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Abstract

The treatment of uncertainty in innovation projects is a critical aspect that must be addressed to improve project outcomes. This thesis focuses on identifying, measuring, and managing uncertainty in innovation projects, specifically emphasizing perspectives from innovation, risk management, and decision-making. The problematic aspects identified in the literature review include long incubation periods, standardized rules and procedures, non-existent market and market unfamiliarity, fuzziness in the fuzzy front end, team-based dynamic shifting capability, and selecting the right project leader.

The research gap identified in the existing literature is the absence of a unified framework or toolbox that comprehensively addresses uncertainty in innovation projects. This thesis aims to fill this gap by proposing a unified toolbox to treat uncertainty effectively. The analytical direction of the research involves identifying the areas of uncertainty, measuring the impact on project outcomes, and developing a toolbox to manage and mitigate those.

The research methodology adopted for this study is a qualitative case study approach, utilizing a multiple case study design. Two European Union projects – RESPONDRONE and ASSISTANCE, are selected for conducting a case study analysis. Thematic analysis is employed to derive meaningful insights and patterns from the data gathered during research.

From the thematic analysis of the selected cases, five key themes are identified that significantly impact the uncertainty treatment of radical innovation projects. The key themes are- technology and innovation, communication and collaboration, adaptive project management, stakeholder engagement, and risk management. Each theme significantly impacts uncertainty treatment in the four critical areas of uncertainty- market, technological, organizational, and resource. These observations steer the study to see the treatment of uncertainty in innovation projects through the lens of existing literature. An impact assessment flowchart is developed, and a unified toolbox is proposed for better uncertainty treatment by putting things into different perspectives.

This thesis concludes that the uncertainty paradigm in radical innovation projects is complex and nuanced. Rather than trying to pinpoint every aspect of it, a better approach for a project team is to understand the common areas of uncertainty generation, measure the impact of an unexpected event as soon as possible and equip themselves with a unified toolbox that can provide them the flexibility to use any tools necessary based on the context of the uncertainty.

Acknowledgment

During the first phase of the thesis, I lost my father to liver cirrhosis. Back in 2020, when I was leaving home for higher education, there was pride in his eyes and a big smile. I am graduating today, but he is not there anymore. The whole process of working on this thesis has been an emotional roller coaster ride. I hope that wherever he is, he is okay and seeing me today reaching the finish line.

I want to express my sincere gratitude to my thesis supervisor, Associate Professor Reidar Staupe-Delgado. Without his tremendous support, I would not have been able to go through this rigorous process of writing a master's thesis. He has been available for any inquiry and has always provided me with constructive feedback and clear direction for conducting research. The knowledge I gained from the interactions has been tremendously valuable, and I will be able to use the knowledge further in my career.

Lastly, the UIS library has been a significant part of this thesis writing journey. 24/7 access, necessary resources, and guidance classes on research, academic writing, and referencing have boosted my confidence and helped me to learn complex things quickly. I am grateful to the library management for arranging all the necessary resources to complete this journey.

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1: INTRODUCTION

In this ever-changing world, organizations, businesses, and projects all over the world face different kinds of internal and external risk factors, which sometimes become an obstacle to achieving their goal. Some elements are common and known risk factors, while others are not. For an organization to set its strategy, achieve milestones and improve its decision-making process, it is imperative to identify and mitigate risks and uncertainty. At the same time, it is also essential that organizations become more resilient from risk insights (ISO31000, 2018). With that said, it is vital to understand how we define risk and uncertainty. In addition, with technological advancement, climate and energy crises, and hundreds of other social, economic, and political issues, different industries in different geo-political locations are facing more drastic changes than ever before. The need for more successful radical innovation projects has risen drastically to cope with these changes**.** In their study, McDermott and O'Connor (2002) mentioned that management practice for incremental and radical innovation projects in an organization is different, and effective management practice for radical innovation is critical for long time survival of a company in the current market. It creates the burning urgency to understand the difference between incremental and radical innovation project and their management approaches. Incremental innovation is an increment of the current product line of a company, while radical innovation brings new and disruptive technology to the market. Because of the novelty of radical innovation projects, pinpointing the uncertainty source of a radical innovation project is complex, thus making the treatment process even harder.

Radical innovation necessitates implementing new technologies or tapping into a new and nonexistent market. Radical innovation projects indicate major paradigm shifts in any current business system and thus lead to process and innovation ecosystem changes. The demand for change leads the organization to determine the new market scope, enable competency stretching and create new roles, responsibilities, and team composition. It puts the radical innovation project into the uncharted water of uncertainty where traditional risk management procedures are obsolete and, therefore, require a different approach towards uncertainty management. This complexity makes this topic interesting because we can observe that during highly unpredictable times, it is tough to identify generic risks and implement risk mitigation procedures (McDermott & O'Connor, 2002). It is also possible that a new kind of risk may arise due to high uncertainty and will impact the project's progress at any time. Still, it will be utterly unrecognized due to unfamiliarity.

McDermott and O'Connor (2002) did a multiple case study on 12 radical innovation projects in 10 large established North American firms. The aim was to explore the challenges of radical new product development in the organization from a strategic perspective, and the findings were grouped into three high-level strategic themes- Market scope, competency management, and people issues. In all the themes, they found that a new market, the need for constant competency development, and the changing roles and responsibilities in teams create high uncertainty, and organizational management and capacity are often not well equipped to support such uncertainty.

Oconnor (1998), in her cross-case comparison of eight radical innovation projects, identified three sets of mechanisms companies use to reduce market uncertainty in innovation projects. It also helps the project team to adhere to efficient learning simultaneously. The first sets of mechanisms were only valuable for managing market uncertainty but did not help with the learning. The second was a helpful learning tool but did not help with market uncertainty management. The third set of mechanisms endorsed overall organizational learning. This study has illustrated common approaches organizations take to handle the uncertainty in innovation projects.

However, none of these studies addressed developing a unified model to treat uncertainty in innovation projects. Through close examination of established standardized definitions of risk and uncertainty and risk management frameworks, I argue that none of them are well equipped to handle the complex dynamics of the highly uncertain nature of innovation projects. I contend that in a world where change is the only constant, the necessity of a unified toolbox to handle uncertainty knows no bounds. In pursuing that, explorative research has been conducted in this paper through multiple case studies. The purpose of doing a multiple case study on the European Union's two novel technology development projects (RESPONDRONE and ASSISTANCE) is to understand their approach to managing uncertainty from a more diversified perspective. The critical focus area of evaluating uncertainty treatment in this research are- Market, Technical, Organizational, and Resource. Finally, I have proposed a unified toolbox based on the knowledge gathered from the empirical evidence of this study that can leverage uncertainty treatment in innovation projects.

This thesis is led by one main research question and three more supporting research questions to find a better uncertainty treatment approach. The main research question of this thesis is:

- **How can radical innovation projects better navigate and treat the unknown territory of uncertainty?**

This question aims to discover how a radical innovation project team can better understand and treat the complex dynamics of uncertainty where traditional risk management approaches are often obsolete.

To further examine this, I will address the following research questions:

- ✓ What are the critical areas of uncertainty in a radical innovation project?

The purpose is to discover the most common areas of uncertainty generation though we know that uncertainty does not arise in patterns or one area. It will help a radical innovation project become more alert on the common areas of uncertainty.

- ✓ How to identify and measure the impact of uncertainty in a radical innovation project?

The purpose is to investigate a mechanism to identify uncertainty and measure its impact on the project. It is crucial because different uncertainties arise from different sources in various timelines

in a project. If the impact of the uncertainty in a project remains unmeasured or misunderstood, it exposes the project team to the possibility of focusing on the less impactful uncertainties while the most impactful uncertainties remain untreated.

- ✓ What combinations of tools and frameworks can better treat uncertainty in radical innovation projects?

The purpose is to examine what combination of tools and frameworks helps a radical innovation project team to deal with uncertainty better. Treating uncertainty can not be done by only one framework or methodology. However, combining necessary tools and frameworks may better equip a project team during extreme scenarios. This investigation will aim to propose a unified toolbox for uncertainty treatment for any radical innovation project team.

In this research, I will employ the term "uncertainty" as a distinct concept delineating its specific definition. SRA (2018) provided a qualitative definition of uncertainty-

> For a person or a group of persons, not knowing the true value of a quantity or the future consequences of an activity. It includes imperfect or incomplete information/knowledge about a hypothesis, a quantity, or the occurrence of an event.

It means that uncertainty can not be measured by calculating a future event by its probability and consequences. Uncertainty refers to incomplete information about an event, things we do not know, things we are not familiar with, or things we cannot measure. If we can measure an event's probability or consequence and its impact, then it is a risk, not uncertainty, and there is a clear distinction between them. Uncertainty is like a quest in the land of unknowns where no one knows what they are looking for, and there is a possibility that it would be unrecognized even when seen because of the unfamiliarity. Thus, the definition relates closely to the context of uncertainty in radical innovation projects. The purpose of such a project is to disrupt a market or industry. Neither the company nor the project team can identify all the risks and threats beforehand.

