sekaran and Bougie (2013) parallel the research design to a blueprint of the research process to collect and analyse the data for a particular research problem.

In the Literature Review chapter, the Judgemental methods have been extensively discussed (the reader may revisit section 2.16 for a general review of these), or sections 4.1.3 and 4.2.1 and 4.3.2 for the specific judgmental forecasting techniques employed in this thesis), in order to engage the reader early with the key approaches/methods employed in this piece of research. In this chapter, the underpinning considerations on the methodology and other available methods are being examined extensively. This will create a more spherical idea of why the researcher adopted this specific strategy.

After a thorough discussion of various viable alternatives, I do argue for the use of controlled experiments as the primary methodological approach in this thesis.

3.2 Philosophical Considerations

"There is nothing so practical as a good theory" (Lewin, 1948).

Researchers tend to adopt the research philosophy that they understand how the knowledge and the process are developed (Saunders et al., 2009). The underlying philosophical considerations based on the meaning of the word "methodology" constitute the approach used to design the methodology and the relative methodological decisions on the grounds of providing clear addition to the development of knowledge.

Saunders et al. (2009) state that in any nature of a study, a research philosophy underpins the development of new knowledge in a particular field. Which research philosophy the researcher adopts and which is better depends on the research questions the researcher is seeking to answer. This study examines the various judgemental techniques to forecast the success of megaprojects. Bryman and Bell (2011) point out that the link between theory and research should answer issues as to what form of theory the researcher is talking about and if data collected to test or to build theories.

Besides and according to Scotland (2012), researchers must support their views on how they perceive things really work and how they really are. Holden and Lynch (2004) distinguish two points of view based on the sociological dimension: regulatory and radical change.

Easterby-Smith et al. (2015) support that ontology is about the nature of reality and existence and describe four ontologies: realism, internal realism, relativism, and nominalism and go on to say that ontology describes the nature of reality and existence; epistemology is the system of questioning the nature of the world. In this study, the researcher adopts the relativist approach to nature's ontology; the truth is subjective to human's interpretation.

Burell and Morgan (1979) state:

> *"The view that researcher interprets the nature for both society and science, develop the philosophical perspective that she/he will adopt to carry the research".*

Saunders et al. (2009) examine various research philosophies, and the term paradigm is seen as the holistic approach to examining social phenomena. As Holden and Lynch (2004) argue, the nature of society and the nature of science are two core elements upon which assumptions are made to develop a philosophical perspective.

Among various epistemological approaches, "positivism" and "interpretivism" are two basic and most important epistemological approaches when conducting sociological research (Saunders et al., 2009). Baker and Foy (2012) suggest: *there are two broad approaches to research – positivistic and interpretivistic*.

3.2.1 Positivism

Auguste Compte (1798-1857) is considered the founder of positivism and stresses that knowledge can be found only through experience. Habermas (1971) supports the same idea and adds that it is only possible for empirical science to produce legitimate knowledge. However, for Easterby-Smith et al. (2015), the key idea of positivism is the ontological assumption that reality is external and objective and the epistemological approach that knowledge should always be based on observations of this external reality. Moreover, Saunders et al. (2009) state that the researcher adopts positivism philosophy chooses to be the observer of the phenomena and their research is based on facts rather than on impressions. To the same extent, Easterby_Smith et al. (2008) support that the social world should be examined only through objective methods; this is the philosophy research approach scientists from physics and nature sciences adapt, according to Remenyi et al. (1998).

Brymal and Bell (2007) state that the positivist approach of positivism is mainly linked with the deductive research approach and Eriksson and Kovalainen (2008) assert that the aim of research should be in finding casual explanations and regularities and they argue:

> *"Other philosophical approaches have more relevance for qualitative research than positivism"* (Eriksson and Kovalainen, 2008:20).

3.2.2 Interpretivism

Of the far side to the positivist orthodoxy stands the interpretivism epistemology (Bryman and Bell, 2011) that contrast the approach of the natural sciences radically. Among the terms that have been used to describe the philosophy of interpretivism are "constructivist", "hermeneutic", and, "phenomenology" approach (Creswell, 2007). The origins of the interpretivism paradigm could be found in the work of German sociologist Max Weber, who is known for being the central influence for this philosophical tradition. Moreover, German philosophers such as Edmund Husserl, Wilhelm Dilthey and many more, developed a further understanding of the philosophy of interpretivism (Mertens, 2005).

An interpretivism researcher engages an interpretative stance and subsequently adopts a more subjective approach to the social activities, and he or she would aim to draw a social-scientific frame out of the interpretations (Bryman and Bell, 2011). In the same vein, Woods and Texler (2001) argue that, unlike positivists' understanding that the world is independent of human knowledge, interpretivism aims to put the interpretation of the phenomena meaning in a social and cultural context. According to interpretivism, research is conducted by the principle of understanding the connection between the world and human experience (Cohen and Manion, 1994)

The interpretivism approach relies on the inductive strategy (Bryman and Bell, 2011), however, the researcher should anticipate that associations are involved among epistemological approaches; these latter ones constitute only tendencies of research practices and for this reason, should not be overstated.

In an interpretivistic approach, the researcher does not start with a theory as with positivists but seek to develop a theory through an inductive approach and qualitative data collection (Creswell, 2007).

The following table sums up the main differences between positivist philosophy and interpretivism philosophy:

Beliefs and Assumptions	Positivist Approach	Interpretive Approach
Nature of reality	Reality is single, tangible and objectively given	Realities are socially constructed, there can be multiple constructions and realities, they are accessed through shared meaning
Relationship of knower to the known	Knower and known are independent (dualism)	Knower and known are interactive and inseparable
Possibility of generalisation	Generalisations are possible, and are time- and context-free	Only time- and context-bound working hypotheses are possible
Possibility of causal linkages	There are real causes, that precede or are simultaneous with their effects	All entities are in a state of mutual simultaneous shaping, so that it is impossible to distinguish causes from effects
Role of values	Inquiry is value-free	Inquiry is value-bound
Research methods usually used	Quantitative	Qualitative
Aim of knowledge	Increase predictive understandings of phenomena	Deep and insightful understanding of phenomena[7]
Attitudes to field practice or action	Practice and research inquiry are separate enterprises	Research is a type of practice that affects the context and can be a deliberate intervention strategy (action research)

Source: adapted from Lincoln/Guba 1985.

Table 3.1 Positivism versus Interpretivism (to be substituted with my own adopted version in the final submission)

An experienced researcher should always consider the possibilities of unexpected issues that he/she might come across during the research process; extra effort to minimise the risk and the uncertainty should be given during the stage of the research design by evaluating and adopting the best possible methods (Kulatunga et al, 2006).

> *Good research designs need to have some link to theory* (Easterby-Smith et al., 2015:101).

As previously mentioned, this study adopts the interpretivism approach that no hypothesis exists and the theory will be drawn based on the outcome that the following areas address:

a. it is of great importance to answer with this study to WHAT individuals believe for a certain condition – in this particular case is WHAT are the best judgemental techniques in forecasting the outcome of megaprojects,

b. HOW do the people that are involved, interpret the entire specific facts and experiences (from conceiving the idea to deliver the service), and,

c. WHY (if that is the case) certain techniques are better than others in forecasting the success of megaprojects.

Having made the above decisions on what research philosophical stance will be adopted and with “what” we need to know and “why” we need to know in mind, the next step is to decide how to obtain that information.

3.3 Exploratory research

Research in any field begins with curiosity (Stebbins, 2001).

This curiosity could be answered through several types of research questions as categorised by Yin (2018, 2009, 1994): "what", "who", "where", "how" and "why"; this study examines "what" are the best judgemental techniques to forecast the success of megaprojects. Kalu and Bwalya (2017) cite that research design and the decision on what methods will be used to collect and analyse data is a fundamental element of the research design because these decisions should answer the research questions. Part of the components of the research design is to outline the purpose of the study, which, in this case, is exploratory. Saunders et al. (2019) further support that research questions in exploratory research usually start with "What" or "How".

Exploratory research offers some attractive alternatives to how individuals see and perceive reality (Stebbins, 2001). The nature of this study is to explore new areas in the forecasting arena, whereas specific characteristics are expected to be identified. It has previously argued in this study the lack of information and the limited knowledge of the best judgemental methods to forecast the outcome of megaprojects. Previous studies on the project management ground are focused on completing the project on time, within the budget and, meet the scope (Simpson, 1987) elements that have been considered in the planning phase of a project. Along these lines, the literature suggests (Sekaran and Bougie, 2013) that exploratory research is fitting well when little is know – the case of megaproject - and more data is needed to draw conclusions. This piece of research will add to the success of megaprojects, that due to their unique characteristics will add to that.

Quite often, exploratory research goes hand in hand with secondary research. An extensive screening on the literature review pertinent to the research topic can provide a good insight into the research problem. On top of that, data collected from interviews, focus groups, projective methods, or case studies can prove qualitative research approaches are appropriate in exploratory research.

"Pure exploration, starting from zero, is impossible" (Reiter, 2013). There is a number of ways to conduct exploratory research. This includes a search of the literature; interviewing "experts" in the subject; conducting in-depth individual interviews or conducting focus groups interviews (Saunders et al., 2019) - interviewing experts is a key concept in this research. Additionally, the low cost and the demand for limited resources to conduct exploratory research make this approach appealing to any research that has a limited budget (Stebbins, 2001). The limited resources in a Thesis strengthen the decision to adopt this research approach along with the suitability of the research questions.

Reiter (2013) suggests that exploratory research is reliable when it is conducted in a manner of transparency and honesty that lead to innovative ways to analyse reality. Gambrill (2007) argues that researchers must provide honesty in data, and they must be transparent about their choices; this can help to identify significant gaps in the current understanding. This study takes into account its contribution to the theory and the practice in judgemental forecasting. Answering which method offers the best forecasts in the success of Megaprojects may bring to light more areas to research and explore.

Literature (Reiter, 2013) also suggests that exploratory research pursues new explanations that haven't been previously documented. The role of the researcher is to remain actively engaged with the process, and, to provide new enlightenments of the actual reality. Exploratory research, like inductive research, focuses on the development of social phenomena rather than the results of human behaviour (Reiter, 2013).

3.4 Inductive reasoning

NEARLY EVERYONE would see the truth as between Hamlet and Puck. Including Hamlet and Puck (Conlisk, 1996).

Inductive reasoning lies in the Socratic method, whereas generalisations gradually attained through dialectical questions and answers. This study aims to reach conclusions and recommendations based on the interpretation of the collected data. No previous assumptions are made; even if we wanted to do so, there is a limited insight on which forecasting methods provide the most accurate outcomes on the success of megaprojects. More specifically, when judgemental techniques applied, we may use some previous arguments and ask research participants to recall incidents and experiences. However, for this study primary data are being collected to draw our conclusions on the best available techniques to forecast the success of the megaprojects; there is no hypothesis we aim to validate.

Goel et al. (1997) argue that valid deductive opinions comprise absolute grounds for accepting the conclusion, and validity is a purpose of the logical structure as opposed to sentence content. Arguments, where the evidences provide only limited grounds for accepting the conclusion, are broadly called inductive arguments. Stebbins (2001) argue that the main objective of exploratory research is to create inductive generalisations based on the subjects under study, rather than testing hypotheses (Reiter, 2013). Brian (1994) additionally support that humans use inductive reasoning when they attempt to apply rationality. These hypotheses will be replaced by the new ones when these new propositions convince the researcher of their validity. In a similar vein, Reiter (2013), support that, exploratory research does not start from scratch; the theory is constructed gradually by the explanations and hermeneutic analysis of the data. Stebbins (2001) further argue that "the art of exploratory research is evident in the ideas that emerge from data".

Brian (1994) suggests that humans adopt an inductive behaviour when we do not have the full picture of a problem and in order to understand it, we use simple models to realise it.

3.5 Quantitative, Qualitative and Mixed Research Methods

Interestingly, Trochim et al. (2015) stress the argument that "truth" and "reality" are subjective and depend on an individual's perspective; they give the example of the movie "*Rashomon"* (1950), in which four crime witnesses account four different perspectives. Saunders et al. (2019) propose that a good research design should state clearly the aim, the objectives and the research questions and further stipulate the sources for gathering the data and outlining how the data will be analysed.

Literature suggests (Aspers and Corte, 2019) that there is a clear distinction between numerical and non-numerical data. A quantitative approach is related to numerical data and techniques to collect data such as questionnaires that are usually designed for statistical analysis (De la Rosa de Sáa et al., 2015). A qualitative approach is a synonym with non-numerical data gathered via methods such as interviews and focus groups, and the analysis is mainly to categorise the data (Gill et al., 2008)

Giddens (1976) support that the two distinctive research approaches to gather and analyse the data represent antithetical propositions in social sciences. He also defines these propositions as positivistic versus interpretivism. Literature suggests (Gilbert, 2008; Creswell, 2007; Saunders et al., 2015) that the adopted approach shall reflect the researcher's philosophical assumptions about the nature of social reality and the relationship between the researcher and the topic under study.

In the research design, the researcher may decide to combine qualitative and quantitative approaches (Fielding and Schreier, 2012). This can be an example of a study that questionnaires have been used, and the analysis showed the need for further understanding in a specific area. Or, on the other hand, interviews have

been conducted and have been quantitatively analysed (Levashina et al., 2014). Gelo, Braakmann and Benetka (2008) support the continuous debate between qualitative and quantitative research approaches end up in developing the mixed method. Bryman (2012) argues that behind any of the above approaches, a combination of epistemological and ontological views guide research decisions such as what research methods will be used to gather data.

In the following part, a depiction of the characteristics of each of the above research methods aims to develop an understanding on what is the adopted research methods for this research and why this is the most suitable approach to answer the research questions.

3.5.1 Quantitative Research Method

> *Quantitative research begins with a problem statement and involves the formation of a hypothesis, a literature review, and a quantitative data analysis (Williams, 2007).*

Quantitative research appeared around 1250 A.D. and was motivated by the need to quantify data (Williams, 2007). Creswell (2007) suggests that in quantitative researches, researchers aim to test theories to support the explanations of their research questions. It is typical in a quantitative study, a considerable part of the research proposal to outline the theory for the study. Gilbert (2008) also cites that quantitative research validates hypotheses by using numbers while Bryman (2012) supports that in quantitative research, the researcher tries to answer why things are the way they are rather than explaining how things are.

Williams (2007) states that quantitative research design involves a numeric or a statistical approach while Lawrence (2014) supports that researchers that implement a qualitative approach adopt methods that will produce data in the form of numbers. The quantitative research approach is described by Bryman (2012) as a deductive approach that is broadly applied in a positivistic strategy. Literature suggests (Glesne and Peshkin, 1992; Creswell, 2007 Lawrence; 2014) that objectivity is the main characteristic of the quantitative approach that

involves the collection of numerical data and underpinned by a positivism philosophy.

Murray (2003) suggests that researchers that use a quantitative research method, have a plethora of available methods to select. Conducting a survey is a widely adopted technique in a quantitative study (Rosenberg and Gleit, 1994). Structures interviews and structured observations can also be used.