The problem is that current risk management standards and traditional methodologies do not provide a solid framework for defining, identifying, and treating uncertainty in a radical innovation project. It also does not explain how uncertainties may arise from the implemented change management processes. For example, ISO 31000 has been a pioneer for a long time and is an established standard for risk management in all kinds of organizations. Their risk management guideline defines risk as the effect of uncertainty on objectives. They mentioned "effect" as any deviation from the expected. This deviation can be positive or negative and result in opportunities and threats. In addition, they have mentioned that objectives may have different angles at different levels, and risk usually includes risk sources, potential events, consequences, and likelihood (ISO31000, 2018, p. 1)**.** The problem with this definition is that they have not provided solid guidance on defining and identifying a risk source. There is no guidance on navigating when the

risk source is unfamiliar or what tools can be used to develop consensus on identifying unknown sources (Aven & Ylönen, 2019).

In contrast, the Society of Risk Analysis (SRA) has a different perspective on risk and uncertainty definition. SRA has a broader view than ISO31000 when defining risk. It includes the possibility of an unfortunate event, its consequences, and uncertainty. SRA focuses on the background knowledge related to consequence and uncertainty. The strength and validity of the knowledge also play a crucial role in this definition (SRA, 2018, p. 4). SRA's qualitative concept of uncertainty and a knowledge-based subjective probability method to quantify it is a more viable approach in highly uncertain times, as it has mentioned the suitability of its matrices and descriptions. It is situation-based and has tried to measure uncertainty from qualitative and quantitative perspectives.

Thesis Structure

The following chapter will review the relevant literature on uncertainty management in radical innovation projects, risk management, and naturalistic decision-making. The existing literature on innovation uncertainty mainly focuses on identifying different areas of uncertainty and their components rather than on better treatment and management. Nine papers on uncertainty in radical innovation projects will be presented to portray the innovation perspectives. The chapter will also present risk management and decision-making perspectives from existing research. Lastly, some research gaps will be identified, and the analytical direction for this study will be presented.

Chapter 3 will provide a comprehensive overview of the methodological decisions made for this project. It will detail the process of data collection and data analysis, address ethical considerations, and thoroughly examine the quality of the research, as well as its limitations.

Chapter 4 will present the findings of this study. The key themes derived from the thematic analysis of the selected case will be described descriptively with necessary data visualizations. To better understand the phenomena of the themes, every theme will be dissected into fewer subthemes. It will help to understand the theme-related nuances better.

Chapter 5 will discuss what uncertainty treatment practices lead the selected projects for this study towards successful completion while developing a novel technology during a pandemic and with different moving parts around the world. The key themes from the previous chapter related to uncertainty treatment in innovation projects will be the center of the discussion. I will analyze what components had a significant value in uncertainty treatment in those projects and how far it can be generalized for other innovation projects. I will also suggest a theoretical uncertainty treatment toolbox based on the knowledge from the literature review and analysis of this case study.

Chapter 6 will summarize the investigation of this research, reflect on the importance and limitations, discuss further research opportunities, and offer concluding thoughts.

2: LITERATURE REVIEW:

This chapter provides a theoretical insight by conducting a comprehensive literature review on innovation management, risk, uncertainty management, and naturalistic decision-making. First, I will portray the innovation perspectives, risk and uncertainty management perspectives, and decision-making perspectives for this study. Then, based on the existing research reviewed here, I will stage the problematic aspects of uncertainty management in innovation projects. Lastly, I will discuss the gap in the existing research and reflect on my analytical direction for this study.

2.1: Innovation Perspectives

It is well-known that the success of radical innovation projects hinges on a collective team-based effort and the ability of teams to dynamically shift their shared goal orientation (Alexander & Van Knippenberg, 2014). It is because radical innovation projects face more uncertainty and risks than incremental innovation projects. It has also been pointed out that team motivation, ambidextrous leadership, and reflexive team processes are crucial to success.

Radical innovation projects are financially more profitable for any company but have more significant uncertainty and risks. Dedicated teams in these projects play a vital role in the success, but the team must be able to shift dynamically back and forth to create a shared goal orientation (Alexander & Van Knippenberg, 2014).

Innovation projects often create some discontinuity and disruption at the micro and macro levels of the organization (Alexander & Van Knippenberg, 2014). In incremental innovation projects, discontinuity happens at the micro level as it is new to the firm or existing customers. However, in radical innovation projects, discontinuity happens at the macro and micro levels- creating new products and services for the market and the world. Current practices in organizations with strict routines, practices, structures, and cultural norms often hinder innovation. The control-based and predictive models underestimate the requirement of learning, flexibility, and team-based goal orientation in radical innovation projects. Radical innovation projects often have unpredictable and longer timelines, ten years or more. Because of the incubation period and the high risk of failure of such projects, the team must develop a collective and shared consensus on whether the project is worth pursuing.

A proposed theoretical model analyzes the relationship between team goal orientation and four types of team behaviors critical to the radical innovation process (Alexander & Van Knippenberg, 2014). It mentions the relationship between team goal orientation and idea innovativeness. Teams with a shared learning orientation are more likely to pursue radical, innovative ideas and continue to do so after failure because failure is appreciated and defined as another learning opportunity in a learning-oriented environment. Teams with a performance prove orientation will also likely pursue more innovative ideas as success is highlighted in such a team, and shame on failure is not as strong as in a performance-avoid team orientation. In the relationship between team goal

orientation and external communication strategies and innovation implementation, teams with a learning orientation primarily engage in technical scouting activities, and teams with performance prove orientation focus on ambassadorial activities. The team's dynamic shifting ability between learning orientation and performance prove orientation is a crucial success factor of successful innovation. Lastly, the role of ambidextrous leadership ensures that the team has the flexibility and capability to shift between learning orientation and performance prove orientation dynamically.

The notion of shared goal orientation is not new, but a collective team-level shift in goal orientation is. The proposed model showed how adaptive shifts in goal orientation and ambidextrous leadership make teamwork a dynamic system and the critical role of shared leadership in identifying the moment of switching goal orientation (Alexander & Van Knippenberg, 2014). The authors mentioned two limitations of this research- innovation speed and team communication. The authors have indicated that this research assumes that the team has the time to implement an intuitive process to shift team goal orientation, but this method will not be applicable in a high-velocity environment where innovation speed is a critical success factor. Also, at the team level, team capability in communication plays a vital role in dynamic goal shifting. For a geographically distributed team, it will be hard to establish quick communication than for a collocated team with face-to-face interactions.

Better management of the risk and uncertainty-related challenges in the fuzzy front end of the radical innovation project is proportional to the innovation team’s leadership, process, and outcomes (Robbins & O'Gorman, 2015). Customer demand and market competition always put big companies in dire need of new product development. However, the success of new product development in radically innovative ways has not been satisfactory. The main reason is high risk and high uncertainty. To reduce the uncertainty of new product development's success, some companies try to take customer input in the product development process. However, the paradox is that when a product is developed based on the customer's wants, it becomes more of an incremental innovation rather than a radical innovation project. Customers do not come up with radical product ideas; innovators do. So, the process of uncertainty reduction by taking customer input is problematic.

A critical success factor of a radical innovation project is the team's dynamic shifting capability between autonomy and following rules (Robbins & O'Gorman, 2015). It is because a self-organizing team can maintain productivity at the highest level and give the best strategy for successful new product development. Implementing standard rules and procedures also plays a similarly vital role in this process. It is because where autonomy provides the team members the flexibility to learn and improve, standard rules and procedures are essential for scaling and project delivery. However, the problem is that most of the time, team members of R&D projects are often resistant to formal rules and procedures. Conflict in team decision-making also happens because of these projects' very nature of uncertainty and complexity.

Team leadership is crucial to the success of an innovation project (Robbins & O'Gorman, 2015). A team leader's initial sense-making capability determines a team's innovation management process and outcomes. Though previous studies identified the critical role of team leadership in the radical innovation process, none provided a framework for choosing the best leader or team for a radical innovation project.

The messier part of the radical innovation process is the fuzzy front end, where new ideas are developed (Robbins & O'Gorman, 2015). Recent research indicates that the fuzzy front-end part of the innovation process is very distinct and behaves differently than the other stages of the radical innovation process. It is because, in this part, new ideas are getting generated and tested, which contains high risks and uncertainty, and everything is known-unknown or unknown-unknown most of the time. Research for developing a management process for the fuzzy front-end of radical innovation projects is necessary. In the early phase of radical innovation projects, a flexible team leadership style brings more results, whereas structured project management works more when the radical innovation projects turn into the phase of incremental innovation.

The importance of a successful radical innovation project for an organization’s long-term success knows no bounds; ironically, traditional project management practices are often ineffective in the vibrant nature of such a project (O'Connor & Rice, 2013). The main problem is that large organizations tend to routinize practices, which is ineffective in highly uncertain domains. One definition of a radical innovation project is given by O'Connor and Rice (2013):

> A product, process, or service with either unprecedented performance features or with such dramatic changes in familiar features or cost that new application domain become possible. Radical innovations transform existing markets or industries or create new ones.

The definition has described how radical innovation works in disrupting a market or creating a new market. However, it always does not have to be only creating a novel technology from scratch. If creative changes in current features can accelerate massive disruption in an existing domain, thus, can also be considered radical innovation. This definition has a broader perspective which is vital for my research to identify radical innovation projects while selecting cases for the analysis.

Enormous uncertainty comes with developing novel technology or services (O'Connor & Rice, 2013). The uncertainty is so high in radical innovation because no one has experienced this innovation before. Therefore, uncertainty cannot be handled or contained; it can only be better managed.
Different researchers along the timeline have discovered different dimensions of uncertainty (O'Connor & Rice, 2013). The most traditional domain of radical innovation is identified by "High technical and market uncertainty," also known as "Suicide Square." The higher uncertainty in these

two domains is a critical success factor for any organization. Recent technological advances come so fast and rapidly that they disrupt the market needs and customer orientation anytime. It exposes an organization to strategic ambiguity in finding the proper action to handle uncertainties.