This study stands in the opposite philosophical assumptions to those discussed in this section; an interpretivistic philosophy underpins the research decisions taken for the research purposes. This study seeks to collect non-numerical data to draw conclusions and theories through techniques that provide explanations on what is the best possible judgemental forecasting methods in forecasting the success of megaprojects. The qualitative research approach is discussed below to provide an understanding of the justification of adopting this approach.

3.5.2 Qualitative Research Method

Quantitative researchers fail to distinguish people and social institutions from ' the world of nature ' (Schutz, 1962).

Kalu and Bwalya (2017) state that the researcher should adopt a qualitative research approach when the phenomena under study can't be measured with quantitative researches. While quantitative research methods are focusing on numerical data, quantitative research methods are centred around non-numerical data. Nevertheless, Bryman (2012) argues that the uniqueness of qualitative research is far more than the absence of numbers.

Sandelowski (2001) recognises a myth that supports that qualitative researchers do not count and they cannot count. Both qualitative and qualitative research approaches are parallel, and they can be adopted to establish the importance of a study and to answer the research questions (Sandelowski, 2001).

Nonetheless, Gilbert (2008) suggests that between researchers that adopt a quantitative research approach and those who adopt a qualitative research approach there are distinctive differences in their philosophical assumptions

about the nature of the reality and the researcher's role. Researchers support that by relying on qualitative data and adopting a qualitative research approach, and they can have a more in-depth insight into social phenomena (Silverman, 2018). Myers (2013) argues that qualitative research methods aim to support researchers in knowing people's beliefs and interpretations of the phenomena by talking to them.

Myers (2013) state that the only way to better understand how and why people act the way they do is to examine their behaviour in context; Kaplan and Maxwell (1994) maintain that participants' judgement is lost when quantified. Silverman (2018) cites that a deep understanding of certain phenomena can only be derived from qualitative studies. Hancock and Algozzine (2017) argue that qualitative research has certain characteristics in principle; however, they point out that numerous differences constitute different types of qualitative research.

Creswell (2007) argues that whenever a problem needs to be explored, a qualitative research approach is more suitable, which is the case for this study. In this piece of work, we are looking to explore the best available judgemental forecasting techniques that give the best forecasts. Nieuwenhuis (2015) also argues that in qualitative exploratory studies, the aim to look into depth specific areas guide the qualitative exploratory design; rather than coming up with final answers or solutions to problems. Creswell (2007) points out that theory generation in qualitative research is the outcome of a study while Nieuwenhuis (2015) states that qualitative exploratory research is principally inductive with data supporting the researcher to get a better understanding of a certain phenomenon.

3.5.3 Mixed Research Methods

In mixed methods research, researchers may both test theories and generate them (Bryman, 2012).

The mixed methods research field is developed around the mid-1980s (Creswell; 2007). However, Maxwell (2016) supports that captions of the mixed approach have been detected earlier in Campbell and Fiske's (1959) work on triangulation. Webb, Campbell, Schwartz, and Sechrest (1966) prolong this statement and support that more than one method must be employed in the validation process. Nevertheless, the literature suggests (Johnson et al., 2007; Bryman, 2012; Creswell, 2007) that researchers may adopt the mixed research method to gather and analyse data because this approach supports a better understanding of the research problem. Johnson et al. (2007) stress that researchers may adopt both quantitative and qualitative research methods in order to address the study's research questions. All these arguments reflect what Webb et al. (1966) state that mixed methods research regards multiple viewpoints, perspectives, positions, and standpoints.

Creswell (2007) argues that researchers who decide to use the mixed method are when the either quantitative or qualitative approach does not produce a legitimate understanding of the research problem. Nonetheless, in their study "The acceptance of mixed methods in business and management research", Cameron and Molina-Azorin (2011) stated that 14 per cent of empirical studies adopt the mixed-method research approach.

Denscombe (2008) state that those researchers use a mixed-method research approach; they are also consistent with a pragmatist research paradigm. Antithetical to this statement, this study follows the interpretivism paradigm. Literature (Molina-Azorin, 2016; Molina Azorin and Cameron, 2015) also suggests that in studies that data show the need to enhance the results, mixed-method can contribute to developing a better understanding. For this study, a mixed-method approach wouldn't add anything to the adopted qualitative research approach that addresses the research problem and creates the outcome to answer the research questions.

3.6 Methods

Choosing the right method to gather the most valuable and appropriate data can be a challenge for the researcher. Gilbert and Stoneman (2015) argue that elements such as time budget and research subject can define which method will be used in a study. Moreover, Bryman (2012) supports that different research methods are associated with different kinds of research design. Nevertheless, Maxwell (1997) supports that a qualitative research design involves a wide concept of "design".

3.6.1 Experimental research

To 'experiment', or to 'carry out an experiment' can mean many things (Robson, and McCartan, 2016).

Dennis and Valacich (2001), state that the primary aim of experimental research is to contribute to theory and that its main strength is precision and control. This view backs up this study that aims to fill the gaps in the judgemental forecasting literature. Judgmental Forecasting methods are adopted extensively in the design of experimental research (Petropoulos et al., 2018), where a series of controlled experiments were run on the potential appropriate use of forecasting methods and the respective choice of them. As such, and given this is the latest article on judgmental forecasting practices in a mainstream operations management journal, it was considered that the use of controlled experiments should be the primary candidate for the methodological choice of this research.

Literature (Tuli, 2010) broadly suggests that fixed designs experimental researches typically draw quantitative outcomes. Nevertheless, Oakely (2000) denies this kind of rule and provides examples of purely qualitative fixed-design studies. Additionally, more researchers (Lee, 1991; Trauth and Jessup, 2000; Dennis and Valacich, 2001) state that it is possible to adopt an experimental research design in a qualitative study – this will help researchers understand the issues better.

Robson and Colin (2011) suggest four different experimental types of fixed designs:

1. the true experimental fixed designs, in which people assigned randomly in two or more groups whereas the researcher actively manipulates the process;
2. the single-case fixed designs that focus on individuals and in which participants are exposed to different experimentally controlled conditions,
3. the quasi-experimental fixed designs that involve the manipulation of an independent variable and lack the random assignment of participants to conditions, and,
4. the non-experimental fixed designs that do not involve any manipulation.

While Robson and Colin (2001) support that in experimental research, a variable is controlled, Dennis and Valacich (2001) cite that in the experimental research, cause-effect relationships among the variables are evident. In a controlled experiment (Sekaran and Bougie,2013; chapter 10) the researcher set a strict environment in order to test how a method or treatment works. In this study, a quasi-experimental fixed design strategy is adopted with participants being split into groups according to their expertise. The variable that is controlled by the researcher is the different judgemental forecasting methods to forecast the success of megaprojects. The available forecasting methods to use are the Unaided Judgemnet, the Structured and semi-Structured Analogies, the Interaction Groups and the Delphi method.

According to psychologists, Fechner (1889) is the "father" of experimental psychophysics and aesthetics (Arnheim, 1985). Smith (2012) argues that among other contribution in the field, fixed design experiments have been used extensively into behavioural studies as well as developing and enlightening theory. The work of Skinner (1938) has also added value to experimental research designs. Psychologists have acknowledged Skinner's influence, and they tend to either embrace his approach or reject it.

Experiments were introduced as a learning exercise to groups of undergraduate and postgraduate students, with of course ethics approval from the respective institution given the outcomes would be used for research purposes, and with consent taken from subjects as per their responses to be used in this thesis, studying at the Indian School of Business, Salford Business School, and Bangor Business School. In the Findings and Discussion chapters, detailed information is given on the details of these experiments i.e. the data collection process, the subjects, the venues and the timeline. The reader may visit section 4.1.2 for the respective details of experiment 1, section 4.2.2 for the respective details of experiment 2, and section 4.3.1 for the respective details of experiment 3.

3.6.2 Case studies

One approach to use the case study method, according to Yin (1994), is to test theory, while the other approach, Eisenhardt (1989) affirms, is to develop theory. Yin (2018, 2009, 1994) perceives a case study as a research strategy through which the researcher tries to understand the dynamics present within single settings. Furthermore, a case study provides a rich amount of data for the researcher to analyse by examining in-depth one or a small number of organisations or individuals (Easterby-Smith et al., 2015; Gummesson, 1988). Furthermore, Tight (2017) cites that a *case study is small-scale research with meaning*, however, its findings could notably contribute to a discipline.

The researcher seeks to develop theory from data analysis. As Baker and Foy (2012:184) state, *case studies are useful and important when seeking to develop theory inductively through description and analysis of new and emerging phenomena.*

Glaser and Strauss (1967) cite:

> *It is the intimate connection with empirical reality that permits the development of a testable, relevant, and valid theory.*

Research problems that fall under the term “what” – the case of this study - may be answered through the case study approach, the most appropriate method to

answer a "what" research question according to Perry (2001). Trochim et al. (2015) argue that researchers conduct qualitative research, predominantly aim to develop some theory through the deep understanding of a phenomenon from individuals' point of view. Chetty (1996) states that in social and management studies, the case study method constitutes a fundamental part of the research. According to Yin (1994), when behaviours are examined – which is what this study aims to do – the strength that the case study method has over the survey method, is that it measures and records the behaviours and doesn't rely on the verbal information only. Nevertheless, Chetty (1996) anticipates the criticism of the case study method, namely that it is limited on generalisation from only one or a few case studies' findings. However, the researcher concurs Chetty's (1996) statement that the case study method's strengths outweigh its weaknesses.

Kidder (1982) argues that case studies could be used in studies aiming to provide description and furthermore, Gersick, (1988), and, Harris and Sutton, (1986) state that through case studies, theory could be developed. Chetty (1996) supports that in studies where literature is insufficient, the case study method is ideal and she also argues that in case study method an organisation is being assessed from more than one single variable. Thus, Zainal (2007) argues that in cases where a researcher wants to examine the data within a particular context, he/she should adopt the case study method. Furthermore, she also adds that it is very common in case study approach for the researcher to include a small number of cases in his/her study or a small geographical area. Holloway (1997) cites that in interpretive research – the case of this research – the number of examined cases is rather small. Nevertheless, different researchers (Yin, 2009; Levy and Powell, 2005) support that multiple cases suggest more robust and persuasive results.

According to Bonona (1985), Hippocrates first originated the concept of case study 2300 years ago by presenting 14 classic case studies of disease. Furthermore, Piekkari et al. (2009) argue that among various strategies in qualitative research, a case study is the most dominant and, more particular as Welsh et al. (2011) cite, a case study is well recognised in qualitative international business. Nevertheless, while Burns (2000) declare case study as an exclusive qualitative method in nature, Easterby-Smith et al. (2015) argue that case study

approach could produce data either qualitative, quantitative or both. Moreover, Yin (2018, 2009, 1994): claims that any of the above kind of data could be collected through several data collection methods such as archives, interviews, questionnaires and observations in case study research strategy.

Yin (2009) stresses the importance of a well-prepared data collection process as the opposite might jeopardise the entire study. Moreover, Yin (2009) support that the following four steps should be part of every well-designed data collection stage:

1. the researcher should fully understand what is being examined, being able to separate her/his personal beliefs from the case, being adaptive and flexible to any new information and investigate the case in an unbiased way.
2. a developed protocol should be followed throughout the data collection process. The researcher should have addressed all possible issues that might pop up during the case study investigation. Yin (2009:79) cites: "The protocol is a major way of increasing the reliability of case study research and is intended to guide the investigator in carrying on the data collection from a single case."
3. which case study(ies) the researcher selects to examine is a crucial part of the process. Out of possible available cases that exist out there, the researcher should "screen" which one(s) fit in the research's framework.
4. a pilot case study is an important stage in a case study method. As Yin (2009:92) states: *"A pilot case study will help you to refine your data collection plans with respect to both the content of the data and the procedures to be followed".*

Yin (2009) argues that among a long list of various sources for findings, the most common are: documentation, archival records, interviews, direct observations, participant-observation, and physical artefacts. Moreover, he also stresses that there is no straight advantage of one source over the other and they should be considered complementary; a good study should use as many as possible for the validity of the research. Furthermore, Creswell (2007) supports that, in qualitative

approach research, several sources of information (observations, interviews, documents and many more) are available for the researcher to investigate *"a bounded system"* (a case) or *"multiple bounded systems"* (cases).

Thus, Eisenhardt (1989) argues that by adopting the multiple-cases approach, the researcher could create stronger arguments by proving repetition among individual cases. In the same vein, in her study "Better stories and better constructs: the case for rigour and comparative logic" Eisenhardt (1991) cites:

> *Different cases often emphasise complementary aspects of a phenomenon. By piecing together the individual patterns, the researcher can draw a more complete theoretical picture.*

Silverman (2018) stresses that attention should be given to the data analysis process rather than the adopted data method, and he cites:

> *Analysing data is the heart of building theory from case studies, but it is both the most difficult and the least codified part of the process (Silverman, 2018.)*

Denscombe (2018) state that for the interpretivistic approach - that is the adopted approach for this study - the data exist only after the researcher has interpreted them and he continues by supporting that the researcher's part in producing and interpreting the qualitative data is of great importance.

Thematic analysis has been widely used for analysing qualitative data (Braun and Clarke, 2006; Nowell et al., 2017) and could be used for organising, describing, and defining themes in a data set (Braun and Clarke, 2006). This study examines individuals' perspectives, and as literature (Braun and Clarke, 2006; King, 2004) suggests, thematic analysis is a suitable approach to interpret interviewee's perspectives by examining the similarities and differences.

The researcher will borrow Nowell et al.'s (2017) step-by-step process of how to deal with the qualitative data in every phase of the process of the thematic analysis in order to establish trustworthiness.

3.6.3 Interviews

Nowadays, as Gubrium and Holstein (2001) argue, we are part of an "interview society" with interviews being all over the place, and furthermore, as King and Horrocks (2010) state, interviews have become a global feature. For research purposes, interviews could provide a more in-depth understanding of individuals' views, beliefs and experiences than any other qualitative research method (Gill et al., 2008). Furthermore, interviews are most appropriate in cases where little is known – the case of this study (Gill et al., 2008).

Based on what this study examines and what the researcher aims to shed light on through this research, in-depth interviews could be considered as one method to collect relevant data – however, this would require many people-months to go over each and every individual while through an observational study or a series of controlled experiments much time could be saved and more data collected. Nevertheless, the literature suggests (Jones, 1985; O'Connel and Cummins, 1999) that the researcher could use in-depth interviews as they leave space to individuals to express why they act as they do in their own terms. Gill et al. (2008) identify three types of research interviews: structured, semi-structured and unstructured. Case study interviews are usually unstructured, in the form of relaxed, informal discussions that could provide the researcher with valuable data (Yin, 2008).

By embracing this method, interviewees will extensively discuss their perspectives on the project management techniques and challenges they have to undertake/adopt/face during the period of the economic crisis. Interviewees will be encouraged to share their views with the interviewer and express in their own words their standpoints and perceptions on this condition.