However, it is not enough to identify the dimension and degree of uncertainty (O'Connor & Rice, 2013). A three-dimensional uncertainty matrix with four different uncertainty categories provides a better understanding. The elements of the three dimensions are uncertainty category (technical, market, organizational, and resource), uncertainty latency (anticipated vs. unanticipated), and criticality (routine vs. showstopper).

Identifying these different dimensions was not new in the radical innovation project management and uncertainty research; combining them into a unified matrix model to quantify the uncertainty was a breakthrough. The introduction of two different uncertainty categories- resource and organizational uncertainty- has provided a fresh new perspective on looking at things from an organizational and managerial point of view. How the organization's locations over the project life cycle will have an impact on the success of the project? What aspects of the project value chain will be handled internally, and what will be outsourced? How will the project get strategic support from the different parts of the organization - these questions give a broader view of uncertainty recognition and a starting point to better deal with it. Resource uncertainty includes project budget, team member competencies, and the adequacy of the resources.

The probability of innovation success is directly proportional to the information infrastructure in an organization and the decision maker's capability to make the right decision in highly uncertain moments (Van Riel et al., 2004). There are two success factors for any organization- internal and external. External success factors often include how a new product or service has been adopted in the market or performs well. Internal success factors usually represent the firm's internal technical and scaling competency, communication, the synergy between the service and organization, leadership style, and cohesiveness between different departments. A noticeable part is the importance of the most underrated skills for an organization or a leader- decision making under uncertainty. Better decisions under highly technical and market uncertainty will bring better innovation success. However, decision-making under uncertainty is challenging and highly subjective to the result. A decision can be highly calculated and well planned, considering all the possibilities, and still can fail in a highly uncertain environment. So, it is also essential to understand how to define a good decision.

Some exciting hypotheses on the service innovation success factors illustrate some proportional relationships (Van Riel et al., 2004). The first hypothesis is that a proportional relationship exists between an organization's effort in intelligence gathering and innovation success. The second hypothesis is that a safe and shared space for informal internal communication is crucial to success. The third hypothesis illustrates the importance of an innovative climate within an organization

because the innovative climate influences organizational efforts on knowledge gathering. The fourth hypotheses indicate the proportional relationship between a decision maker's experience and innovation success. The information processing outlook has proven to be an essential success factor in new service innovation projects. For example, market orientation has usually been considered an external success factor for a long time; however, Van Riel et al. (2004) demonstrate that market orientation works as both internal and external success factors. An interesting fact is that customer information and input are a huge success factor in new service development projects.

Robbins and O'Gorman (2015) argued that customer input and experience-based information could hinder new product development projects. Radical innovation is bringing something new to the market that has not existed before. Innovators use their imagination and technical expertise to develop something radically new. Customer input is irrelevant in this project because customers cannot give insightful input on something they have not used or experienced before. However, the idea is different in radically innovative new service innovation projects. The initial idea of a service innovation project is developing and implementing new services. The service is always for the customer to improve their experience. If the newly innovative service does not serve the customer, the project cannot succeed (Van Riel et al., 2004). So, customer input is vital in developing NSD projects. However, if the service development is only based on customer input and needs from the existing customer base, the project can lose its radicality and become more incremental. The best approach for such a project is implementing a feedback loop in the service development process where customer feedback will help innovators generate new ideas for continuous improvement. The following figure will help to visualize the process-

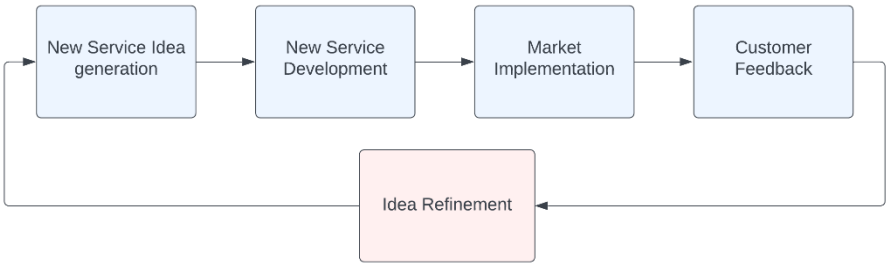

Figure 1-Integration of Customer Input in New Service Development Projects

As we can see, the process will start with a radical idea generation of the innovators, leading to a new service development project. The service project will get implemented for customers' input and experience in the market. An idea refinement process can be integrated into the loop where innovators will consider the inputs from the customers to fine-tune their service innovation. It will help ensure that the project's success criteria are met and that the radical innovation part is alive, ensuring the organization's long-term benefits and market survival.

Contextual differences in innovation projects necessitate the development of a contingency cube for innovation success. Despite context differences, new product development and commercial research projects shared the same market and technological uncertainty, production cost, and development process (Balachandra & Friar, 1997). Both controllable (internal organizational factors) and uncontrollable factors (external organizational factors) significantly influence project success. Previous research has conceptualized and proposed different models for developing a successful project. Some were process-based, while others were outcome-based; however, none were contingency-based. A solid number-based success factor analysis might be irrelevant in radical innovation projects. Radical innovation projects are about creating new products, markets, and customer experiences. Considering contextual variables discovers three critical success factors for innovation projects - the nature of the innovation, the nature of the market, and the technology.

In the context of innovation's nature, it is arguable that the market for radically innovative products does not exist. Where the market does not exist, analyzing historical or current data might be irrelevant to the project's success (Balachandra & Friar, 1997). The analysis approach and technique are also very different in existing and new markets. The high uncertainty of a new market type makes it difficult to understand the variables in the analysis. The complexity level of the technology itself also has a significant impact on its success. The uncertainty of the technology has a proportional relationship with complexity; in other words- high complexity creates high uncertainty. In this kind of technological development, the approach to product development is rapid and incremental, which can ensure a quick product introduction. The downside is that this kind of development has no standards or measures. The product's later phases can pose a greater risk to compliance and market survival.

In a proposed contingency plan, a total of eight blocks of combinations have been introduced from different dimensions, and positioning of these dimensions can help the project managers and organizations to understand the emphasis and the required degree of emphasis (Balachandra & Friar, 1997). For example, for an incremental innovation product just trying to increase the product outreach and customer experience, the market analysis and technical complexity will differ from introducing a radically new product. So, understanding the context, pinpointing them, and taking necessary actions is the best way to ensure success in radical innovation projects.

Incremental and radical innovation project management practices differ due to market scope, competency, and people-related uncertainties (McDermott & O'Connor, 2002). Effective development of radical innovation confirms a firm's success in the long term as radically innovative products bring a competitive advantage in the market. However, radical innovation indicates significant paradigm shifts, leading to process and innovation ecosystem changes. Also, the successful incubation period for a radical innovation project is typically longer, ten years or more. When a project goes on for a long time and success gratification is delayed, companies can have a high-risk perception towards that project. It is possible that within this long period, the

market context has changed, and the product is not relatable anymore; new management can come in with a different product vision, or funding can get canceled on the current project due to perceived high risk on projects success.

Technological radicality plays a crucial role in the uncertainty management of a radical innovation project, but market existence is a driving factor for project and change management (McDermott & O'Connor, 2002). In a familiar market, available competency, people, and business models give a company initial inertia to start the project. Nevertheless, companies need time to develop strategies and business models in a new market. Sometimes it hinders the project's progress and catches R&D teams off guard due to unfamiliarity with the market.

Organizations exploit current competencies widely to build radical innovation projects (McDermott & O'Connor, 2002). They use their current knowledge and market experience as a starting base for radical innovation projects. Then they stretch their skills as needed in different turfs and unfamiliar areas. From the observation, this is a way to manage uncertainty from a firm's perspective. Though conceptually, the definition of radical innovation indicates that radical innovation happens in high technological and high market uncertainty, firms and project teams tend to manage uncertainty in the continuous development process in the project lifecycle.

Informal communication and networking significantly influence the success of radical innovation projects. Informal networks are critical in gaining technical and market insights and moving the project forward(McDermott & O'Connor, 2002). Radical innovation projects pose higher risk and uncertainty, so the project teams must act quickly and proactively. Informal communication practices make it easy for project team members to reach out for help and share necessary information with essential stakeholders regularly to fix the course of action quickly. This kind of mobility of the project team in an organizational context is one of the secret sauces of the radical innovation project's success.

Traditional project management practices of evaluation, monitoring, and control do not always contribute significantly to managing market, competency, and people uncertainty (McDermott & O'Connor, 2002). The predictive project management style focuses on planning everything before the work, and change is very bureaucratic once the project starts. However, the very nature of radical innovation projects creates uncertainty and ambiguity at any point in time. Therefore, the team needs to stay focused to work on the goals. The skills of negotiation, handling ambiguity, clear communication, and setting boundaries for the project team to protect them from external distractions are the critical skills needed for a project manager in a radical innovation project.

Organizations and project leaders tend to believe too much about their historical experiences and past project performances (McDermott & O'Connor, 2002). There is a misconception that what has always worked so far in incremental projects will also work in radical innovation projects.

However, it is impossible because the nature of such projects induces uncertainty in every functional domain. Project leaders must develop a learning mindset, and organizations must create a learning environment to let newly skilled radical innovation project managers thrive.

Market learning is critical in the early development stage of new product development projects (Oconnor, 1998). Ironically, traditional market data collection and analysis is not very useful in such projects' early idea and product development stages. In addition, there is no "one size fits all" strategy for handling market uncertainty. Companies have different approaches to handling market uncertainty to develop their product successfully.

Previous research has proposed market learning strategies for radical and incremental new products. Visioning and creating demand for the market is essential first, whereas listening to the market and efficiently addressing existing demand is critical for the latter. However, there has not been a clear guideline or framework for creating a demand for the product that has never been in the market before, or nobody can perceive the product's value yet. These approaches leave a grey area (Oconnor, 1998).

Some other researchers have emphasized market learning methods and processes in pursuit of reducing uncertainty. The paradox is that they have tried to solve the market uncertainty in radical innovation projects focusing on the methods of incremental innovation projects (Oconnor, 1998). However, the market uncertainty in these two kinds of projects lies in totally different spectrums. For example, customer input is integral to uncertainty treatment in incremental innovation projects. Market research data reflect customer needs and demand, and existing products get improved and developed by adding new features based on market research data. However, this does not apply to new product development projects. Radical innovation projects are always about introducing something new in the market, not adding features to the existing product base. When the product is new to the market, and customers have never seen it, they cannot correctly understand its value. Therefore, in the initial development stage of radical innovation projects, customer input will not add any value.

The scope of responsibility in collecting the market data and the validity of the research also play a crucial role in reducing market uncertainty (Oconnor, 1998). In the early stage of product development, it may be the technical people who can provide a better vision of the market data, whereas, in the later stage, it may be the sales and marketing people who are in day-to-day interactions with customers receiving feedback on the newly developed products. It is hard to pinpoint in the timeline who will provide what kind of data in different stages, thus, increasing the uncertainty in radical innovation projects.
Traditional market analysis techniques and questions are not valuable in the fuzzy front end of radical innovation projects (Oconnor, 1998). The market-related questions' characteristics depend on market familiarity and the product development stage. In an entirely new market and early

development phase, the most critical question is to which degree the newly introduced product will offer value to the market rather than understanding what customers want to see in the product features.

Market familiarity also significantly determines the research methodology for radical innovation projects (Oconnor, 1998). Traditional analytical tools or historical data may be sufficient to understand the market paradigm in a familiar market. However, dealing with an unfamiliar market is a different game. There, project managers must approach the market with empathy and open eyes for direct observation. They need to have room for mistakes and learning by doing attitude. The market learning mindset is crucial in reducing uncertainties in an unfamiliar market orientation, and learning gets maximized when it happens continuously.

A team's autonomy and decision-making capability significantly generate valuable data from market learning (Oconnor, 1998). An autonomous learning environment allows team members to open themselves without fearing failure or consequences. It builds a solid trust-based mechanism proportionally related to data quality.

Openness in the fuzzy front end is integral to service innovation (Thanasopon et al., 2016). The innovation process's fuzzy front end begins when any opportunity gets considered for ideation, exploration, and innovation. It is the most critical phase for a radical innovation project for two reasons: The quality of this phase is the determinator of the success/ failure of the project, and the innovation process can be significantly improved with cost and time savings.

Innovation project results and management are very context-sensitive, and the openness competence of a team is a crucial success factor for a radical service innovation project (Thanasopon et al., 2016). Openness competence ensures information gathering for the team and reduces uncertainty for decision-makers. Data-driven decision-making is an integral part of the success of such projects.

Reduced market and technical uncertainty improve an innovation project's financial and non-financial success (Thanasopon et al., 2016). Traditional market intelligence (user survey, user feedback, competitor study) significantly helps reduce uncertainty. However, these intelligence data are valuable only in incremental innovation projects where the innovation extends any existing product or service. When a company works on a radical service innovation project, traditional market intelligence cannot provide reliable data for gaining a competitive advantage or long-term success. More interestingly, early reduction of fuzzy front-end market uncertainty will also have almost zero impact on the project's financial or non-financial success. It is because the type of service introduced to the market is entirely new, and users have no prior experience with it. In the fuzzy front end of a service innovation, project managers and team members are working with a hypothetical idea of a service that may positively impact the company's long-term financial

or non-financial success. In the early ideation and exploration phase, no type of market intelligence will impact the project's long-term success as it does not have a solid idea of the valuation of the product.

Interestingly, reducing technical uncertainty has no proportional relationship with the radical service innovation project's success (Thanasopon et al., 2016). It is a contradictory idea in radical new product development projects. In the context of new product development projects, technical uncertainty reduction is integral to the project's success. It makes sense because firms try to develop a completely new and innovative product in new product development projects. If the product cannot get developed due to high technical uncertainty and complexity, the project dies even before it starts.

Openness competence is the dynamic capability of a team who can shift its goal and adjust its scope as necessary (Thanasopon et al., 2016). Sensing capability has a massive impact on developing openness competence. The very nature of the radical service innovation project is exploring the unknown. There is no factual data or solid direction for what will happen, what will work in the market, and what will fail. However, a team with sensing capability based on their tacit knowledge and exemplary technical expertise can sense many things. They can strongly guess what may or may not work out. They will not always be correct, but they are the best person to rely on for an opinion on driving a radical service innovation project toward success. To increase the team's openness competence, choosing the right team members with good technical and tacit knowledge is essential. Project managers must also ensure an open, collaborative environment where ideas are valued, voices are heard, and market volatilities are embraced instead of denying it.

In incremental innovation, companies often have routinized procedures to run the project, increase efficiency, and maximize value (Lee & Kelley, 2008). However, routinized procedures become irrelevant in projects with high uncertainty and ambiguity. Companies need room for developing dynamic capabilities distinct from organizational capabilities to address this problem. Dynamic capabilities are associated with change. They do not exhibit any highly patterned routine procedures. They provide best practices for the management team with room for learning and iterative experimentation.

The challenge arises when figuring out the critical components of dynamic capabilities (Lee & Kelley, 2008). Is it a resource or a process? The answer is that neither a single resource nor a process can define a dynamic capability. A firm can have top technical and organizational resources, but if they do not have the process to optimize the resource and generate value, then there is no point. Similarly, too many processes and routine practices can hinder innovation and handling uncertainty and ambiguity. So, a more sensible approach can be implementing routinized procedures to bring order in a chaotic situation and increase efficiency but also have room for some

chaos in a highly uncertain environment to ensure innovation. That is where the role of dynamic capabilities among the team members and managers illustrates its significance. In addition, relational and decision-making support also has an overlapping interest in creating dynamic innovation capabilities. Navigating through uncertainty can be very challenging from time to time for the team members due to market, technical, organizational, and resource uncertainty. It is vital to have the proper functional support from the management during a critical time to continuously work on the project's success. Other key external and internal stakeholders in the projects, front-end, and back-end, also must ensure continuous support to the innovation project team to achieve its goal.

Innovation team project leaders are not perfect and will not be perfect (Lee & Kelley, 2008). They are continuously working with unknowns and uncertainty. So, it is impossible for them always to have the correct answers. Sometimes aligning their decision-making with project goals and success can be challenging. Management must ensure the hurdle does not discourage them from trying new solutions. When management can create a safe environment where mistakes are a learning opportunity, give project leaders direction, and help them understand organizational goals in the proper context, it improves their cognitive decision-making capabilities. They will seek new challenges and innovative solutions daily.

Strategic resource allocation boosts an innovation project’s performance (Klingebiel & Rammer, 2014). Some organizations like to delineate resources across a broader range of innovation projects to ensure the overall success of the project portfolio. In contrast, other organizations do technical analyses of the most promising projects and allocate the most resources to developing those projects. Both have their shortcoming alongside their benefits. For example, allocating resources to a broader project range maximizes portfolio performance. If all the resources are allocated for the project's early stages, regardless of their future performance, sufficient resources will not be available in the later stages of the project development. Also, performance depends not only on allocating resources along a wide range of projects. It depends on allocating resources to a suitable wide range of projects.

A better way to handle uncertainty in resource allocation is a combination of a breadth range of projects with an appropriate selectiveness mechanism (Klingebiel & Rammer, 2014). Though a firm's overall innovation expenditure depends on both project allocation breadth and project resourcing, breadth significantly influences performance independent of resourcing. A broad range of resource allocation increases the odds of market success and can outperform the magnitude of resource allocation. Market uncertainty is way too high in the early stage of any radical innovation project. There is no analysis technique to determine if a radical new product will perform well in the market. So, allocating a huge chunk of resources to a few projects that can potentially succeed is a bad idea. A project manager or business analyst's forecasting is based mainly on market data and customer preferences. However, the loophole in this approach is that the product has not been

on the market before. The technical product is radically new, so the forecasting and analysis are unaligned with the proper context. On the contrary, if the firm has a wide range of innovation projects to capture the market with different product segment, distributing a fair share of resources amongst all the projects in the early stage of development have the potential of a huge performance boost for the company. Though some projects may inevitably fail, it still provides greater odds in the overall portfolio performance.

In the later stage of product development, firms generally require a different strategy to maintain portfolio performance (Klingebiel & Rammer, 2014). After the initial build of a product, introducing it to the market to get feedback or in the changing market demand, firms need a selective strategy to determine the continuity of resource allocation. Lack of selectiveness in the later stage can lead breadth into a more disadvantageous position. This efficient strategic dynamic adaptability with efficient selectiveness mechanisms gives a robust long-term performance continuity in their project portfolio.