Researchers tend to adopt an interview position either as a passport to the experience or as a benchmark of individuals' say (Gubrium and Holstein, 2009; Riessman, 2016; Silverman, 2014). Having said that, researcher's stance for this study includes both positions, as the main aim is to interview people and ask about their views and perceptions; the researcher will take the research further and adopt a role as an observer to examine what people actually do.

Using mixed methods can be attractive as they provide the researcher with a broader picture (Silverman, 2018), and they satisfy broader methodological considerations as they cover triangulation and internal validity. Please see next section for the full commentary.

3.6.4 Observation studies

'Observation' and more particularly 'Participant observation' is according to Mason (2007) a term used to describe the process during which the researcher is fully engaged and is part of the whole experience to the method of gathering data into the research spot. Furthermore, Kawulich (2005) states that in various disciplines, the term 'participant observation' is a tool for qualitative research to collect data when either people or processes or cultures are examined. In the same vein, Mason (2007) argues that in cases that various dynamics such as individual's views, interpretations and experiences are examined or other verbal or non-verbal behaviours needed to be investigated, participant observation method could help to assemble these data.

In this study, the researcher wishes to undertake the observational method on top of the in-depth interviews to better understand and examine people's views and tactics in practice. By additionally adopting this method, the researcher would participate actively in the research's setting and will gather data that interviewees might not have shared during the interviews in the first place. As Mason (2017:142) states:

> *"Choosing to use observational methods usually coincides with the view that social explanations and augments require depth, complexity, roundedness, multidimensionality and contingency in data, for which a close up and dynamic view is required".*

Mason (2017) adds that the researcher might decide to use this method to participate and observe whenever the data required for the research is not available in different ways or forms. In this study, data required are most related to peoples' interpretations in a certain condition – this of economic crisis – so the researcher should base her data to not only what individuals' views are but also

being able to check in what extend what is said is being undertaken as well. Thus, Morgan et al. state that observations support the researcher to see what individuals do rather than what they say they do. Literature also argues that the researcher could gain more information by observing individuals than via other self-completion data collection method. People might not be able to remember, or be aware of, decide or choose to report.

3.7 Comparison of Data Collection Methods

The following table 3.2 summarises the strengths and weaknesses of various approaches, as discussed in the previous paragraphs, and confirm my decisions to select a series of controlled experiments in order to answer my main research question in this thesis:

Source of Evidence	Strengths	Weaknesses
Documentation	· stable - repeated review · unobtrusive - exist prior to a case study · Exact - names etc. · broad coverage - extended time span	· retrievability – difficult · biased selectivity · reporting bias - reflects author bias · access - may be blocked
Archival Records	· Same as above · precise and quantitative	· Same as above · privacy might inhibit access
Interviews	· targeted - focuses on case study topic · insightful - provides perceived causal inferences	· bias due to poor questions · response bias · incomplete recollection · reflexivity - interviewee expresses what interviewer wants to hear
Direct Observation	· reality - covers events in real time · contextual - covers event context	· time-consuming · selectivity - might miss facts · reflexivity - observer's presence might cause a change · cost - observers need time
Participant Observation	· Same as above · insightful into interpersonal behaviour	· Same as above · bias due to investigator's actions
Physical Artifacts	· insightful into cultural features	· selectivity
Experiments	· insightful into the effect of one change at a time in the forecasting process	· needs very careful and detailed design

Table 3.2 Six sources of evidence: Strengths and Weaknesses - adopted by Yin 2009

3.8 Ethical considerations - Validity – Reliability – Accountability

The more sophisticated research design is, more guarantees on accuracy, confidence, generalizability can be achieved (Sekaran and Bougie, 2013).

3.8.1 Ethical considerations

Researchers must adopt ethical behaviour when they conduct any kind of research; they have to take into consideration how their activities may affect others (Gilbert and Stoneman, 2015). Saunders et al. (2019) argue that researchers need to have ethical considerations in place to make sure they treat those they participate in the research ethically and in a manner not to create any harm to them. It is vital to put a lot of consideration on practices that researchers adopt, and the processes followed to maintain the high ethical approach (Bryman, 2015). Cooper and Schindler (2011) also cite that ethics refer to the right behaviour and respond to how researchers must act in a morally responsible way.

This study takes into account the Salford Business School Ethics Framework. An ethical approach has been maintained during all stages of this research. In the designing stage, a participant information sheet has been developed to provide the rationale of the study and the research problem to potential participants. These forms have been handed to those they took part in the experiment. Participants have also had the opportunity to raise any questions before they decide to participate. It is made clear to every participant that they had the right to withdraw from the experiment at any time they wanted and that their answers will be treated with confidentiality and anonymity.

3.8.1 Reliability and Validity

The terms reliability and validity are used to prompt that research processes are rigorous, and the research outcome is trustworthy (Roberts and Priest, 2006). Bryman (2012) states that reliability is mainly an issue connected with quantitative research. For qualitative research, Gibbs (2007) states that reliability signposts the level of consistency across the data analysis process. For the analysis

in this research, consistency has been followed. Qualitative validity, according to Creswell (2007), means that the researcher checks for the accuracy of the findings by engaging specific actions.

3. 9 Triangulation

Literature suggests (Silverman, 2018; Blandford, 2013; Willig, 2008) that there are no right or wrong methods in the data collection process; there are methods more appropriate for a particular study over the others to answer the specific research objectives.

Yin (2009) state that for a high-quality case study, a good data collection process needed and for validity and reliability purposes the following three principles should be followed:

a. The first principle is about the *Triangulation: Rationale for using multiple sources of evidence.* Multiple sources of evidence make the case stronger and the *development of converging lines of inquiry*.
b. The second principle to be followed is of the importance for the researcher to organise and document the data collected for case studies.
c. The third and last principle that according to Yin should be followed when collecting data in case studies methods is to maintain a chain of evidence.

Yin (2018, 2009, 1994) argues that whenever the aim of a study is to build theory, the researcher should adopt multiple data collection methods; interviews, observations, and archival sources are particularly common in inductive researchers. Moreover, another strong feature of using multiple sources is to avoid subjective bias (Chetty, 1996). However, the researcher could achieve a more in-depth investigation by adopting multiple-data collection methods and through quantitative study (Chetty, 1996).

Nevertheless, Glaser and Strauss (1967) cite that cases are chosen for theoretical, not statistical reasons, with further statement from Pettigrew (1988) who debate, that given the small number of cases usually studied, the researcher should

carefully choose cases that will possibly stipulate the evidence to answer the research aim and to develop the theory in the literature gap.

Silverman (2018) stresses that attention should be given to the data analysis process rather than the adopted data methods. The analysis process that the researcher will implement for this study is being further discussed later in this chapter.

According to Nigel and Jane Fielding (1986) when the researcher uses triangulation, he/she should first take into consideration the theoretical perspective of the study and secondly choose the data collection method that will give the answers to this perspective. *Many qualitative case studies combine observation with interviewing. This may be because you have several research questions or "because you want to use different methods or sources to corroborate each other so that you are using some form of methodological triangulation"* (Mason, 2002: 25). Silverman, 2018: 208.

Morgan et al. (2017) argue that apparently, triangulation provides more in-depth findings when several data sources are used in case study research. Nevertheless, the literature suggests (Cronin, 2014; Yin, 2008) that the credibility of the research findings are supported by triangulation, and the research is more accurate and complete.

3.10 My methodological approach for this thesis

This section has presented and has analysed the methodological approaches and the various possible decisions that need to be considered in any research. As discussed previously, the researcher should adopt those methodological approaches and techniques that will answer the research questions. In conclusion, this study is underpinned by the interpretivism philosophy based on the deductive approach to theory development. This study aims to get an insight into individuals' views in order to build theory. An exploratory qualitative methodological approach has been adopted to gather data with the method of the experiments.

The table below summarises the discussed techniques in this chapter:

Methods	The key concept/advantage	Type Research Questions	Qualitative vs Quantitative	Justification to thesis
Experiments	Contribution to existed literature	What	Qualitative and Quantitative	Quasi-experimental fixed design strategy was applied in this study. The data collection process was based on the outcome of the application of various Judgemental Forecasting techniques. Furthermore, the comparison between those methods provide better forecasts examined.
Case studies	Develop theory from data analysis	What	Qualitative	For the experiments, disguised cases have been provided to participants. Participants needed to answer the questions based on their understanding of what happened in the provided cases.
Interviews	Interviews could provide a more in-depth understanding of individuals	Why, What, How	Qualitative	Interviews have not been used in this research. However, since the researcher needed to moderate the process of the experiment, elements of how to deal with individuals are present.
Participant Observation	Whenever the researcher need to fully engage with the process of data collection	What	Qualitative	This method is not directly applied to the data collection for this research. However, observing how the participants interact and monitoring the process is a vital aspect of the experiments.

Table 3.3 Key approaches for this research

4. Experiments, Analysis, And Results

In this chapter,

I present the set of experiment I have setup and run respectively with students in three different institutes: in the Indian School of Business in 2018, in Salford Business School in 2019 and in Bangor Business School in 2020. I detail the data that were collected and the methods that have been employed by the subjects – undergraduate and postgraduate (MSc & MBA) students, and present the analysis and respective results of my empirical investigation.

4.1. Forecasting the success of Megaprojects with Structured Analogies and Interaction Groups[2]

Forecasting for social good entails the ability and capacity to forecast the success, failure, and impact of one-off Special Events – with one notable example being the initiation and implementation of major projects – usually referred to as Megaprojects. However forecasting the socio-economic impact of projects like Olympic games or space exploration is a very difficult but also extremely important task; not only for the resources allocated in such project but predominantly for the great expectations around them.

Flyvbjerg et al., (2014) argue vividly of how difficult is to forecast the success of such major projects. They claim that:

> *"Large capital investments that are completed on schedule and within their budgets are probably the exception rather than the rule—and even when completed many fail to meet expected revenues. Executives often blame project underperformance on foreseeable complexities and uncertainties having to do with the scope of and demand for the project, the technology or project location, or even stakeholder opposition. No doubt, all of these factors at one time or another contribute to cost overruns, benefit shortfalls, and delays."*

[2] A much later version of section 4.1 is now available advance online on https://www.sciencedirect.com/science/article/pii/S0169207019301967 with the liaison of my main supervisor and colleagues from Bangor university and Durham University, in a special issue on "Forecasting for Social good" in in the International Journal of Forecasting: K. Litsiou, Y. Polychronakis, A. Karami, K. Nikolopoulos (2020). Relative performance of judgmental methods for forecasting the success of megaprojects. International Journal of Forecasting. I thank the student-participants in the Indian School of Business for giving their consent to participate in this research, as part of a formative forecasting assessment in the Forecasting Analytics elective module of the PGP in Management in January-February 2018.

Turner and Zolin (2012) even claim that we cannot even properly define what success is – or what it will be when the Megaprojects target are materialized to some extent. They argue that we need to reliable scales in order to predict multiple perspectives by multiple stakeholders over multiple time frames – so definitely a very difficult long term problem.

This could be done via a set of leading performance indicators that will enable managers of Megaprojects to forecast during project execution how various stakeholders will perceive success months or even years into the operation.

Megaprojects have many stakeholders who have different objectives for the project, its output, and the business objectives they will deliver. The output of a megaproject may have a lifetime that lasts for years, or even decades, and ultimate impacts that go beyond its immediate operation. How different stakeholders perceive success can change with time.

Megaprojects most of the times run for the first time in such a scale, and there is no previous experience or data per se exist on the expectations around the duration, budget and potential socio-economics impact to be achieved. Thus quantitative methods are not the initial choice of weapons in our forecasting arsenal there, and we rely on experts and judgmental forecasting for the aforementioned challenging task. This study evaluates the performances judgmental forecasting methods of Unaided Judgment (UJ), Structured Analogies (SA) and semi-Structured Analogies (s-SA) as well as Interaction Groups (IG) in forecasting the impact of such projects.

The reason and motivation for the experimentation and evaluation of the relative performance of the aforementioned judgmental methods comes from a series of studies in the broader field of structured judgmental forecasting methods: Savio and Nikolopoulos (2009, 2010, 2013) evaluation of s-SA and SA versus UJ for individual forecasters – in a very difficult forecasting problem; and Nikolopoulos et al (2015) that extend the scope of such endeavours via including groups judgmental forecasts with IGs and Delphi approaches.

Results and discussion

The megaproject examined in this section is about space Exploration – the project tis sufficiently disguised so the experts cannot – and should not – identify it. The detail of the project description and the experimental setups for UJ is provided in detail in table 4.1, the actual required forecasts in table 4.2 while the actual outcomes in table 4.3.

Megaproject : Space Exploration

Description

A number of space probes left Earth for Planets in the past few years. One of the missions is estimated to cost £250m to £300m and it would become a European built probe on a spacecraft touching down on another planet. The aim is always simple - to find evidence of life, past or present, on another planet. The mission carries scientific instruments that will study the geology of planets and search for water under the surface. Research institutes throughout Europe have provided the instruments. A consortium of more than 20 companies from more than a dozen European countries and the USA built the spacecraft. The spacecraft will fly around the target planet for an entire planet year. Scientists are confident that if water is present on the Planet, the spacecraft with the probe will find it.

European scientists want the mission to:

a) map the composition of the surface at 100-m resolution
b) map the composition of the atmosphere and determine its global circulation
c) determine the structure of the sub-surface to a depth of a few kilometres
d) determine the effect of the atmosphere on the surface, and,
e) determine the interaction of the atmosphere with the solar wind

On landing, cameras on the probe's robotic arm will take close-up images of soil and rocks to look for interesting specimens. The samples will be analysed for chemical signs of life using a package of instruments on the probe.

The Launch

The spacecraft carrying the probe would be launched from earth and placed

on the right trajectory for the interplanetary voyage. If all goes well, the journey would take a few months.

Table 4.1. Disguised description of the Megaproject

1). To what extend do you think objectives a-e will be achieved? a. 0% - 20% [ ] b. 21% - 40% [ ] c. 41% - 60% [ ] d. 61% - 80% [ ] e. 81% - 100% [ ] 2). Do you think water will be found? Yes [ ] No [ ] 3). Do you thing close-up images will be captured? Yes [ ] No [ ]

Table 4.2. Actual questions for the Megaproject

In order to finalize the exact phrasing of the narrative of the disguised case and the respective questions a pilot experiment has been run in an executive MBA class in Salford university with six participants in November 2017

Table 4.3 presents the actual results of the project.

Megaproject	**Question**	**Outcome**
Q1	Success rate of project.	80%
Q2	Boolean result 1.	No
Q3	Boolean result 2.	Yes

Table 4.3 Actual outcomes of Megaproject**.** 'Shaded' are the right answers/forecasts

The detail of the project description and the experimental setup for forecasting with the modified version of structured analogies s-SA is provided in detail in section 4.1.7

Experts

The experts were MBA students in a top-30 MBA programme (Global MBA FT 2017 rankings) and had at least three years of industrial experience and full training in quantitative forecasting methods. In total - from a class of 69 experienced and excellently educated students - 55 experts responded positively to the call and participated in the research. These experts were sourced from a wide variety of sectors, including academia, industry, financial services and consultancy firms, all, however, having south-east Asian origin, almost all of them raised in India.