Breadth and selectiveness are proportional to boosting portfolio performance (Klingebiel & Rammer, 2014). Now, the question arises about what factors influence that relationship. The answer is – the innovation intent of a firm. A firm with creative ambition achieves peak performance if it maintains a broader project portfolio. Extreme innovative intent increases a firm's risk tolerance level. Increasing the risk tolerance level allows firms to deal with more uncertainty and thus build their resilience. The more resilient and uncertainty savvy a firm becomes, it boosts the more innovative intent of the firm and therefore increases the breadth of resource allocation across projects.

2.2: Risk Management Perspectives

The IRGC Risk Governance Framework offers a comprehensive guideline for early identification and managing risks (IRGC, 2017, p. 9). It also provides the flexibility to involve multiple stakeholders. The framework helps to conceptualize, analyze, and manage substantial risk and indicate the gaps in the risk governance process. The framework follows a five-step interconnected process - pre-assessment, appraisal, characterization and evaluation, management, and cross-cutting aspects. The following figure provides a comprehensive illustration of the framework-

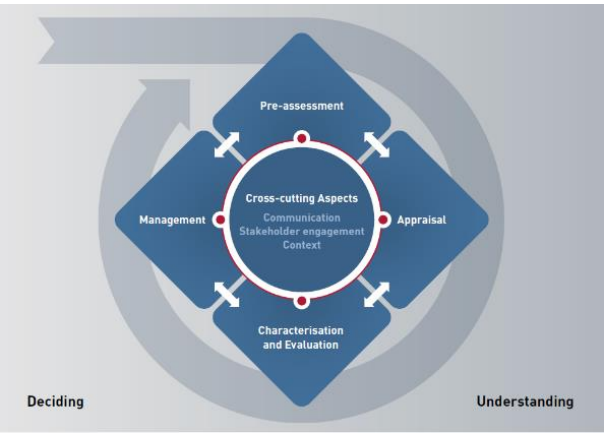

Figure 2- IRGC Risk Governance Framework (IRGC, 2017, p. 9)

It is evident from the figure that the boundaries of the risk or system get identified and framed in the pre-assessment phase (IRGC, 2017, p. 10). Technical and superficial causes and consequences of risks get assessed in the appraisal phase. In the characterization and evaluation phase, a judgment on the risk is done, which also directs the management requirements of the risk. Finally, the decision on the risk management option gets done, and they go for implementation. Communication, stakeholder engagement, and acting according to the context are at the heart of the whole process and must be maintained at every step. The main benefit of this framework is that it creates a clear distinction between understanding the risk and deciding on the risk management procedures.

2.3: Decision-Making Perspectives

Human experience enables them to rapidly categorize situations to make effective decisions (Klein, 2008). Researchers have long developed different frameworks or models for the decision-making spectrum. Most of the identified optimal ways of thinking were in a well-structured controlled environment. However, the heuristics and biases paradigm by Kahneman, Slovic, and Tversky illustrated that people do not adhere to optimal performance by comparing different available options in real life; they rely on their heuristics. Following that observation, researchers took a new approach to investigate the phenomenon. Rather than giving people decision choices in a controlled environment, researchers observe how people made tough decisions under complex conditions such as limited time, uncertainty, high stakes, vague goals, and unstable conditions. Though several naturalistic decision-making models were developed from the quest, the recognition-primed decision model got widely accepted.

The model states that people use their previous experiences to build cognitive patterns (Klein, 2008). The patterns highlight the most relevant cues, provide expectancies, identify plausible goals, and suggest typical reactions. It helps people to make decisions when a similar decision-making conundrum happens quickly. They compare with their prebuilt cognitive patterns, which results in rapid decision-making. However, there is a catch. In this process, how can an option be

evaluated without comparing it to others? To answer, the model emphasizes the importance of mental simulation. Decision makers play a mental simulation in their heads on the chosen option and predict the consequences based on their experiences. The whole notion in this process is to find the first workable option rather than the best option in the context of high uncertainty and time stress. Therefore, the recognition-primed decision model is a blend of intuition and analysis. Pattern matching is intuitive, whereas metal simulation is conscious, deliberate, and analytical. It can be compared with Kahneman's "system 1" and "system 2" cognition. System 1 is fast and unconscious, whereas System 2 is slow and deliberate.

Uncertainty can be defined as a block that delays action in the action-oriented context. (Lipshitz & Strauss, 1997). The conceptualization of uncertainty has three widely observed elements- inadequate understanding, undifferentiated alternatives, and lack of information. However, how do people cope with uncertainty in real life? The observations in the study identified five coping strategies- reduction, forestalling, assumption-based reasoning, weighing pros and cons, and suppression.

Decision-makers use different coping strategies to deal with uncertainty (Lipshitz & Strauss, 1997). In the case of inadequate understanding, reduction is the most suitable technique. When uncertainty is due to incomplete information, assumption-based reasoning is the best solution. Weighing down different pros and cons gives the best alternative in conflict among alternatives.

Lipshitz and Strauss (1997) developed the R.A.W.F.S (Reduction, Assumption, Weighing Pros and Cons, Forestalling, Suppression) heuristic based on the observations. The heuristic model illustrates the conceptualization and coping mechanism of uncertainty by decision-makers in a naturalistic setting. Like the recognition-primed decision model by Klein, the heuristic presumes that decision-makers first do the situational assessment with serial option evaluation and then make decisions based on their knowledge and familiarity with the situation. The heuristic portrays the flexibility of making choices based on situational data rather than standard procedures. This heuristical approach towards uncertainty gives the decision-maker more autonomy to deal with the complex paradigm of uncertainty.

2.4: Problematic Aspects of Uncertainty Treatment in Radical Innovation Projects

Some critical but exciting aspects of uncertainty treatment have surfaced from synthesizing existing innovation project management literature. These aspects have been mentioned repeatedly by researchers over time. Though the problematic aspects of uncertainties have some commonalities, existing literature indicates that different organizations have different approaches to addressing them. Investigating the reason behind that is not the focus of this thesis. However, the identified problematic aspects of uncertainty treatment provide a better understanding of the complex nuances of the phenomenon.

Long Incubation Period

We can see that organizations in different timelines face some common challenge areas while identifying, characterizing, and managing uncertainty (Alexander & Van Knippenberg, 2014; McDermott & O'Connor, 2002). Radical innovation projects face far more risks and uncertainty than incremental innovation projects. In incremental innovation projects, disruption and discontinuity happen only at the micro level, but in radical innovation projects, it happens at both micro and macro levels. Radical innovation projects generally have a very long incubation period (Ten years or more). Due to this long incubation period, it is tough to pinpoint all the market, technical, organizational, and resource-related uncertainty beforehand. When a firm cannot identify all the uncertainty nuances beforehand, sometimes it increases the risk perception towards that project. Moreover, during a long incubation period, there is a possibility that the project may not be related to the market anymore.

Standardized Rules and Procedures

Organizations tend to establish complex rules and regulations and standardized procedures in their projects and operations as soon as possible to reduce waste and maximize efficiency and output (Alexander & Van Knippenberg, 2014; McDermott & O'Connor, 2002; O'Connor & Rice, 2013; Robbins & O'Gorman, 2015). It effectively contains the chaos and establishes a standard work order for daily operational activities and incremental innovation projects. However, the radical innovation project paradigm is different. Radical innovation projects grow in an unknown territory of high technical and market uncertainty, typically known as "Suicide Square." There are other associated uncertainties related to such projects. Standardized rules and procedures usually do more harm than help in a turbulent situation. They usually get designed with the known aspect of risk and uncertainty. They do not take into consideration of extreme situations or unknown unknowns. When the proper information and impact of uncertainty is unknown, there is no point in following a bunch of rules and procedure just to put a tick mark on the checklist. In addition, establishing these kinds of procedures can expose a firm to a more problematic situation as they will not be cautious enough to see beyond the procedure, which can have a massive impact on the project's success and organization. This challenge of managing radical innovation projects has surfaced in other research over time, and all the research has indicated that whenever a company tries to contain or handle uncertainty rather than embracing and managing it, it becomes an obstacle to growth and project success.

Nonexistent Market and Market Unfamiliarity

In the area of market uncertainty reduction, the nature of the market and market familiarity plays a vital role in developing the proper method (Balachandra & Friar, 1997; McDermott & O'Connor, 2002; O'Connor & Rice, 2013; Oconnor, 1998; Thanasopon et al., 2016). Radical innovation project markets are usually nonexistent and unfamiliar. The markets are nonexistent because the whole point of such projects is to create a new product that will create a new market for company growth and competitive advantage. If a product is just a better or a modified version of an existing

product, then the project is incremental, not radical. In addition, companies must deal with market unfamiliarity-related uncertainty as well. For example, the market is unfamiliar if a European company tries to enter the Asian market with new technology and product. The project management method for a familiar and unfamiliar market will differ. Usually, companies tend to do market research or gather market intelligence before introducing a new product to the market. The dilemma is that market intelligence-gathering techniques for the European market and Asian markets can be different. It is also possible that the metrics and the method company is using to gather market intelligence are irrelevant to the Asian market, and their gathered intelligence with the wrong methodology and context is giving them a false sense of the market.

Fuzziness in the Fuzzy Front End

For any radical innovation project, the critical part is to survive and grow through the fuzzy front end of the innovation process. It is a critical phase because there is no precise determinator of success and failure, and it has distinctiveness from the other part of the project's process as it processes higher risks and uncertainty (Oconnor, 1998; Robbins & O'Gorman, 2015; Thanasopon et al., 2016; Van Riel et al., 2004). The fuzzy front is part of the innovation process where strategy and idea generation happen. The well-known practice is to take customer input from the market in this phase to develop a new product idea which will eventually add to a company's profitability and reduce uncertainty. However, the problem with this practice is that it works when a firm is developing an incremental innovation project, not a radical one. The whole purpose of a radical innovation project is to create an entirely new product to create a new market. The customer can not share the experience of a non-existent product; therefore, standard customer input and market intelligence do not contribute to the product development's fuzzy front end. Due to technical uncertainty, a fuzzy front end poses higher risks than any other product development phase. The project team starts with an idea of what might and might not work. However, reality always hits differently.

Technical challenges arise in this phase due to knowledge gaps, design change, technical complexity, etc. The organization's standard project and operational management procedures also create intricacy in the fuzzy front-end phase of the project. Due to market uncertainty and technical complexity, the fuzzy front-end development phase requires agility in the project team's work process and goal setting. Standardized procedures can hamper that agile mindset resulting in more chaos. On-demand resource availability also works as a critical success factor in this phase. As the project team constantly experiments with new ideas, it requires many resources to turn them into reality. The harsh reality is that some of them will work, and some will not. However, even to figure out what will not work, the project team needs resources to experiment and fail.

Project Team and Dynamic Shifting Capabilities

The key to success for any radical innovation project team is a combined team-based endeavor and the ability to shift dynamically as necessary through the changes in the project lifecycle (O'Connor & Rice, 2013; Robbins & O'Gorman, 2015; Thanasopon et al., 2016). The team deals with market, technical, organizational, resource, and other uncertainties in the fuzzy front end and other project phases. The project team works through these challenging times and brings positive results. That is why team motivation and reflexive team processes are crucial to success.

Team motivation comes from the team's capability to generate and implement new ideas, make mistakes, learn, and grow through the process. That is why shared learning or performance proves orientation is significant in creating the team's motivational atmosphere. In a learning orientation, teams are encouraged to try out new ideas. Failures get identified as learning opportunities and create an ownership sense among team members. In a performance prove orientation, team members are encouraged to bring results, but the failure does not disgrace them, which makes them mentally safe and motivates them to do more. Motivation challenges arise when an organization establishes a performance-avoid orientation, as the team always gets cautious about failure's consequences rather than success's reward. Teams become skeptical about trying out new innovative ideas, and most dangerously, they start avoiding creativity in building innovative solutions to avoid the consequences of failure.

Establishing a team's dynamic shifting capability is proportional to the level of autonomy the team gets. A team's autonomy is crucial because radical innovation projects undergo sudden changes throughout their lifecycle. Every change needs a different approach to an innovative solution to achieve the best result through failure and mistakes. A team with dynamic shifting capability can quickly correct its course of action. It also helps teams switch between learning and performance prove orientations. In the fuzzy front end of the innovation process, teams can practice learning orientation to generate and experiment with new ideas and product design. However, in the later phase, the team can shift into a performance prove orientation to maximize the result and minimize mistakes. This dynamic shifting is impossible without autonomy in decision-making. In the traditional predictive project management methodology, changes go through a change management team, which delays the process. However, in radical innovation projects, bureaucratic process delays can create more uncertainty and chaos, ultimately resulting in project failure.

Choosing the Right Project Leader

Ambidextrous project leadership plays one of the most crucial roles in creating the right environment for a radical innovation project's success. Project leaders ensure the team has the elasticity to shift between learning and performance prove orientation (Klingebiel & Rammer, 2014; McDermott & O'Connor, 2002; O'Connor & Rice, 2013; Oconnor, 1998; Thanasopon et al., 2016; Van Riel et al., 2004). They create a team dynamic and identify the right moment for switching team-based orientation. They communicate with stakeholders and project sponsors at

the different project stages to ensure everybody is on the same page and the project is going in the right direction.

The critical aspect of project leadership begins from the very first phase when a project idea goes through the proposal. The project leader needs to determine if it is even the right project. A project may seem radically innovative or profitable initially, but there can be many technical, market, organizational, and resource uncertainty that will lead the project to failure. Choosing the right project is the first critical step to the success of a radical innovation project. It will prevent the organization from failure in the long term. For example, an e-commerce company may want to develop a new VR wardrobe walkthrough for all the visitors to their site. Their technical team may be technically very skilled in developing such a system, and the initial testing of the project became very successful. They are testing their prototypes in high-performing rigs and virtual machines. However, most of the visitors to their site use mobile apps. A high-quality lossless compression engine is required to run a VR walkthrough in a mobile app. However, no compression company has developed a compression algorithm like that so far. So, even after wasting years of time and valuable resources to develop a technology that works, it may fail for technical uncertainty outside the organization's control.

The project manager also needs to ensure the proper allocation of resources in the different phases of the project. It is about finding the right balance of resource allocation at different project phases. In an earlier phase of the project, a breadth of resource allocation may be a good idea; however, in the later stage, maybe it needs to be more value-focused and result oriented. If the resource allocation is imbalanced across a project lifecycle, the project may get out of resources to finish, ultimately leading to failure.

An organization needs to choose the right project leader with an agile and growth mindset, ambidextrous leadership, and naturalistic decision-making capability who will thrive in the uncertainties of a radical innovation project. The project leader helps identify the right project by considering all aspects of uncertainties; they help the team build an agile mindset in work progression and provide autonomy and learning space to produce the best results. They continuously communicate with the project sponsors and stakeholders to ensure the project is going in the right direction and protects the team from distractions.

2.5: Research Gap and Analytical Direction

Research across different timelines has identified different critical areas of uncertainty in radical innovation projects. Some have addressed the market and technical uncertainty in the innovation process's fuzzy front end, while others have identified the importance of team leadership and the team's dynamic capabilities in the uncertainty treatment. Some have identified the importance of decision making and sense-making in reducing uncertainty. Some have illustrated the problematic side of traditional market intelligence, customer input, and standardized organizational rules and

regulations in uncertainty management and project success. Though previous research gives us the knowledge of identifying different areas of uncertainty and how it affects the success or failure of radical innovation projects, none gives us an outline to handle uncertainty in the different areas across the project lifecycle. Uncertainty arises in different areas in various forms in different timelines throughout the project lifecycle. Radical innovation project thrives in the grey areas of uncertainties and unknowns. It creates long-term profitability opportunities for a company. I question, “Can a singular framework or rigid methodology navigate a radical innovation project in the land of unknowns?” I believe that the paradigm of the answer to this question is complex because of many associated variables; however, a comprehensive set of tools can assist in managing the intricacy of uncertainty in a radical innovation project.

From the synthesis of the existing literature, a few patterns have emerged repeatedly concerning the market and technical uncertainty and emphasizing the role of agile leadership, flexible management techniques, and teams with dynamic capacity. In treating market uncertainty, it is visible that market familiarity, understanding a nonexistent market, and developing a context-based project management method is challenging (Alexander & Van Knippenberg, 2014; Balachandra & Friar, 1997; O'Connor & Rice, 2013). Traditional market intelligence also does not help in radical innovation projects' uncertainty treatment. Technical uncertainty also poses a significant challenge. During the long incubation period of new product development, dynamic technical changes may make the whole project unrelated to the market. Technical complexity can also hinder project development as the team members may need time to learn a different technology for product development, and resources may not be available for learning. The impact is severe in the fuzzy front end of the radical innovation project. The combination of market and technical uncertainty has been labeled "Suicide Square."

Companies tend to follow standardized rules and procedures to implement in the radical innovation project's management to reduce uncertainty (Alexander & Van Knippenberg, 2014; McDermott & O'Connor, 2002; O'Connor & Rice, 2013; Robbins & O'Gorman, 2015). Ironically, standardized rules and procedures fail during extreme uncertainties because it does not scale up with the complexity. They also tended to contain or handle uncertainty. However, uncertainty can not be contained or handled; it can only be better managed.

Decision-making and team management in a radical innovation project, especially in the fuzzy front end, is a tremendous challenge for a project leader (Klingebiel & Rammer, 2014; McDermott & O'Connor, 2002; Thanasopon et al., 2016; Van Riel et al., 2004). The project leader needs to create a learning orientation for the team where they can learn and grow. He must provide them autonomy, improving their dynamic shifting capabilities while protecting them from outer distraction. He must also communicate clearly with different project sponsors and stakeholders to ensure resource availability and organizational support throughout the project life cycle. Choosing

the right project leader with all the right skills is challenging for an organization because ambidextrous leadership is vital to the project's success.
In this research, we are discovering the critical areas of uncertainty in radical innovation projects, measurement techniques for identifying the impact level, and proposing a unified toolbox with substantial risk and uncertainty management frameworks to address the challenges of treating uncertainty. As we have learned from the existing research, uncertainty generates in different areas from different angles. So, only one approach or methodology is not practical enough to address the obscurity of uncertainty treatment. Uncertainty treatment methodology also needs dynamic shifting capabilities, like the team members and project leaders in a radical innovation project.