No monetary but an in-kind incentive was provided to the participant for taking part in the experiment: that was a bonus grade of 0.5 in case students fell below 2.5 (with a maximum of 4.0) in their grade for the Forecasting analytics course- so more like a 'safety net' rather than bonus per se.

Judgmental forecasting methods

Four methods have been evaluated in this study; the first – Unaided Judgment – is the benchmark. The methods that were deployed included the following:

Group A -(53 experts from a pool of 69 students), Unaided Judgment(UJ): This method is a simple and quite popular Judgmental Forecasting approach. Experts are given no guidance except for a general description of the intended policies. The task lasted for 5 minutes

Group B - (45 experts from the same pool of 69 students), semi-Structured Analogies (s-SA): The Structured Analogies approach was proposed by Green and

Armstrong (2007a) and is based on forecasting by analogy by exploiting the similarities of past events or experiences. These past events/situations have the same or similar characteristics as the problem to be forecasted and can be used as templates. These types of mental templates are the analogies. The experts are first asked to recall as many analogies as possible. Subsequently, they produce a quantitative similarity rating between each analogy and the problem to be forecasted and state the outcome of that analogy. The administrator uses the experts' data to produce a final forecast. In this study, a slightly simpler version of the method, called semi-Structured Analogies (s-SA, Savio& Nikolopoulos, 2013) was implemented. In this approach, similarity ratings and outcomes are not used by the administrator to generate forecasts because the final forecasts are produced by the experts. The task lasted for 15 minutes

Group C- (6-7 experts per group - from the same pool of 69 students),8 (eight) Interaction Group(IG): These groups met in a restaurant/cafeteria for an hour with their laptops and internet connection available. The entire process was supervised by a relatively inexperienced facilitator – the team captain. The meeting lasted three hours and was recorded. The first hour was spent with introductions and a light dinner. In the next two hours, the group forecasting exercise occurred, in which the experts were first given the questionnaires, then encouraged to recall analogies and their corresponding outcomes, and then to rate those analogies in terms of similarity. Finally, the experts were asked to select the most appropriate analogies to produce point forecasts as well as 90% prediction intervals. This process was first performed individually and was then followed by the group interaction in which experts repeated the process aloud and exchanged their information until a consensus group forecast was reached.

Group D - (6-7 experts; experts - from the same pool of 69 students), one (1) Delphi group (D): This approach is a popular group Judgmental Forecasting method that includes multiple rounds of questionnaires administered to a group of experts. Although several variations of the method exist (Rowe and Wright,

1999, 2001), only two rounds were run in the current implementation – with a few hours in between them - to limit the process to one day (and to avoid having experts drop out). In the first round, the experts forecasted with SA. Once the forecasts were collected, feedback was provided to the group in the form of an average forecast for the group, in addition to the maximum and minimum forecasts and the justifications for those extreme forecasts (in a short memo). In the second round, the participants could revise their forecasts in light of the initial feedback. The average of the second round of forecasts was used as the group forecast.

Participants' Expertise

The participants' expertise was rated based on the self-administered questionnaire provided with the SA method – see appendix; however, this was a very homogeneous group given the admission nature of the MBA programme, and thus most of the candidates had 3-5 years of experience with a very small deviation.

Measuring Performance

Forecasting accuracy was measured through a [% success] metric of how often the correct answer was achieved from every group. Given the nature of the question and respective answer/forecast as % in steps of 20%, we considered the calculation of any other metrics such as RAE or MAPE unnecessary – however these can be easily calculated given the data and forecasts will be made publicly available.

Results

For the three questions presented in Table 2. (with the realized outcomes listed in Table 3), all errors for the experts' forecasts were calculated. For each of the methods and questions, the % success was estimated.

All groups forecasted perfectly question 2 and 3 that were the yes/no one's so everybody agreed that pictures would be taken while water would not be found in the unexplored planet. So these were perceived and proved to be the easy ones both given the Boolean nature as well as the recent memories of most space projects.

Thus, our focus was on question one, where the extent of the success of the mission could be judged across five objectives in a scale of 1-100% with steps of 20%. The results are as follows where the IG group method clearly outperformed the alternatives:

- **Unaided Judgment**

  The accuracy for the UJ (Group A) for Q1 – so forecasting accurately that 80% of the objectives were achieved - was: **22.64%.**
- **Semi-Structured Analogies**

  The results for s-SA for Q1 was: **27.27%** so better by almost 5% in absolute terms and as a performance improvement in the range of 20%

  Many experts recalled one to two analogies per policy, whereas others provided no analogies at all.
- **Interaction Group (IG)**

  The results for IG was a success rate of: **57.14%** so better by almost 30% in absolute terms and as a performance improvement over 100%
- The Delphi Method(D)

  There is only one team provided results – promising but statistically insignificant and as such these are not presented here until we have a bigger sample to draw some more convincing insights. Evident however has been the difficulty of the team to coordinate the task given the qualitative nature of the exercise and thus a more structured version of Delphi needs to be implemented. Experts tend to try communicating narrative and analogies as well and not only the outcome – and that was a challenge in the process

Discussion

The proposed judgmental algorithms are very simple so very easy and cheap/cost-effective to use in practice, definitely cheaper to implement or outsource than a CBA or IA analysis; in between these simple approaches, the more structured one seemed to prove more accurate and the teaming of experts really paid back – a result consistent with the overall body of literature and especially the results of the recent and widely popularized Superforecasting project- on the aspects of training (here the SA training and respective use of methods) and teaming up (Tetlock and Gardner, 2016)

Simplicity should be a negative factor in the evolution and promotion of science; to the contrary the application of the simplicity principle to theories is sometimes defended as an application of Occam's Razor, that is, “accept the simplest theory that works” (Simon, 1979). Zellner (2007), a leading economist, believed that complicated problems could be solved by the application of a few powerful, simplifying concepts, which he called "sophisticated simplicity". These powerful and simplifying concepts have been implemented in a myriad of industries and services. Simplicity also plays an integral role in shaping decision-making heuristics. Gigerenzer (1996) argues that biases that stem from heuristics can be eliminated by utilizing particular methods in a suitable context. In our case this aforementioned methodological approach translates into using structured judgmental forecasting methods in a very complex and long term forecasting problem

Although the empirical evidence in this study was derived within a megaproject context, the results may be generalized and applied to a variety of other project situations in which the proposed forecasting methods might be used to successfully in order to forecast critical success factors of projects. In essence, the literature that favours the use of simple methods to forecast with information cues (Nikolopoulos, Goodwin, Patelis, and Assimakopoulos, 2007), we may claim that is has been sufficiently corroborated.

Conclusions and Further Research

Forecasting megaprojects is challenging. This experiment utilizes Space Exploration, one of the most challenging, multinational and long-range type of Megaprojects, in which available historical information is limited and the forecasting horizon is extremely long. The results presented here could well be generalized and applied to many other Megaprojects – however more research should be thrown towards that direction.

The empirical evidence reveals that the use of s-SA Analogy leads to accuracy improvement compared to UJ. This improvement in accuracy is greater when introducing the pooling of analogies through interaction in IG. A smaller scale experiment has been conducted to compare Delphi with IGs with inconclusive results however revealing the difficulty of implementing the Delphi method in some contexts. The results also corroborate the stream of forecasting research in the presence of information cues. The empirical findings suggest that overall actual forecasting improvement might exceed100%. These results are consistent with the previous body of literature; however, the exact effect size varies depending on the context of each study.

With the aforementioned results, it can be claimed that this study corroborates the existing body of evidence that supports the forecasting principles as maintained by J.S. Armstrong (2001a) at www.forprin.com. In further detail, empirical evidence is provided in favour of the following forecasting principles (Armstrong, J. S., 2001b).

Principle 3.5: *Obtain information from similar (analogous) series or cases.*

Principle 6.3: *Use structured forecasting methods rather than unstructured.*

Principle 7.1: *Keep methods simple.*

Principle 8.3: *Ask experts to justify their forecasts.*

Principle 12.2: *Use many approaches (or forecasters), preferably at least five.*

Principle 13.26: *Use out-of-sample (ex ante) error measures.*

The results presented herein are based on small-sized samples of experts, a fact that might be an impediment for generalizing the findings, or not… (Armstrong 2007a, 2007b). However, if the context of this case study was to be taken into account, and how Megaprojects are managed and more importantly a-priory forecasted in real life conditions, these results might provide valid insights into the performance and usability –real-life usability - of each forecasting method. Repetition in other case studies might help to prove the validity of the findings and provide a generalized output for the superiority of some these methods, especially the simpler ones, such as Structured Analogies.

As far as the future of such studies is concerned, the proposed approaches could also be tested in different contexts for smaller and bigger Megaprojects – however space exploration is one (if not the-) of the most challenging one's -in order to gather further evidence that would allow for the full generalization of the results.

Moreover, an evaluation of other judgmental approaches, such as the Nominal Group Technique (Van de Ven and Delbecq, 1971), might be explored (Graefe & Armstrong, 2011). In addition, sampling more experts would offer the opportunity to test more treatments, such as IGs with UJ versus IGs with s-SA or to test SA, direct comparisons of IGs and Delphi and versus UJ/s-SA as well as versus SA as it was originally designed by Green and Armstrong (2007b).

Finally, the option to offer strong incentives to the participants/experts has not yet been tested – not to mention that who is an expert is a big question anyway - , and this feature has provided strong insights into similar studies in the past. Certainly, more avenues could be pursued in this research domain, and it is hoped that this study will provide interest for future investigations.

Note: A full description of the experiment can be found in Appentix 1: Description of the Experiment for the 'Structured Analogies method.

4.2 Forecasting the success of Megaprojects with Structured Analogies, Delphi and Interaction Groups: the different stakeholder perspectives[3]

In this section, I describe the second experiment that I run. The experiment run in Salford university in March 2019, in two different cohorts, one large group of MSc students in Project Management, and two very small groups of undergraduate students in Project Management. As such it is difficult to attain any statistical significant results from the latter, but for the sake of completeness, I do report both in this thesis and leave further investigation for future research. We classified the former as semi-experts (Savio and Nikolopoulos, 2009), while the latter as novices (Savio and Nikolopoulos, 2010). Ethics approval has been sought and acquired from Salford University, and the experiment was contacted as formative exercises during class time as this was an excellent way to learn to use judgmental forecasting techniques.

The Experiment

The students after been imposed in one hour (1h) hour of training in Judgmental forecasting and had to complete sequentially the task of forecasting 6 questions relating the success of Megaproject 2 ('a major recreational facility in the city centre of a major cosmopolis') with four different methods: UJ, SA, IG and D. All tasks were completed within 4 hours over two (2-hour) sessions.

[3] A much earlier version of section 4.2 has been accepted for presentation in ISF2020 in June in Rio, Brazil and in POMS 2020 in May 2020 in Minneapolis, but unfortunately both conferences have been cancelled due to the COVID-19 pandemic. I thank the student-participants in the Salford Business School for giving their consent to participate in this research and the school for granting the respective ethics approval, as part of a formative forecasting assessment in the Masters and Undergraduate classes in Project Management in March 2019.

In this experiment and respective section, the subjects had to forecast with individual and group judgmental forecasting methods the potential excess in the budget and the duration of a megaproject (Megaproject 2). They also forecast the extent to which the socio-economic benefits realisation is achieved. I do analyse three different stakeholder perspectives: that of the

a) project manager,

b) funders, and

c) public.

I do control for two levels of expertise – novices, and semi-experts - through two separate repetition of the same experiment and test the following methods: Unaided Judgement (UJ), semi-Structured Analogies (s-SA), Delphi Groups (DG), and Interaction Groups (IG) through a sequence of four phases:

- phase I: individual forecasting with (UJ),
- phase II: following phase I, same students individual forecasting again, this time with (SA),
- Phase III: approximately half the students put into (IG) groups and repeating phase II,
- Phase IV: the remaining half of the students put into (D) groups and repeating phase II. Phase IV run in parallel with Phase III, in the same room, but obviously in different parts of the room.

Results

The empirical evidence from the large group of MSc students (in a 'Msc in Project Management', thus the characterisation as semi-experts), reveals that the use of Structured Analogies (s-SA in specific) leads to accuracy improvement compared with UJ.

This improvement is amplified further when introducing pooling of analogies through teamwork in IG. In between group methods IG shows more promising performance than the Delphi alternative (D). In all the experiments I do not find evidence that accuracy is positively correlated with levels of experience (withing the group of semi-experts as measured with the years of experience) and the number of analogies recalled – rather than the results remain constant for different level of expertise (among students however) and even when more analogies are recalled.

The empirical results are in a nutshell as follows (details following in Tables 4.4 – 4.10):

IG >D >>SA>>UJ

(>: better, >> way better)

IG (5 groups) >D(5 groups) >>SA (50 semi-experts) >>UJ (50 semi-experts)

In detail in table 4.4 we see the performance with the Mean Absolute Error across the 50 participants (MAE) for UJ, where for Q1, Q2 and Q6 the lower the MAE the better the forecasts are, while for Q3, Q4, Q5 the higher the percentage the more accurate the binary forecast (yes/no) is:

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	14.20	61.80				30.00
MAE	20.52	56.36	64.00%	54.00%	90.00%	32.80

Table 4.4 Performance of **UJ**, Megaproject2, Semi-experts

The absolute error (AE) is calculated as the absolute value (always positive) of the difference between the forecasts of the excess (in time, budget) as given by the each student, versus the actual value that the excess had. AS we have 50 forecasts provided by the students (semi-experts) in phase I with UJ, we do have 50 forecasting errors (AE) and we can calculate the average of these (MAE) and the median (MdAE) – the one in the middle if we rank these errors from lower to higher). Similar calculations of errors are done across phase II -still 50 responses, and phase III and IV (5 responses in each of the latter two phases).

I also report the Median Absolute Error (MdAE) across the 50 participants as if the MdAE is smaller than the MAE – as is the case in this table, this is an indication of extreme values, thus some students that did very large errors; while if MdAE is smaller, then that is an indication that there some students with very good forecasts.

For Q3, Q4, and Q5 where the three different stakeholder perspectives are sought, that of the project manager (Q3), the funders (Q4), and the public (Q5) we observe that consistently different forecasts are given, thus the semi-experts believe each stakeholder has a different perspective, and we observe that the latter (that for the public) always achieves higher accuracy.

In detail in table 4.5 we see the performance (MAE) for SA, where for Q1, Q2 and Q6 the lower the MAE the better the forecasts are, while for Q3, Q4, Q5 the higher the percentage the more accurate the binary forecast (yes/no) is. SA is better than UJ in all six questions and this is a consistent result with both section 4.1 and the respective literature (Nikolopoulos et al., 2015; Savio and Nikolopoulos, 2013):

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	14.20	46.80				20.00
MAE	19.97	51.57	72.00%	66.00%	96.00%	24.40

Table 4.5 Performance of **SA**, Megaproject2, Semi-experts

In detail in table 4.6 we see the performance (MAE) for D, where for Q1, Q2 and Q6 the lower the MAE the better the forecasts are, while for Q3, Q4, Q5 the higher the percentage the more accurate the binary forecast (yes/no) is. D is better than SA in five out of six questions:

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	14.80	48.20				20.00
MAE	16.50	43.70	100.00%	60.00%	100.00%	16.00

Table 4.6 Performance of **D**, Megaproject2, Semi-experts

In detail in table 4.7 we see the performance (MAE) for IG, where for Q1, Q2 and Q6 the lower the MAE the better the forecasts are, while for Q3, Q4, Q5 the higher the percentage the more accurate the binary forecast (yes/no) is. IG is better than D in four out of six, equal in one and worse in one question. IG is better than SA in five out of six questions:

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	10.80	46.80				20.00
MAE	12.16	39.80	60.00%	100.00%	100.00%	12.00

Table 4.7 Performance of **IG**, Megaproject2, Semi-experts

I now focus more on the performance of SA (Green and Armstrong, 2007) versus s-SA (Nikolopoulos and Savio, 2013). In detail in table 4.8 we see the performance (MAE) for SA but excluding s-SA, where for Q1, Q2 and Q6 the lower the MAE the better the forecasts are, while for Q3, Q4, Q5 the higher the percentage the more accurate the binary forecast (yes/no) is. In table 4.9 we see s-SA only and comparing, we see that SA is slightly better than s-SA.

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	13.30	31.80				20.00
MAE	18.98	35.30	100.00%	100.00%	100.00%	24.00

Table 4.8 Performance of **SA** (excluding s-SA), Megaproject2, Semi-experts

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	14.20	46.80				20.00
MAE	20.08	53.37	68.89%	62.22%	95.56%	24.44

Table 4.9 Performance of **s-SA**, Megaproject2, Semi-experts

Finally in table 4.10 we see the performance (MAE) for SA with more than one analogies, where for Q1, Q2 and Q6 the lower the MAE the better the forecasts are, while for Q3, Q4, Q5 the higher the percentage the more accurate the binary forecast (yes/no) is. We do not see better performance versus SA with any number of analogies, in contrast of the results of Nikolopoulos et al. in 2015.

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	20.00	36.80				20.00
MAE	22.28	44.93	50.00%	62.50%	100.00%	27.50

Table 4.10 Performance of **SA>1 Analogy**, Megaproject2, Semi-experts

For the two very small groups of undergraduate students in Project Management – the novices, we have pooled the results together, despite these run in different days. The sample in total is very small (7 and 6 student respectively in the two groups) and thus no Delphi groups were formed, and only one IG group for each group. I do however report the results here for the sake of completeness:

IG >>SA>UJ

(>: better, >> way better)

IG (2 groups) >>SA (13 novices) >UJ (13 novices)

In tables 4.11 – 4.13 we confirm that IG>>SA>UJ. We also wee by direct comparison to tables 4.4, 4.5, and 4.7 that in between novices and semi-experts we see mixed results, most probably in par, and definitely given the small sample of novices, not statistical-significant differences. Thus, in my experiments, the assumed levels of expertise (assuming PG students are more experienced than UG) did not show any difference in the forecasting performance.

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	9.20	51.80				20.00
MAE	15.45	104.64	70.00%	85.00%	95.00%	34.00

Table 4.11 Performance of **UJ**, Megaproject2, Novices

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	12.50	26.80				20.00
MAE	33.10	35.31	80.00%	90.00%	95.00%	29.00

Table 4.12 Performance of **SA**, Megaproject2, Novices

	Q1	Q2	Q3	Q4	Q5	Q6
MdAE	6.80	11.80				30.00
MAE	6.80	11.80	100.00%	100.00%	100.00%	30.00

Table 4.13 Performance of **IG**, Megaproject2, Novices

Note: A full description of the experiment and the instructions the students received can be found in Appendix 2. Description of the Experiment 2: MegaProject2 : Recreational Facility

4.3 Forecasting the success of Megaprojects with Scenarios[4]

Introduction

In this section, I run the third and final experiment. The experiment has run in Bangor university from 17-24 June 2020 and ethics approval have been sought and acquired from Bangor University through a colleague based there at the time, that facilitated the execution of the experiment. Due to the COVID-19 situation and lockdown, the experiment was done from distance via Blackboard and asynchronous exchange of emails via the participants and the facilitator.

Experiment

The students after been imposed in six hours (6h) of training in Data Analytics, Judgmental forecasting and Scenarios have completed within 90miutes the following task:

[4] A much earlier version of section 4.35 has been submitted for presentation in ISIR2020 in August in Budapest, Hungary – postponed for August 2021 due to the COVID-19 Pandemic; and in the second IIF Workshop on 'Forecasting for Social Good' in Kedge Business School in Bordeaux in June 2020 – postponed for June 2021 due to the COVID-19 Pandemic. I thank the student-participants in Bangor Business School for giving their consent to participate in this research and the school for granting the respective ethics approval, as part of a formative forecasting assessment in the MBA & Masters classes in Management, Marketing, Accounting, Finance and Economics in June 2020.

Results

The scenarios as expected consist of pure narrative and as such only qualitative analysis can be performed and high-level insight to be obtained. The real interesting question here is if these scenarios contain pure forecasts or not, and moreover what kind of information do provide and how can these be used by the stakeholders interested in the task.

To that end the main finding from a thorough read and a qualitative analysis of the scenarios are as follows:

- I didn't come across with the terms "forecast*" or "Predict*" in none of the provided scenarios; nevertheless, implicitly forecasts did appear across the scenarios- but have not been named as such
- The closest to producing a forecast comes from the use of the term "estimat*" that appears twice in one scenario,
- For the worst-case scenarios, the participants discussed more elements of Project Management comparing to the other scenarios,
- No specific term is repeated at a sequence worth reporting – no consistent repetitions of terms throughout,
- One participant produced excellent scenarios, very well-developed in a professional style,
- Most of scenarios focused on the scope of the project and how this megaproject project will be implemented,
- In about half of the scenario produced, apart from the scope, the elements of the time and the cost/budget have been discussed.
- In terms of quality – this was scored subjectively in a scale 1-5, the average was three (3) and median of three and a half (3.5) (Likert scale 1-5) indicating the existence of some poor scenarios as the median is higher than the average in the set of the eight (8) scenarios that was analysed,
- Overall the scenarios provide insight and a holistic perspective of how the megaproject will evolve, but no specific quantitative forecasts, yet expression of the evolution and the expectations about the megaproject are recurring; thus these can complement very well statistical or judgmentally derived forecasts, but not substitute them

Conclusion and the Future

Forecasting the success of megaprojects is a very difficult task because of the complexity of such projects. This is more important in the post-COVID-19 post-pandemic new normal. The economy - and new life as we will know it, is expected to be driven by these very massive projects.

Pure forecasting is one thing, but foresight and broader insight in a complex phenomenon is equally important, and scenarios come exactly to fill this void: think for example HS2 (https://www.hs2.org.uk/) and all the implications and benefits (or not) of it in the near and distant future, and how in that context, forecasting, foresight and insight are similarly important.

From the preliminary empirical evidence we presented here, the scenarios can provide insight and a holistic perspective of how a megaproject will evolve, but no specific quantitative forecasts (unless specifically instructed to do so in the instructions phase), yet expression of the evolution and the expectations about the megaproject are recurring; thus these can complement very well statistical or judgmentally derived forecasts, but not substitute them, at list based on the empirical findings of this study.

For the future we leave and propose larger scale experiments with more subjects, more and more diverse megaprojects, and more scenarios (an impossible scenario could also be provoked), for the sake of the corroboration and generalisation of the current findings and beyond.

Note: A full description of the experiment can be found on Appendix 3 3:

Description of the Experiment 3: Using Scenarios for Megaprojects

5. Discussion, Conclusions, Limitations, and Future Research

In this chapter,

I provide the critical discussion of the results presented in the previous chapter in the quest of the 'why' (and not the 'what') I found what I found. I further conclude the main finding and via exploring the limitations of this research I pose the basis of the generalisation of my results. I also detail the implication from my research for theory, practice, and implementation. Finally, I lay the roadmap for future research in this field.

5.1. Conclusions

The main research question for this study that I aspired to shed light on is:

> *"Which judgmental forecasting methods can we employ in order to get the best possible forecasts for the potential success of megaprojects?"*

To that end I found concrete evidence from my three experiments that:

a) Structured judgmental forecasting methods work well, especially SA and less of s-SA.
b) And if the latter are applied via a group forecasting framework, either in an interaction fashion or a Delphi setup, the forecasting performance is increased.
c) When all is said and done, IG via using SA is by far the most promising forecasting approach, thus IG>D>>SA>UG.
d) Furthermore, I managed to achieve isolating separate forecasts for three different stakeholder perspectives: that of the a) project manager, b) funders, and c) the public. This is a well-needed innovation by itself and the forecasts received where different, illustrating that these perspectives are perceive as different from the expert-participants.
e) The results of the second experiment also showed that for two level of (medium) expertise, there is no evidence to suggest the one group is doing better than the other and as such novices and semi-experts are on par – a finding consistent with the literature (Savio and Nikolopoulos, 2010). Possible explanations of this result as argued in the literature is that analogy recall of experts was hindered by four constructs: information, complexity, worldview, and expertise.
f) Scenarios do not provide tangible forecasts, but do complement the aforementioned judgmental forecasting methods very nicely via providing insights and narratives to enrich the forecasts; insights and narrative that cannot be captured from quantitative forecasts (judgmentally derived however).

These are also the main conclusions on the technical front of this thesis.

5.2 Discussion & Reflection

Reflecting on the whole process, and most notably the anecdotal feedback from the participants of all three experiments in three different institutions and in three different nations and cultures (India, England, and Wales), all agree that it needs to be emphasized that forecasting the success of megaprojects is a very difficult but also a very important task. This is because of the complexity of such projects. In the current climate especially and the global pandemic, it is becoming even more important to be able to forecast the evolution of such large projects, as these are meant to be the ones that will drive the countries out of the woods.

A common critique to my theoretical and methodological approach – although to my eyes unsubstantiated – is as if forecasting is needed in this context in the first place: in project management in general and in megaprojects in specific. One could argue that forecasting is not needed in this context: that of projects in general. One could argue that the master Gantt chart plus the respective BOM would suffice to provide a very accurate estimation for the duration, cost, and the socioeconomic benefits to be achieved of a project.

However, If that was the case, then every project would finish on time and on budget – but this is far from true as the numerous examples attest: HS2, Channel Tunnel, IT public healthcare projects in NHS, to name a few.

I would like to give a striking example – and I do acknowledge that an example can not actin science as a proof, but a counter example does! And this is exactly what this example does, proves that Gantt charts and BOM are not enough to forecast the duration of a projects, especially a complex by nature, Megaproject.

So my most notable – and constantly in the UK news- counter example is the HS2's costs and delays that are running out of control (https://www.theguardian.com/uk-news/2020/may/17/hs2-costs-and-potential-delays-are-out-of-control-warn-mps) where the predicted costs have gone from £245m to £1.2bn, before even the project starts! A second good striking example is the Channel Tunnel that many project managers were fired, the aspired socioeconomic benefits were never achieved, and ended up in a delay of a year and went £2bn over budget (http://news.bbc.co.uk/1/hi/business/4088868.stm). So unfortunately projects are not just nuts and bolts, and forecasts are needed, not just BOMs and Gantts.

Furthermore, reflecting in an even more critical aperture here, this aforementioned calculation is not actually a true forecast- it is merely a calculation assuming every single operation will start, and finish on time, which is irrational to propose today the least. This is very rare and seriously underestimates the true uncertainty in operations and life in general, and as such true a-priori forecasts are needed, based if possible on historical data of past delays of similar projects, or in the absence of such data, based on experts.

Thus a true forecast just based on the nature of the project is essential: a forecast on the potential excess of budget, excess of project duration, and missing key targets given the (challenging) nature of the endeavour in hand. This should be done in parallel, complementing, and not substituting any calculations done base on the Gantt charts of the megaproject.

5.3 Structured Analogies aNd Scenarios (SANS)

Combining the results of the three experiments, I herewith propose a new theoretical construct, a new judgmental forecasting method, a 360-degree method using both the past (analogies) and the future (scenarios) in order to forecast from the present to the future: Structured Analogies aNd Scenarios (SANS).

I propose a hybrid method that combine two of my main results:

- IG via using SA is the best-performing forecasting approach, thus **IG>D>>SA>UG**
- **Scenarios** do not provide tangible forecasts, but do **complement** the aforementioned **judgmental forecasting** method very nicely via providing insights and narratives to enrich the forecasts

As such by combining those two (IG with SA) and (Scenarios) we do get the best of both worlds: narrative and insight and true forecasts/predicitions. The same group of experts in an interaction fashion should:

a) Individually use SA
b) Individually build scenarios: a base-line, a best-case, a worst-case, and an impossible scenario
c) Bring into the common table the individually SA and discuss until consensus is reach interactively and a group forecast is achieved in a group SA fashion
d) Bring into the common table the individual scenarios and build four group scenarios at this stage
e) Compile a report with both the numerical and qualitative elements as a final output of the SANS method

I leave the testing of the full method for future research, but the empirical evidence from this thesis strongly suggest that this proposition is valid and worth further investigating.

5.4 Contribution to theory, practice and implementation

My **theoretical** contribution is trifold:

a) responding to the call Cicmil (2006), Winter et al. (2006) among others, my research provides concrete empirical evidence of the variety of forecasting tools and practices to be used in project management, especially for megaprojects.

b) covers to some extend the discrepancy between theory and practice through the findings of the research.

c) contributing to the literature in forecasting and management science, and especially the one in judgmental versus statistical methods as elaborated by Arvan, Fahimnia, Reisi, & Siemsen (2019).

My **practical** contribution comes from the fact that this research gives the opportunity to practitioners working in project management, especially for megaprojects, to better understand the challenges they have to face in their projects and use the appropriate range of forecasting tools in order to estimate the potential success of their projects.

My contribution to **implementation** comes from the fact that my propositions can be embedded in software systems as well as PM frameworks like th PMBOK and Prince2

5.5 Limitations & Generalisation

As any other piece of qualitative research comes with a score of certain caveats and limitations:

- The samples are small
- What is an expert remains and open and ongoing question?
- A few megaprojects have been used, not covering the full range of project activities

With all these in mind I still believe my results can be fully generalised and apply to any kind of megaprojects and the suggested – tested and proposed- methods can be employed in any forecasting setting within PM; and further more been implements with the current dominant PM frameworks like PMBOK and Prince2 or the EU propositions.

5.6 The future

Finally, as potential roadmaps for future research the following recommendation are set and left for the future generation of PM researchers:

- Run experiments with more participants for corroboration to this research
- Run experiments with more megaprojects for corroboration to this research
- Run experiments with more diverse megaprojects
- Run experiments with true experts high-level PMs, CEOs, CTOs etc to see if the results of Savio and Nikolopoulos 2013 stand
- Run the experiments in a true Superforecasting context (Katsagounos et al., 2020)
- Test in practice the proposed methods
- Test the applicability and forecasting performance of the SANS method

It was quite a journey! Thank you

Publications

From the PhD

Journal articles

K. Litsiou, Y. Polychronakis, A. Karami, K. Nikolopoulos (2020). Relative performance of judgmental methods for forecasting the success of megaprojects. International Journal of Forecasting, forthcoming

Conferences

K. Litsiou, Y. Polychronakis, S. Sapountzis, K. Nikolopoulos (2021). Judgmental Forecasting for megaprojects: Structured analogies versus Delphi and Interaction Groups. POMS 31st Annual Conference of the Production and Operations Management Society (POMS), Online, May 2021.