The significance of such a dynamic toolbox approach with different frameworks for the uncertainty treatment is that it can help to get a more detailed perspective on identifying uncertainties from different angles and establish cohesiveness in the different phases. The literature synthesis shows that some studies have identified the components of technical and market uncertainty in new product development projects. Some studies have focused on leadership's role in ensuring a project's success during uncertainty. Some have provided insightful angles on resource allocation techniques, and some have illustrated the organization's position in driving a radical innovation project's success. This study will help approach the uncertainties in a radical innovation project more scientifically and systematically while highlighting previous research. Both project managers and team members have a first-row seat to transform a radical innovation project into business success. Earlier research has repeatedly mentioned that their dynamic capabilities and agile mindset are crucial for project success. Dynamic capacity building can be more successful when they have a unified toolbox for uncertainty reduction in complex and unpredictable scenarios. It can help to broaden their perspective and see things by throwing different balls in the air. Uncertainty can only be managed well when it can be understood well. The toolbox can give them the right lenses to pick up and see things differently to understand uncertainty from a broader perspective and new angles. I will use different frameworks and knowledge from existing research knowledge for toolbox development. Combining foremost frameworks and ideas can significantly improve the treatment of uncertainty in radical innovation projects and give us new insights into how we can recognize the impasses of uncertainty contrarily.

Identifying and treating uncertainty in radical innovation projects is still a grey area. Some key areas and components that result in uncertainties have been identified in many pieces of research over the last two decades. However, a unified toolbox inspired by valuable risk and uncertainty science research is more necessary than ever because of the rapid technological advancement in the product development industry.

3: RESEARCH DESIGN AND APPROACH

This chapter illustrates the research design and methodological approaches concerning this case-study research. I will begin by explaining the deliberative choices, such as explorative research design with the qualitative approach. I will also explain why I used secondary data sources (project reports and documentation from two European Union's Horizon 2020 projects) as the data collection method. This study's methodological and data collection choices have been a combination of deliberate choices and requirements from the study's scopes and limitations. I will portray it in the following sections, discussing thematic analysis as my choice of data analysis method and the process of conducting it in this study. Lastly, I will reflect on the quality of the research by discussing the validity and reliability, ethical considerations, and limitations of the study.

3.1: Research Approach

As the objective of this research has been to identify key components to handle uncertainty in a radical innovation project, a qualitative case study approach was considered the best choice. According to Stake (2005), a case study is suitable for qualitative inquiry (p. 443). He also pointed out that case study research is neither new nor qualitative. He identified case studies as more of a choice of what to study rather than a methodological choice. Researchers choose their methods to study the case while the focus always remains on the qualitative applications of the case. Therefore, I designed case study research to understand the nuances of uncertainty management in innovation projects. The rationale behind this design choice was based upon the qualitative concentration opportunity case study that provided me to discover the key components that play a significant role in an innovation project's uncertainty management.

Stake (2005) described a case as a bounded system or functioning body (p. 444). He argued that a case cannot be a general thing. A case study is both a process of investigation about the case and the product of that investigation; the case itself is a system (Stake, 2005). He also mentioned that sometimes the case is not intrinsic enough to understand a phenomenon. He suggested comparing two or more cases is a good approach in such a scenario.

While designing this study, three epistemological questions were considered: What can be learned from my choice of case, what kind of design should the study have, and should I design the study to optimize the understanding of the case rather than to generalize beyond it? In the pursuit of answering the first question, I found out that I needed a case of a large-scale innovation project where market, technical, organizational, and resource uncertainties were high because of the sensitivity and complexity of the project. This kind of case would give me a comprehensive understanding of how the project team experienced and conceptualized uncertainty, their methods to identify and address it, and how the mismanagement of uncertainty negatively impacted the project. A significant factor in a case study is the context of the case because case studies are usually built upon some issues with complex, situated, and problematic relationships (Stake, 2005,

p. 449). These issues create the opportunity of learning from a case study. Though the context of the case study is crucial, it creates some distinctive technical challenges, making it hard to understand the phenomenon (Yin, 2003, p. 4). The phenomenon under a large-scale project case is not easily distinguishable from its context because of the richness of the context in the project itself.

The complexity of the phenomenon identification also brings us to our second question of design choice. A case study can be done in Single or Multiple Case Studies. On the one hand, a single case study is a good approach when a case is fascinating in its particularities and ordinariness rather than representing other cases or generalizing a problem in a broad context. On the other hand, a multiple case study is helpful to provide insight into a specific issue or draw a generalization. Stake (2005) mentioned them as "instrumental case studies" (p. 445). The instrumental case study method gives the researcher direction to portray his findings in light of literature from other researchers and theorists. It can also be called exploratory case studies (Yin, 2003). The work in this type of case study is reflexive, where the researcher digs into meaning and links them to the context and experience of other research.

In addition, the case study also seeks more particularity than ordinary. The study primarily focuses on what is happening, mainly the functioning and activity (Stake, 2005, p. 447). Later, the case study can take a theory-based approach to focus on the generalization where theories and frameworks are developed from a literature review and other substantive resources (Yin, 2003, p. 6). It also creates an opportunity to evaluate the identified phenomenon from the study with the existing research

Considering all these nuances, I designed multiple case-study research where I studied two large-scale technical innovation projects. Though each case was intrinsic enough to do a separate case study to understand their particularities, none could identify the complex phenomenon of uncertainty in innovation projects alone. The study of the two cases helped me to set the proper context and identify the critical variables of uncertainty management in innovation projects. This method also helped me to relate my findings with the existing literature on innovation, risk, and uncertainty management and address a few gaps in uncertainty management and innovation management research.

3.2: Data Source, Case Selection Criteria, and Screening Procedures

One of the most challenging steps in case study research is to select the case or cases to be studied (Yin, 1993, p. 8). For this thesis, the challenge was massive because uncertainty in an innovation project does not come from a single source in an innovation project. It can arise in different areas, from different sources in various timelines. This research aimed to find the key areas of uncertainty and critical components to handle the uncertainties in innovation projects. However, the uncertainty treatment is not a one-off task to be managed separately. It is integrated into the regular

project management and operational management procedures. Therefore, the project cases for this study had to be large enough that they had enough project management and operational management nuances. This linkage of uncertainty treatment in innovation projects is simple in concept but very hard to define operationally. So the challenge was to figure out what kind of cases would be relevant.

As I became uncertain about the case selection, I leaned into my literature review, research questions, and key objectives of this study. It gave me guidance on selecting the case. I examined a series of case studies on this research phenomenon on different international and intergovernmental organizations' websites. I made the final selection of two large-scale European Union technical projects completed in 2022. The fundamental rationale behind this choice was that it satisfied the research phenomenon that surfaced from the literature review and had sufficient nuances of uncertainty areas and treatments around the study's objective.

Data Source

Unlike surveys, case study research is not limited to a single data source. Multiple sources of data can aid case study research. The data sources can be used in different combinations, and the shreds of evidence can include both qualitative and quantitative data. Yin (2012) mentioned six familiar data sources in case study research (p. 10). They are-

- Direct Observations (Example- Human actions or a physical environment)
- Interviews (Example- Open-ended conversations with key participants)
- Archival records (Example- Student records)
- Documents (Example- Newspaper Articles, Letters, Emails, Reports)
- Participant-observation (Example- Being identified as a researcher but also filling a real-life role in the scene being studied)
- Physical artifacts (Example- Computer downloads of employee works)

For this study, my initial plan was to interview key project stakeholders and team members of innovation projects in some of Norway's tech startups and innovative companies. Unfortunately, I could not establish communication with them via email and LinkedIn messages. Only one company gave me a reply; however, they did not agree to participate in case study research due to their time constraints in project activities and the project sensitivity. Therefore, after discussing the issue with my supervisor and taking his guidance, I sought publicly available project reports from international and intergovernmental organizations. Specifically, I surfed through project reports from World Bank, European Union, and OECD (Organization for Economic Co-operation and Development). After evaluating different project reports with my units of analysis and selection criteria, I chose two successful European Union Horizon 2020 projects – RESPONDRONE and ASSISTANCE. The details of my unit of analysis, selection criteria, and screening procedure for case selections are described in the following sections.

Unit of Analysis

A critical aspect of case study research is defining the unit of analysis. A case study can be seen and evaluated from many different perspectives. Therefore, it is essential to define the unit of analysis before the beginning of the study. It limits the boundary of the study and sets the study in the right direction to address the issues underneath (Yin, 1993, p. 9). In this study, I tried to find the critical components of uncertainty management in innovation projects and what is the better way to treat them. However, in doing so, the first question regarding the unit of analysis arises: Is uncertainty management a stand-alone process, or is it integrated into the traditional project and operational management activities?

The second challenge was figuring out the context for innovation projects and uncertainty management (Yin, 1993, p. 10). There are two types of innovation projects- incremental and radical. Incremental innovation works in developing existing technology or service, whereas radical innovation works with novel and disrupting technology or service. Because of the novelty, radical innovation projects face more uncertainty than incremental projects; thus, radical innovation projects set the proper context for our study. In addition, which areas of uncertainty would be focused on in the study was also crucial because uncertainty can happen in any area of innovation projects. Without setting the proper boundary of where to look for the traits of uncertainty, the study would not successfully identify the critical phenomenon. The literature review in this study illustrates that there are mainly four critical areas of uncertainty in an innovation project – Market, technical, organizational, and resource. We also investigated within the boundaries of these four areas of uncertainty in the context of radical innovation projects.

An interesting observation from this study's literature review is that existing literature was always more interested in finding the areas of uncertainty generation and identification rather than uncertainty management frameworks. However, this study was more interested in advancing knowledge on creating a cohesive framework to generalize uncertainty management.