W.S. Alghassab, A. Karami, K. Litsiou, K. Nikolopoulos (2019). Long-Term Economic Forecasting with Structured Analogies and Interaction Groups. ISF, Thessaloniki, June, 2019.

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Appentices

Appendix 1. Description of the Experiment for the 'Structured Analogies method

Megaproject1 : Space Exploration

Description

A number of space probes left Earth for Planets in the past few years. One of the missions is estimated to cost £250m to £300m and it would become a European built probe on a spacecraft touching down on another planet. The aim is always simple - to find evidence of life, past or present, on another planet. The mission carries scientific instruments that will study the geology of planets and search for water under the surface. Research institutes throughout Europe have provided the instruments. A consortium of more than 20 companies from more than a dozen European countries and the USA built the spacecraft. The spacecraft will fly around the target planet for an entire planet year. Scientists are confident that if water is present on the Planet, the spacecraft with the probe will find it.

European scientists want the mission to:

f) map the composition of the surface at 100-m resolution
g) map the composition of the atmosphere and determine its global circulation
h) determine the structure of the sub-surface to a depth of a few kilometres
i) determine the effect of the atmosphere on the surface, and,
j) determine the interaction of the atmosphere with the solar wind

On landing, cameras on the probe's robotic arm will take close-up images of soil and rocks to look for interesting specimens. The samples will be analysed for chemical signs of life using a package of instruments on the probe.

The Launch

The spacecraft carrying the probe would be launched from earth and placed on

the right trajectory for the interplanetary voyage. If all goes well, the journey would take a few months.

Judgmental Forecasting

We are interested in the following **Forecasts**:

1). To what extend do you think objectives a-e will be achieved?

2). Do you think water will be found in?

3). Do you thing close-up images will be captured?

You are going to follow the process for **Structures Analogies** for producing your forecasts as in the **following pages**

Judgmental Forecasting with <u>Structured Analogies</u>

In the tables provided below, please describe any analogous project to the one described. Please include details on:

- the similarities and differences between your analogous project and the target projects.
- their source (e.g. your own experience, media reports, history, literature, etc.)
- a similarity rating between your analogous project and the target projects (0 = no similarity… 5 = similar… 10 = high similarity)
- the outcome of your analogous project (which of the outcomes a-e found at the bottom, is most similar, in terms of effectiveness, to the outcome of your analogy?).

<u>Example analogy</u>

Description	Landing to the Moon – Apollo mission
Similarities and differences	Similarities: same objective Differences: different budget available

Source __ <u>Media</u> __ Similarity rating __8__ OUTCOME:

Q1. To what extend think objectives have been achieved?

a. 0% - 20% [ ] b. 21% - 40% [ ] c. 41% - 60% [V]

d. 61% - 80% [ ] e. 81% - 100% [ ]

Q2. Was water found ?

Yes [ ] No [V]

Q3. Have close-up images been captured?

Yes [V] No [ ]

1. Your Analogies

Analogy 1

Description	
Similarities and differences	

Source _____ Similarity rating _____ OUTCOME:

Q1. To what extend think objectives have been achieved?

a. 0% - 20% [ ] b. 21% - 40% [ ] c. 41% - 60% [ ]

d. 61% - 80% [ ] e. 81% - 100% [ ]

Q2. Was water found ?

Yes [ ] No [ ]

Q3. Have close-up images been captured?

Yes [] No [ ]

Analogy 2

Description	
Similarities and differences	

Source _____ Similarity rating _____ OUTCOME:

Q1. To what extend think objectives have been achieved?

a. 0% - 20% [ ] b. 21% - 40% [ ] c. 41% - 60% [ ]

d. 61% - 80% [ ] e. 81% - 100% [ ]

Q2. Was water found ?

Yes [ ] No [ ]

Q3. Have close-up images been captured?

Yes [] No [ ]

Analogy 3

Description	
Similarities and differences	

Source _____ Similarity rating _____ OUTCOME:

Q1. To what extend think objectives have been achieved?

a. 0% - 20% [ ] b. 21% - 40% [ ] c. 41% - 60% [ ]

d. 61% - 80% [ ] e. 81% - 100% [ ]

Q2. Was water found ?

Yes [ ] No [ ]

Q3. Have close-up images been captured?

Yes [] No [ ]

Analogy 4

Description	
Similarities and differences	

Source _____ Similarity rating _____ OUTCOME:

Q1. To what extend think objectives have been achieved?

a. 0% - 20% [ ] b. 21% - 40% [ ] c. 41% - 60% [ ]

d. 61% - 80% [ ] e. 81% - 100% [ ]

Q2. Was water found ?

Yes [ ] No [ ]

Q3. Have close-up images been captured?

Yes [] No [ ]

if you need MORE analogies reprint this page

2. Your OWN Forecast

Q1. To what extend do you think objectives a-e will be achieved?

a. 0% - 20% [ ] b. 21% - 40% [ ] c. 41% - 60% [ ]

d. 61% - 80% [ ] e. 81% - 100% [ ]

Q2. Do you think water will be found in?

Yes [ ] No [ ]

Q3. Do you thing close-up images will be captured?

Yes [] No [ ]

How **confident** you are about your Forecast in

Q1[ ]%,

Q2 [ ]% and,

Q3[ ]%?

3. Questionnaire

(1) Roughly, how long did you spend on this task?
{include the time spent reading the description and instructions} [__] mins.

(2) How likely is it that taking more time would change your forecast?
{0 = almost no chance (1/100) … 10 = practically certain (99/100)} [__] 0-10.

(3) If you knew that this case was from the UK, how likely would you be to change your forecast?
{0 = almost no chance (1/100) … 10 = practically certain (99/100)} [__] 0-10.

(4) How many people did you discuss this forecasting problem with? [__] people.

(5) Roughly, how many years experience do you have working in a project management (PM) issues setting?
[__] years.

(6) Roughly, please rate (out of 10)

- your experience with project management (PM). [___] 0-10

- your experience with projects similar to this one. [___] 0-10

- your suitability for predicting the success of major projects. [___] 0-10

(7) If you were contracted to produce such a forecast what process/process would you adopt? [___ _____] In what sort of time-scale? [___]

Appendix 2. Description of the Experiment 2: MegaProject2 : Recreational Facility

Phase I: UJ, Megaproject2

MegaProject2 : Recreational Facility

Description

This project is about about building a major recreational facility in the centre of a major metropolitan capital visited by millions of tourists every year. This extremely challenging and technically innovative project is undertaken by a big number of suppliers/manufacturers from across the continent. The whole project had to be designed to withstand extreme weather conditions for ultimate public safety. It involves a number of important influential and well-known stakeholders and sponsors with numerous potentially conflicting priorities. The original design for the project had been conceived in two decades ago, but was altered significantly after that, increasing the cost by a few million pounds in the process and almost doubles the overall project cost.

Following all the aforementioned changes the main site works Gantt chart is prepared, comprising more than 100 major site activities, that are grouped together into "work packages" such as civil engineering works, watercourse works, etc. Work is scheduled to begin in week 2 with a completion target in week 50. Following numerous delays associated with technical difficulties some works has to be rescheduled in an attempt to bring the programme back on track and due to that the construction and commissioning of certain tasks has been brought forward. The finishing time of the project and adherence to all pertinent deadlines is of paramount importance to certain sponsors and shareholders and certainly to the end customer and user.

Judgmental Forecasting

We are interested in the following **Forecasts**:

1). Do you think there will finally be delay in the completion time of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

2). Do you think there will finally be excess in the completion (revised) budget of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

3). Do you think the project overall will be a success for the Project Managers?

Yes [ ] No [ ]

4). Do you think the project overall will be a success for the Funders?

Yes [ ] No [ ]

5). Do you think the project overall will be a success for the Public?

Yes [ ] No [ ]

6). To what extend you think the aspired socio-economic benefits for the public have been achieved?

a. 0% - 20% [ ]

b. 21% - 40% [ ]

c. 41% - 60% [ ]

d. 61% - 80% [ ]

e. 81% - 100% [ ]

Phase II: SA, Megaproject2

Megaproject 2 : Recreational Facility

Description

This project is about about building a major recreational facility in the centre of a major metropolitan capital visited by millions of tourists every year. This extremely challenging and technically innovative project is undertaken by a big number of suppliers/manufacturers from across the continent. The whole project had to be designed to withstand extreme weather conditions for ultimate public safety. It involves a number of important influential and well-known stakeholders and sponsors with numerous potentially conflicting priorities. The original design for the project had been conceived in two decades ago, but was altered significantly after that, increasing the cost by a few million pounds in the process and almost doubles the overall project cost.

Following all the aforementioned changes the main site works Gantt chart is prepared, comprising more than 100 major site activities, that are grouped together into "work packages" such as civil engineering works, watercourse works, etc. Work is scheduled to begin in week 2 with a completion target in week 50. Following numerous delays associated with technical difficulties some works has to be rescheduled in an attempt to bring the programme back on track and due to that the construction and commissioning of certain tasks has been brought forward. The finishing time of the project and adherence to all pertinent deadlines is of paramount importance to certain sponsors and shareholders and certainly to the end customer and user.

Judgmental Forecasting

We are interested in the following **Forecasts**:

1). Do you think there will finally be delay in the completion time of the project - and if so by what %?

2). Do you think there will finally be excess in the completion (revised) budget of the project - and if so by what %??

3). Do you think the project overall will be a success for the Project Managers?

4). Do you think the project overall will be a success for the Funders?

5). Do you think the project overall will be a success for the Public?

6). To what extend you think the aspired socio-economic benefits for the public have been achieved?

You are going to follow the process for **Structures Analogies** for producing your forecasts as in the following page

Judgmental Forecasting with Structured Analogies

In the tables provided below, please describe any analogous project to the one described.

Please include details on:

- the similarities and differences between your analogous project and the target projects.
- their source (e.g. your own experience, media reports, history, literature, etc.)
- a similarity rating between your analogous project and the target projects (0 = no similarity… 5 = similar… 10 = high similarity)
- the outcome of your analogous project (which of the outcomes a-e found at the bottom, is most similar, in terms of effectiveness, to the outcome of your analogy?).

EXAMPLE ANALOGY

Description	DISNEYLAND PARIS
Similarities and differences	Similarities: similar objective Differences: different budget available

Source __ Media __ Similarity rating __6__ Closest outcome __ __

We are interested in the following **Forecasts**:

1). Do you think there will finally be delay in the completion time of the project - and if so by what %?

[30] % (Put 0 if you believe there will be no delay at all)

2). Do you think there will finally be excess in the completion (revised) budget of the project - and if so by what %?

[90] % (Put 0 if you believe there will be no delay at all)

3). Do you think the project overall will be a success for the Project Managers?

Yes [X] No [ ]

4). Do you think the project overall will be a success for the Funders?

Yes [X] No []

5). Do you think the project overall will be a success for the Public?

Yes [X] No [ ]

6). To what extend you think the aspired socio-economic benefits for the public have been achieved?

a. 0% - 20% [ ]

b. 21% - 40% [ ]

c. 41% - 60% [ ]

d. 61% - 80% [X]

e. 81% - 100% [ ]

1. Your Analogies

Analogy 1

Description	
Similarities and differences	

Source _____ Similarity rating _____ Closest outcome _____

We are interested in the following **Forecasts**:

1). Do you think there will finally be delay in the completion time of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

2). Do you think there will finally be excess in the completion (revised) budget of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

3). Do you think the project overall will be a success for the Project Managers?

Yes [ ] No [ ]

4). Do you think the project overall will be a success for the Funders?

Yes [ ] No [ ]

5). Do you think the project overall will be a success for the Public?

Yes [ ] No [ ]

6). To what extend you think the aspired socio-economic benefits for the public have been achieved?

a. 0% - 20% [ ]

b. 21% - 40% [ ]

c. 41% - 60% [ ]

d. 61% - 80% [ ]

e. 81% - 100% [ ]

Analogy 2

Description	
Similarities and differences	

Source _____ Similarity rating _____ Closest outcome _____

We are interested in the following **Forecasts**:

1). Do you think there will finally be delay in the completion time of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

2). Do you think there will finally be excess in the completion (revised) budget of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

3). Do you think the project overall will be a success for the Project Managers?

Yes [ ] No [ ]

4). Do you think the project overall will be a success for the Funders?

Yes [ ] No [ ]

5). Do you think the project overall will be a success for the Public?

Yes [ ] No [ ]

6). To what extend you think the aspired socio-economic benefits for the public have been achieved?

a. 0% - 20% [ ]

b. 21% - 40% [ ]

c. 41% - 60% [ ]

d. 61% - 80% [ ]

e. 81% - 100% [ ]

Analogy 3

Description	
Similarities and differences	

Source _____ Similarity rating _____ Closest outcome _____

We are interested in the following **Forecasts**:

1). Do you think there will finally be delay in the completion time of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

2). Do you think there will finally be excess in the completion (revised) budget of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

3). Do you think the project overall will be a success for the Project Managers?

Yes [ ] No [ ]

4). Do you think the project overall will be a success for the Funders?

Yes [ ] No [ ]

5). Do you think the project overall will be a success for the Public?

Yes [ ] No [ ]

6). To what extend you think the aspired socio-economic benefits for the public have been achieved?

a. 0% - 20% [ ]

b. 21% - 40% [ ]

c. 41% - 60% [ ]

d. 61% - 80% [ ]

e. 81% - 100% [ ]

if you need MORE analogies reprint this page

Your OWN Forecast

Please select your **forecast** for

1). Do you think there will finally be delay in the completion time of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

2). Do you think there will finally be excess in the completion (revised) budget of the project - and if so by what %?

[ ] % (Put 0 if you believe there will be no delay at all)

3). Do you think the project overall will be a success for the Project Managers?

Yes [ ] No [ ]

4). Do you think the project overall will be a success for the Funders?

Yes [ ] No [ ]

5). Do you think the project overall will be a success for the Public?

Yes [ ] No [ ]

6). To what extend you think the aspired socio-economic benefits for the public have been achieved?

a. 0% - 20% [ ]

b. 21% - 40% [ ]

c. 41% - 60% [ ]

d. 61% - 80% [ ]

e. 81% - 100% [ ]

How **confident** you are about your (as a percentage out of 100) Forecast in

Q1[ ]%, Q2 [ ]% , Q3[ ]%, Q4[ ]%, Q5 [ ]% and Q6[ ]%?

Questionnaire

(8) Roughly, how long did you spend on this task?

{include the time spent reading the description and instructions} [__] mins.

(9) How likely is it that taking more time would change your forecast?

{0 = almost no chance (1/100) … 10 = practically certain (99/100)} [__] 0-10.

(10) If you knew that this case was from the UK, how likely would you be to change your forecast?

{0 = almost no chance (1/100) … 10 = practically certain (99/100)} [__] 0-10.

(11) How many people did you discuss this forecasting problem with? [__] people.

(12) Roughly, how many years experience do you have working in a project management (PM) issues setting?

[__] years.

(13) Roughly, please rate (out of 10)

- your experience with project management (PM). [___] 0-10

- your experience with projects similar to this one. [___] 0-10

- your suitability for predicting the success of major projects. [___] 0-10

(14) If you were contracted to produce such a forecast what process/process would you adopt? [___ _____] In what sort of time-scale? [___]

Phase III: IG, Megaproject2

Participants got with them their completed forms from phase II, formed a group and within 30 min had to reach consensus and give final forecasts for all questions as a group. They had also to report the process they followed in order to reach the consensus.

Phase IV: D, Megaproject2

Participants got with them their completed forms and four more anonymised form of other participants. In the light of these 5 complete packs, they had within 30 min had to reach a new set of final forecasts individually. Consensus as a group was reached ex post when the administrator calculated the average forecasts per group.

Appendix 3. Description of the Experiment 3: Using Scenarios for Megaprojects

Task: **Using Scenarios for Megaprojects**

Step 1: Fill in your consent form first, and, choose a comfortable **PLACE** to think and minimize distractions. Do not PUT your name or any identifier anywhere in this form.

Step 2: Please, **READ** carefully the case study below:

"Megaproject: Space Exploration"

Description

A number of space probes left Earth for planets in the past few years. One of the missions is estimated to cost £250m to £300m and it will become a European-built probe on a spacecraft touching down on another planet. The aim is always simple – to find evidence of life, past or present, on another planet. The mission carries scientific instruments that will study the geology of planets and search for water under the surface. Research institutes throughout Europe have provided the instruments. A consortium of more than 20 companies from more than a dozen European countries and the USA built the spacecraft. The spacecraft will fly around the target planet for an entire planet year. Scientists are confident that if water is present on the planet, the spacecraft with the probe will find it.

European scientists want the mission to:

a. map the composition of the surface at 100-m resolution
b. map the composition of the atmosphere and determine its global circulation
c. determine the structure of the sub-surface to a depth of a few kilometres
d. determine the effect of the atmosphere on the surface, and
e. determine the interaction of the atmosphere with the solar wind

On landing, cameras on the probe's robotic arm will take close-up images of soil and rocks to look for interesting specimens. The samples will be analysed for chemical signs of life using a package of instruments on the probe.

The Launch

The spacecraft carrying the probe will be launched from earth and placed on the right trajectory for the interplanetary voyage. If all goes well, the journey will take a few months.

Step 3: Develop the **SCENARIOS**

Write down, in the following two pages, in 60-90 min, three (3) scenarios (of no less than 200 words):

- **Scenario A: the baseline scenario**
- **Scenario B: the best-case scenario**
- **Scenario C: the worst-case scenario**

of **how the project will evolve and to what extent it will succeed in your view**. *Try to develop these scenarios without the use of any research (internet,etc) as here we are interested in your raw thoughts of how such a megaproject may evolve.*

Step 4: in no more than 300 words describe the **PROCESS** you personally followed in order to derive the three scenarios

Develop the Scenarios

Scenario A: the baseline scenario:

Scenario B: the best-case scenario:

Scenario C: the worst-case scenario:

PROCESS description:

Once the task is completed, and the students receive their formative feedback, their scenarios will be analysed in the period 24-06-2020 to 1-7-2020.

During the experiment, I managed to collect eight responses from eight students, thus in total 24 scenarios given that each student had to produce three of them. The acquired scenarios are presented in the following pages, followed by the summary of the analysis as performed judgmentally and subjectively by me.

4.3.3 The Scenarios

Participant 1

Scenario A: the baseline scenario:
Water is made up of hydrogen and oxygen, but water doesn't spontaneously decompose. So to verify that a planet has water, you can collect the gas around the planet. Water is known to decompose into hydrogen and oxygen and can be distilled at high temperatures by electrolysis of water. So if the surface of the planet contains hydrogen and oxygen, and the surface temperature of the sphere is above 80 degrees, the planet may contain water. Or one or more of the elements on the planet will generate electricity to help the water element electrolyze water, indicating that the planet may contain water. However, this sampling should be carried out in a certain space, not at the poles of the planet. At the same time, the chemical composition of the water suggests that hydrogen is twice as abundant as oxygen in the gas on the surface of the planet.

Scenario B: the best-case scenario:
Usually, the main component of stone is calcium carbonate. However, in the sandstone mountains formed by the uplift of the ancient riverbed after the crustal movement tens of millions of years ago, the cobblestone composition produced in the process of mountain flood impact and flowing water transportation is silica. Assuming that all planets experienced similar crustal movements a thousand years ago, it is possible to infer whether the planet has water resources by sampling the surface. Therefore, the probe can explore the surface of the planet for sampling analysis. If the sample contains silica and is the main constituent element of the sample, it can guess that the planet has water resources on the surface or ever had water resources.

Scenario C: the worst-case scenario:
The element water is an unstable chemical composition that is subject to evaporation (a form of vaporization). The higher the temperature, the faster the wind speed and the lower the pressure, the faster the water will evaporate. The more obvious the evaporation reaction is, the higher the relative humidity is. If there is no water on the surface, humidity is only affected by other factors in the atmosphere. When the wind speed, air pressure, temperature and other factors around the planet are consistent, the relative humidity on the surface of the planet should also be consistent. When the probe takes multiple samples around the planet, the relative humidity of the samples should be consistent or similar. However, if the humidity of the gas samples is different in the samples taken at different points, the existence of water element in the planet can be indicated.

PROCESS description:

All three are based on atmospheres similar to or close to the earth's surface. Consider also the composition of the water element, or the differences in other substances affected by the water element. Meanwhile, the rest of the stars in the Milky Way are influenced by other stars similar to or close to Earth. The baseline scenario is based on the fact that the composition of the water does not change, although other factors may affect the sample, but do not change the composition of the water. The best-case scenario is based on the difference in surface sample composition caused by the evolution and change of the planet itself over thousands of years. The worst-case scenario is based on the properties of water, but it's heavily influenced by the outside world.

Participant 2

Scenario A: the baseline scenario:

There are adequate resources and intellectual capacity to achieve the objectives of the mega-project as it stands. Economies of European nations and the companies involved have the capability of raising the required amounts of money. An ever-increasing interest in finding extra-terrestrial life is fuelling the race for space exploration. The involvement of More private entities and increasing research funding in space technologies boost similar projects. There is also adequate scientific knowledge and technology to develop useful tools for the explorations. The project is also able to draw experiences and lessons from similar undertakings both inside and outside Europe. It is also worthy to note that there is a prevailing political will for such a project as a demonstration of European power and might in space Science. The political will accompanied by average global peace is increasing cooperation and technological exchanges among former adversaries. Even with a worldwide health emergency, infrastructure for collaboration still exists to propel the project. All prevailing conditions point to the success of the endeavour.

Scenario B: the best-case scenario:

If all projections in both technology and finance remain valid, the project is destined for success. In many projects, estimated costs have been reported to sometimes double or triple. For this project, the best case would be that the budget does not face any radical changes. Radical changes could result from priority realignment from the participating nations and companies. Similarly, technology and its regulations are known to sometimes change drastically within short periods. Such changes can affect existing programs, and engineers may have to do a total rethinking. If no such changes occur, the budget and timelines will be in favour of the proposed exploration. With the successful launch and in the correct trajectory, the probes are then able to avail useful information that ensures value for money spent. The robotic probes discover water and confirmatory signs of past or present life on the planet. The massive investment by the participating nations and companies is meant to lay a foundation for the exploitation of space resources. In the occurrence of the best-case scenario, more intense exploratory missions can then follow to start exploiting space resources and collecting more critical data for more missions.

Scenario C: the worst-case scenario:

Things can sometimes go wrong for such mega projects. Economic turbulence can cut funding available from participating nations. Failures may also come from engineering flaws, as have been witnessed in the past. Spacecraft launches have failed before. The worst-case scenario for this project is that funds are no longer available in time and so it takes longer and becomes more expensive to achieve. Unpredictable occurrences like global health emergencies can prompt realignment of resources to cater to more pressing needs like equipping hospitals. This realignment can put indefinite pauses on mega projects like this space probe. In addition to that, the launch may fail. Technological difficulties could result from any unforeseen problems. Structural materials may fail even after several tests; the software may also cause malfunctions. If the launch succeeds and the correct trajectory is achieved, it is still possible that the instruments will not obtain meaningful information. No groundwater is confirmed, and no signs of life are found. The project then becomes a futile activity with no value for money. Additionally, it is also a possibility that in one sporadic case, a space accident occurs, destroying the spacecraft before it reaches its destination. This occurrence would be a loss in both time and money.

PROCESS description:

I read the provided case study to comprehend the situation to derive the three scenarios. During the reading, there was a keen exploration of the case to identify possible problems, gather provided data and facts, separate uncertainties from certainties, and then use them to develop the scenarios.

First, problems identified within the provided case were possible financial headwinds and technological challenges. These problems have caused failures in similar projects. There are chances of funding withdrawal for many reasons, including politics and global emergencies, whenever there is an externally funded budget.

Secondly, I determined that the data provided within the case study was the approximate cost and specific aims of the project. The case also provided data about the number of involved parties, but that did not have much bearing on success or failure. Success or failure of a project is measured by how much it achieves its goals within a stipulated time. This information was useful in developing the best case and worst-case scenarios. The cost in comparison to the partner nations' economic abilities dictates whether those funds will be available.

The next step was separating certainties from uncertainties. There is no guarantee that the funds will be adequately available and in the required time. It is also uncertain that political goodwill will stay as it is currently given economic challenges and competing and more urgent needs for resources. However, my understanding determined that money would be available one way or another with a probable increase in time in case of financial challenges. The technology required is also undoubtedly available, and if more were needed, exchange with other nations would make it possible.

Participant 3

Scenario A: the baseline scenario:
The overall cost of the mission will be £275. Regarding the space probe, the baseline scenario involves it touching down on the target planet and finds any evidence of life whether it is past or present. Furthermore, majority of the scientific instruments to be carried within the probe reaches the planet in proper conditions and mange to search the planet's geology especially looking for water. In this regard, it does not matter whether the search discovers water or not. What is vital is that a search is conducted on the planet. Regarding the probe carrying spacecraft, the baseline scenario involves it managing to fly around the planet for almost a full planet-year in which it can be a full year or fail to reach a year by a few days. The cameras as well as the instruments manage to map the surface structure with an appropriate resolution. Lastly, the overall mission takes few to several months but does not exceed a year. Overlay, under baseline scenario, the success rate of the mission ranges from 75% to 100%.

Scenario B: the best-case scenario:
The overall cost of the mission will be £250 and the mission will take very few months. After being launched into the right orbit, the spacecraft manages to fly around the planet for a full planet year while the subsurface and surface analysis find presence of water in both the past and present indicating that the planet can support life. As such, all the scientific instruments carried on the probe reach the planet in optimum conditions allowing the cameras to map the surface composition at a resolution of 100-m. Similarly, the developed instruments in the probe are able to map the composition of the atmospheres and also evaluate the global circulation, determine the sub-surface structure by a depth exceeding five kilometres, and evaluate the interplay between the atmosphere, the planet surface, and the solar wind.

Scenario C: the worst-case scenario:
The overall cost of the mission surpasses £300 as the mission duration takes several months extending into years. The spacecraft carrying the probe is unable to orbit the target planet for a full planet year. Whereas the probe managers to land on the target planet, the cameras that are the primary equipment for surface evidence of the planet's structures fail to take pictures with sufficient resolution for analysis. Moreover, adverse whether challenges, which were unknown during planning affect the probe's ability to perform any surface and subsurface analysis of the planet. The weather and visibility challenges cause failure of cameras and other equipment thereby affecting communication back to analysis centers on earth, which forces the mission to be aborted. Overlay, the success rate is less than 40%

PROCESS description:

The process of analyzing and developing each scenario was based on the variances between probable outcomes and the level of uncertainty regarding the mission's success. Ideally, in deriving various considerations for success and trying to quantify the level of risk involved, historical data as well as experiences on past probes that have left the earth was critical. Notably, most probes that have left Earth in the past never returned with scientists loosing communications with some along the way. However, there are also success stories as some probes are still on target to attain their missions.

Deriving the base scenario involved balancing between the probability of attaining success as well as the mission failing. Ideally, the process involved evaluating the mission based on the plans as well as the risk analysis carried out by the mission management and command teams. In this regard, the main assumption is that most of the pre-mission planning was carried out well to meet all the mission needs. However, it is also becomes vital to leave same room for uncertainty. As such, the base scenario guarantees high chances of success, but it does not offer 100% as the expected outcome. On the other hand, the best-case scenario is evaluated from an optimistic perspective in which all the adverse experiences from previous probe explorations. Moreover, the best-case scenario assumes that the planning and development of the probe has taken into consideration all risks of uncertainty leading to 100% success rate. The worst case scenario is derived from a high risk perspective. Each mission risk is magnified to have the most severe impact on the mission. For instance, the weather could distort communication while equipment may fail to work in the environment of the new planet thereby resulting in a low success rate.

Participant 4

Scenario A: the baseline scenario:
As the world begins to cautiously enter a recovery phase following the Coronavirus pandemic, social distancing requirements are relaxed, and factories across Europe are permitted to reopen and operate at a limited capacity with a 'skeleton staff'. This means production activities for the research instruments and raw materials needed for the project are back up and running, but at a limited capacity compared to normal conditions. This is helped by engineers and scientists being able to return to work and continue construction and testing of the spacecraft needed for the voyage. Cloud computing and remote networking services continue to receive strong support from the government as well as the private sector, encouraging a high level of innovation. This has driven greater levels of international collaboration on the project and has allowed more research institutions from Europe and the US to take part in the project. European governments continue to subsidise the Space sector as the global economy enters a stage of economic recovery. While continuing with the project, European research institutions allocate large amounts of investment to R&D with the objective of becoming a world leader in space exploration. As a result of greater sharing of knowledge and investment, new methods for the probes data collection have been discovered, including more efficient and accurate methods of determining the structure of the sub-surface of the target planet, for example. Geopolitical tensions have fallen as the UK and EU secure a mutual agreement regarding Brexit.

Scenario B: the best-case scenario:
Following the pandemic, governments across the EU relax social distancing procedures as we enter a global stage of recovery. Factories are now allowed to reopen for full operation and production activities for the project can resume as normal; the project is now back on track for its scheduled launch. The pandemic has highlighted to governments how vital cloud computing and remote networking services have been to keep economies running while in a state of lockdown. Therefore, European governments allocate larger amounts of investment to cloud computing infrastructure and R&D, allowing for faster internet speeds, more traffic and, in turn, greater international collaboration on megaprojects, such as space exploration. This ultimately leads to the project being completed ahead of schedule. Moreover, after reallocating institutional budgets towards more immediate sectors of the economy during the pandemic such as tourism, aviation and retail, governments now begin to re-establish financing for the Space sector, which is heavily tied to government budgets and wider public agendas. This is sustained by a period of strong economic growth across the EU. Likewise, retail banks seek to regain losses made on loans due to lower interest rates set by the central bank and turn to project funding within the Space sector. Overall, extra funding and greater international collaboration efforts between scientists has led to a successful mission that has come in under budget and ahead of schedule.

Scenario C: the worst-case scenario:
As a consequence of the Coronavirus pandemic, governments across Europe have put in place strict social distancing protocols. For manufacturers, this has meant the continued closure of factories so they can prepare the workplace for the distancing requirements. This has not only meant that production activities for instruments used on the voyage have been halted, but also means that materials needed for the construction of the spacecraft itself (metals and

electrical components etc) have become more expensive. Transportation of raw materials for the project has also become significantly difficult to arrange as cargo ships and aviation companies operate at a limited capacity. Social distancing procedures also limit the number of engineers permitted to work on the shuttle at any given time. The combination of these restrictions has resulted in the project going past the scheduled launch date as well as coming in over budget. These setbacks have been exacerbated by poor economic conditions across Europe that have not only caused governments to reallocate funding to more immediate sectors within the economy (retail and hospitality etc) but whatever finance that was available for space exploration has now been further reduced. Additionally, private sources of financing such as hedge funds and private equity funds are looking for less risky projects to fund. What's more, geopolitical tensions have begun to rise as some countries within Europe begin to suffer from increased import tariffs from the UK due to a hard Brexit outcome. This has increased the cost of certain materials needed for the project and their transportation.

PROCESS description:

While considering how the project would evolve and to what extent it would be a success, I began by considering any current trends and the impact that they would have on the project. One of the most significant current trends that first came to mind was the economic consequences of the Coronavirus pandemic and to what extent it would have affected megaprojects such as space exploration.

I began by considering the key uncertainties brought about by the pandemic.

- *Issues within the supply chain – as production activities in factories around the world had been halted, the supply chain of megaprojects would certainly have been negatively affected.*
- *The amount of funding for the project was another uncertainly that required attention – as the Space sector is heavily reliant on government budgets and wider public agendas, funding for space exploration projects would have certainly been in a decline more recently as governments across the world inject large amount of emergency funding into more immediate sectors such as retail, tourism, catering and hospitality as well as aviation.*
- *Cloud computing, which has seen growth on an exponential scale over more recent months as we converge towards a 'stay-at-home economy'. In relation to the project, I believe this to be of great importance considering the amount of scientific data and research that may now be easily and instantaneously shared between project runners around the world.*
- *These factors encompass the period of economic uncertainty that we are currently experiencing.*

Lastly, I also considered an uncertainty of what will happen in the more distant future. The fate of the relationship between the UK and the EU hangs on whether we achieve a deal at the end of 2020 that satisfies both parties – a hard Brexit and soft Brexit scenario.

Participant 5

Scenario A: the baseline scenario:

The tension between the US and Europe grows after the decisions made after the pandemic, even so, the team assigned to the project manages to stay on the sidelines. They take extreme security measures both on the ground base and in the spaceship to avoid possible contagion. On take-off day, nerves fail to paralyze the team of professionals, so everything happens as planned. Little by little, the spaceship approaches the target, but since the calculations had been made according to assumptions and not past experiences, it takes longer than expected to arrive. After being placed in position, the study and collection process begins. Time passes and despite having repeatedly recognized the place, they fail to find clear evidence of life. The ground team evaluates the situation and concludes that the information and samples obtained from the environment would be more than enough to continue with the ground investigation, so they authorize the return of the team. Once on Earth, the researchers collect all the samples and tests and begin their study to find out if there is any kind of life on another planet.

Scenario B: the best-case scenario:

The spaceship leaves the land without experiencing any type of problem, given the thoroughness of the preparation for takeoff. Being in perfect conditions, the mission advances with a firm step, beating the pre set times of arrival at the target location. The brilliance of the design team, makes that the gravitational force of the planet is not an impediment to archive the positioning of the spacecraft. Thanks to this positioning, the can start the search and recognition process. After a time of waiting and thanks to space probes, the team detects signs of possible life in the form of a liquid substance. The expedition is sent for its recognition and the extraction of samples. Once the work is finished, the team returns to the ship, from where they wait for the approval of the team on Earth to start the return mission. The ground team after the analysis determines the validity of the finding and authorizes the return of the team as soon as possible. Once back, the team delivers to the researchers the documentation and evidence collected, and the sample in particular. Scientists begin the process of in-depth analysis with the illusion of being closer to demonstrating the existence of life outside of Earth.

Scenario C: the worst-case scenario:

The exceptional nature of the moment in which we find ourselves causes everything to be paralyzed. In the case of the mission, given the difference in protocols and the uneven advance of the pandemic in different countries, it was delayed until further notice by the supervisory agencies. After the accusations launched by the US and the measures taken by the different countries, the consortium and its plans are left in the background and the team fears that the mission will take longer than necessary. Thanks to security measures and the great work of the medical and scientific team, the pandemic remits, again opening the door to the mission. After resuming negotiations, the launch is finally approved and the preparation process is reactivated, this time, further increasing security measures. A couple of days before departure, one of the members of the expedition team received a visit from his sister, who despite taking extreme precautions had continued to work as a lawyer during the pandemic, being expose to the virus. The next day he goes to the operations center where they take his temperature before entering. By showing no signs of contagion, he participates in all pre-departure checks and meetings. The next day, the team works early to get everything ready before launch. However, the exposed expedition team member begins to manifest some discomfort. His

commitment to the mission, make him report it immediately. After doing a quick test, the worst suspicions are confirmed, he is infected. Given the level of exposure of the rest of the team, it is decided to paralyze the mission until the focus of infection has been control.

PROCESS description:

First, for the development of scenarios I have taken into account the objectives and the time horizon of the research. On the other hand, I have tried to analyze the entire process that the device must follow,

detecting possible turning points in achieving the objectives. The main ones are the following:

- *TENSIONS BETWEEN THE USA AND EUROPE (-)*
- *INCIDENCES IN TAKEOFF (-)*
- *TO GET IN ORBIT (+)*
- *EQUIPMENT OPERATION (+)*
- *GRAVITATIONAL FORCE HARDS THE PROCESS (-)*
- *EXTERNAL ADJUSTERS DAMAGE THE DEVICE (-)*
- *FAVORABLE CONDITIONS OF STRACTION (+)*
- *FINDING EVIDENCE (+)*

Once detected, I analyzed their incidence and their positive or negative impact on the success of the mission. Once done, to create the scenarios I grouped the positive sign statements to elaborate THE BEST OF THE SCENARIOS, the negative sign statements for THE WORST SCENARIOS and for the last one, I logically selected the most probable events that could occur in the process.

Once grouped, I checked the compatibility of the facts, which made me modify some scenarios, and finally, I developed them.

Participant 6

Scenario A: the baseline scenario:

The standard process of launching probe from surface earth to space by many countries all over the world is for research, weather studies and communication purposes. The process involves sending probes to space with an extensive research on atmospheric patterns on climate, humidity, atmospheric pressure, time, and temperature etc… This mission involves sending a probe to capture high resolution images, surface conditions and possible exploration for fossils and resources which may be useful for mankind on earth. This mission is probably aimed to explore the conditions, existence of living creatures, weather patterns based on solar radiations. The process starts with interested multinational companies investing for better creative solutions involving research on Space. To initiate the process, Extensive study on the success rate on previous space missions will be explored with data creating a pattern. Each mission will not be targeted for single goal since it involves millions of Euros. After extensive research, a launch vehicle or using a reusable launch vehicle (Falcon-SpaceX), satellites and probe designs, security software to avoid breach are primary factors to build. Once the launch happened and the probes will reach the desired destination collects data and transmitted to the earth station through a secured network. Once the process is completed the probe will be destroyed in earth's atmosphere.

Scenario B: the best-case scenario:

The best scenario involves creating a low cost model in launching a partial reusable satellites from space X carrying heavy equipment to space for multiple purposes, This can be made to use from multiple organisations to send their probes or satellites for their specific purposes(Provided zero security breach is achievable). This way can reduce the ample amount of capital investment. On successful launch with supporting environmental factors, launch vehicle returning back to its start point safety and probes entered in to destined space, High resolution cameras capturing 100m resolution pictures which is encoded, transmitted and decoded back successfully on reaching earth's station. The atmospheric conditions, solar patterns, wind conditions and weather patterns are read for probe's optimisation to enter specific areas to study. The probes on touching the surface analysing the surface conditions, starts to collect samples for study. With infrared/x-ray technology the sub surface study will be analysed for possible fossils which can be used as fuel alternatives or increasing the quality of life on earth. The best case involves probes with foreign conditions staying healthy, carries out the process precisely on collecting and transmitting the data for desired study. The positive and usable angle involves finding a source(Fossils) which can be used or its composition which can be recreated in earth used as an alternative source of power in any means(Like battery) which can be used as power source in cars, cell phones or even houses will be a deep breathed relaxed mission.

Scenario C: the worst-case scenario:

The worst-case scenarios may start with not so desired investment which can lead to many possible impacts like Quality defects on the mission, Compromised NDA which can create security breaches, Findings from the mission could be non-patentable. The possibility of failed launch due to atmospheric conditions, fault in launch vehicle which can end to a blast results ultimately with huge loss. Despite clearing these hurdles and achieving a successful launch can also lead to lots of uncertainties. Crash landing on destined spot could impact the probe and spoil the mission completely. Probes operated with solar panels could lose its energy if the

circuit system fails. Even though these missions are carried with secured network the possibility of security breach can create an ultimate criticism to the mission. If any of the scenarios led to failure of the mission will create a huge ruckus with media and public especially if it involves government funded projects in Developing nations like India when lives of common men are under stake spending millions on uncertain space mission which lead to a failure and loss can create a bad image to these projects affecting space research and damage the economy as well.

PROCESS description:

I developed the 3 scenarios from my previous exposure to space news from media channels, social network reviews, news articles and personal feelings and beliefs.

The baseline scenario is developed from the early education on space and rockets, how the process is evolved and how satellites and launch vehicle operate. The curiosity of meteorology and navigation helped me to understand the process better. Every advancement on these 2 studies will ease the life on the mankind on earth. So, investment and collection of information is utmost required. The best scenarios are developed, if the aim of the process is achieved from a raw angle with the previously exposed examples from SpaceX, ISRO and NASA. The worst-case scenarios are explained again from my own exposure to such happened scenarios in the past in India with ISRO's failed missions.

Participant 7

Scenario A: the baseline scenario:
The probe and the launch vehicle is launched from a launch pad, provided the weather *conditions are favourable. The instruments inside the probe is needed to be totally intact during the travel and operational once the probe lands. The travel which takes months to complete can be affected by the external factors such as solar wind and also other technical factors such as communication between the probe and control station. Since the spacecraft is made by a consortium of more than 20 companies from different countries, the risk factors such as development of the instruments and if faulty product is present, replacement time, cost etc. should be carefully computed. The scientists requires to find about the composition of surface and atmosphere and their effects on each other. They are also required to determine the structure of sub-surface and effects of surroundings on the atmosphere. The main aim of finding water, which is the basic source of life, whether it be in the past or present, can be probed into by using the spacecraft which has equipment which can trace the content in the soil and chemical analysis can be done. The spacecraft will be analysing the data while flying around the planet for a whole planet year.*

Scenario B: the best-case scenario:
The probe which is made by the consortium will get the highest quality instruments which can be used to study and analyse the geology of planet, within the projected budget. The spacecraft and all its components are safe during the launch. The spacecraft will be set on the right trajectory for the interplanetary voyage. The external factors such as availability of sunlight, solar wind the working of thrusters and other mechanical and electronic elements works perfectly. The communication between control center and the probe will be smooth. The critical components and equipment can be easily arranged if there is a fault in any of the components. All the members in the consortium work hand in hand to meet its objectives. Once reaching the other planet, the spacecraft will be able to orbit it to detect the presence of water. The probe will be able to land on the ground which enables it to study and analyse the composition of atmosphere and soil along with determining the structure of sub-surface to a depth of a few kilometres. The cameras provided on the probe will be able to take images of rocks and soil and results of the chemical analysis taken by the instruments can provide details regarding the presence of water.

Scenario C: the worst-case scenario:
The spacecraft can have faulty equipment which can increase the expenses above the budget. This can lead to political strife within the consortium which can lead to delay in the project. The availability of the components and its replacements can also lead to delay in the project. The conditions for the launch can be unfavourable which can lead to problems in putting the spacecraft in the right direction as the planetary positions keeps changing. Other effects such as solar wind etc. can harmfully affect the trajectory and motion of the spacecraft. The objectives of the probe is highly dependent on the equipment which can lead to failure of the mission if anything goes wrong. The probe can get damaged while landing which again can lead to failure of the mission. The composition of soil at 100-m resolution might not be possible because of the soil or other factors. The composition of atmosphere and its effects on the surface etc. might not be correctly studied. The cameras might not be operational which can hinder the mission from getting close-up images and collected specimens. The photos and

results might not be send to the control panel due to issues in communication between probe and earth.

PROCESS description:

The process I used was partly brainstorming as well as extreme world method. Firstly, the issue of concern and the time frame was identified. As the project is a megaproject, time frame will be more than two years. The major factors that can have an impact on the project was identified along with the uncertainties that can occur. Then the effect on the factors whether it be positive or negative is considered. Then these information and factors were used to create the extreme worlds that is, the worst case scenario and best case scenario. The scenarios were also checked for consistency. Brainstorming was also done to develop the scenarios. The effects of surroundings on the probe and spacecraft was developed using brainstorming techniques which helped to obtain various points that have to be considered in each stage of the project such as forming the consortium, launch and even landing on the planet.

Participant 8

Scenario A: the baseline scenario (500 words)

Europeans decided to find evidence of life, past or present, on another planet. For this mission European built probe on a spacecraft touching down on another planet, which cost about £250m to £300m. The mission carries scientific instruments that will study the geology of planets and search for water under the surface. Research institutes throughout Europe have provided the instruments. A consortium of more than 20 companies from more than a dozen European countries and the USA built the spacecraft. The spacecraft will fly around the target planet for an entire planet year. Scientists are confident that if water is present on the planet, the spacecraft with the probe will find it.

Scenario B: the best-case scenario (500 words)

The space probe successfully landed on planet and able to send the data about life and water on that planet. The space probe is able to map the composition of the surface at 100-m resolution and the composition of the atmosphere and determine its global circulation

(FURTHER THINGS ARE DECIDED ACCORDING TO RESEARCH AND HISTORICAL BACKGROUND)

Scenario C: the worst-case scenario (500 words)

The space probe won't be able to touch the target planet or space probe successfully reached on the planet but instrument isn't responding or they won't be able to capture any data. (THERE COULD BE ANY KIND OF TECHNICAL ISSUES WHICH IS DECIDED ACCORDING TO RESEARCH HISTORICAL EVENTS)

PROCESS description:

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