Based on the observations mentioned above, this study's final units of analysis were uncertainty management as an integrated process in a radical innovation project and how uncertainty arises from a project's market, technical, organizational, and resource areas. This unit of analysis created the opportunity to understand the phenomenon of uncertainty and aim for a cohesive framework development for uncertainty management.

Case Selection Criteria

In the initial design of the study, I considered the selection of multiple cases though the number of available cases that fits into the context was minimal. I aimed to collect extensive data from the selected cases, and the data sets should illustrate the dynamics of uncertainty in each area. Therefore, two "exemplary" cases were chosen for this study, reflecting solid and positive examples of the phenomenon of the research interest. According to Yin (1993), multiple case

studies should follow replication rather than sampling logic (p.34). It indicates that when two or more cases are included in the same study, they should illustrate similar results as predicted by the investigator. When replications of results are found in several cases, it builds a solid foundation for overall results. In short, the growth of consistent findings over multiple cases is the base of robust discoveries from case study research. I followed the replication logic for my case selection. Therefore, I chose two projects from the same international organization- European Union. I also chose the same type of project to ensure the theoretical result replication from the selection. RESPONDRONE and ASSISTANCE projects aimed to build a novel technology to aid emergency management operations and training in European countries. Both projects had a similar budget, scope, timeline, team, and governance structure. These similarities ensured that the findings from both studies would be consistent and replicated regarding uncertainty management in innovation projects.

Now a question can be asked- Why replication logic but not the sampling logic for case selection in this research? Because sampling logic usually represents a larger universe, the selected cases satisfy a predefined representation criterion (Yin, 1993, p. 34). My study is multiple-case, so the sampling logic is off-base here. In multiple case studies, replicating results from an investigation is vital to understand the critical phenomenon of a research problem rather than representing a larger population in a generalized way. If an inquiry requires sampling logic of generalization, a better research method can be an inquiry, survey, or experimental. However, that is irrelevant to this study; therefore, we selected our cases RESPONDRONE and ASSISTANCE based on replication logic, not sampling logic.

Case Screening Procedure

One significant effort in the case selection process was the case screening for the study. I had to carefully avoid screening all kinds of cases, especially the "mini" ones with insufficient information to support the research (Yin, 1993, p. 12). For example, initially, I went to the case study section of the PMI's (Project Management Institution) website. I expected to find some good case studies regarding radical innovation projects there as they are a worldwide dedicated organization for project management. Though they had many exciting case studies listed, all of them were introductory reflections for educational purposes. None were informative enough to be helpful in this case study research.

As I mentioned before, in the initial phase of this study, I tried to gather information from a few tech startups and innovative companies in Norway. Specifically, I contacted nine tech startups and one renewable hydropower producer company working on different radical innovation projects in various sectors. My communication method was mainly email, and I also tried to communicate with the CEOs of some tech startups via LinkedIn messaging. However, none of these attempts were successful, and neither of the tech startups gave me a reply. The renewable hydropower

producer company replied to me; however, they could not participate in the study because of the time constraint and sensitivity of their projects.

After mentioning the challenges to my supervisor and taking his guidance, my second approach was to look for publicly available reports of large-scale and large-budget projects from international and intergovernmental organizations. In pursuit of that, I started looking through the project reports section of the World Bank, OECD (Organization for Economic Co-operation and Development), and the European Union. Initially, I tried to understand the project's relevancy through heuristics (reading the project title, summary, and the name of all the reports). If a project passed the initial heuristic screening, I did the detailed screening of the project based on the selection criteria mentioned previously. In this way, I screened 20 different projects from these three organizations and selected the two used in this study from European Union. Before beginning the study, I also shared my selection with my supervisor and had his feedback on the relevance of the selected project to the study.

3.3: Data Analysis

Choosing a data analysis method is challenging because of the qualitative analysis's incredibly diverse, complex, and nuanced nature. Based on the requirements of this study's scopes and limitations, I decided to do a thematic analysis. Thematic analysis is a qualitative data analysis process that minimally organizes and describes a large data set, and through data identification analysis, it projects the themes within data (Braun & Clarke, 2006, p. 79). There were a few rationales behind my choice of data analysis. As thematic analysis is a flexible method, its theoretical freedom gave me a rich, detailed, yet complex account of data from case study reports of both projects. The selected data set for analyzing uncertainty treatment in innovation projects helped me to identify critical patterns. Now a question can be asked- Why thematic analysis, not some other pattern analysis method like IPA (Interpretative Phenomenological Analysis) and Grounded Theory? Pattern analysis methods like IPA and Grounded Theory are highly theoretically bounded. For example- in grounded theory, researchers try to develop a theoretical framework from the data analysis. However, the thematic analysis does not force us to commit to theoretical commitments. The construction of a theme happens based on the researcher's judgment and perspective on the research problem. The process of thematic analysis also does not require detailed theoretical and technological knowledge of the analysis approach (Braun & Clarke, 2006, p. 80-81). Therefore, based on the flexibility, theoretical framework, and accessible analysis process, I chose thematic analysis as a data analysis method in this study.

Defining a Theme

A theme usually depicts something important from a dataset and represents that in a patterned manner. However, the question was how I would define a theme. In the pursuit of the answer to this question, I found out that there are no hard and fast rules around it. So I decided to remain flexible and use my judgment through the glass of my research problem to define the theme (Braun

& Clarke, 2006, p. 82). In the analysis, when many initial codes indicated that they belonged under the same oversight, I looked at the research questions and used my judgment to determine if that oversight was associated with the research problem. When the answer was yes, I considered that as a "theme."

Semantic Approach toward Data Set Description

I took a semantic approach while presenting my themes for this research (Braun & Clarke, 2006, p. 83). The semantic approach means themes are identified on the surface level of the data rather than going beyond the presented data. My particular area of interest in the analysis process was to look for uncertainty treatment and management strategies in the selected projects. Therefore, when I identified a theme related to uncertainty management from reviewing the project reports on the surface level, I presented all datasets from the projects related to the nuances of that theme. I subcategorized themes into subthemes for ease of understanding and cohesively presented them.

Deductive Approach toward Theme Identification

Theme identification in thematic analysis can be made in either an inductive or deductive way. The inductive approach means themes will be surfaced purely from the data, and there is a possibility that it is not correlated with the initial research questions and the direction of the research may change from the identified theme (Braun & Clarke, 2006, p. 83-84). However, in the deductive approach, theme identification happens from a predefined analytical interest and theoretical point of view, and identified themes from the analysis try to satisfy that. I did an extensive literature review on the issue of uncertainty management in innovation projects. I identified four critical areas of uncertainty generation and five problematic aspects of uncertainty management in innovation projects from my literature review. It gave me a theoretical standpoint on the uncertainty management phenomenon in an innovation project. This theoretical standpoint heavily influenced my theme identification.

The Analysis Process

Braun and Clarke (2006) suggested a six-step analysis process for thematic analysis (p. 87). I went through all of them step-by-step to gather my findings and present them in this paper.

Familiarizing with Data

In this research, my data source was various project reports (final report, communication plan, dissemination report, risk, opportunities register, etc.) publicly available on the project websites. I read all the reports thoroughly several times to familiarize myself with the structure and content and noted my initial thoughts and ideas.

Generating Initial Codes

I used the qualitative research software "Delve" for my initial coding process. The software allowed me to do coding, merge them, and put memos. It journaled the whole coding process as well. I systematically coded interesting paragraphs from all the reports I reviewed. Whenever a

paragraph or a section of the report was related to some phenomenon of uncertainty management, I put a relevant code for that part.

Searching for Themes

After the initial coding process, I came up with almost fifty codes associated with the research problem of this study. It was much information that needed to be sorted out. I did the sorting in a two-step process. From my theoretical knowledge of literature review and initial code generation, I have developed some subthemes that will only group a small number of codes. When the subthemes were created, and they seemed relevant, I collated them into a theme. This approach enabled me to present the data more understandably and cohesively.

Reviewing Themes

In this phase, I reviewed all the themes and cross-checked them with the entire data set and the research problem. The key to reviewing themes was to use my judgment to determine whether the presented theme made sense in the context of the research question and the case itself.

Defining and Naming Themes

When I became satisfied with the sense-making of themes, I went through a refining process of setting the specifics of themes and naming them. The goal of naming and defining themes was to ensure the themes generated clear definitions and illustrated a compelling overall story.

Producing the Report

After going through the abovementioned steps, I presented my understanding and findings through comprehensive reporting. While creating the report, I ensured my selected topics were vivid and compelling, portraying my understanding of the phenomena with justified analysis and visualization and relating with the literature analysis and research questions.

3.4: Research Quality

The most crucial question that itched my mind while conducting this study was how to ensure the quality of the research. Ensuring validity and reliability in quantitative research is relatively straightforward; however, this is not true for qualitative research. Qualitative research has different viewpoints; the same data in qualitative research can be interpreted in many different ways based on the research problem. However, rigor is standard in qualitative research (Gibbert & Ruigrok, 2010). The magic of good qualitative research lies in the rigor of the process. Rigor refers to the step-by-step recording of the research's data selection, collection, and analysis process. It encourages the transparency and change handling process in the research. Therefore, I decided to follow the three-step strategy suggested by Gibbert and Ruigrok (2010) to ensure rigor in this case study research. I reported all my concrete actions in this research process. I mentioned my decision-making process, interactions with my supervisor, changes to my initial plans, software used for the analysis process, and step-by-step analysis process. In addition, I focused more on the

internal and construct validity of the research over external validity. Also, during the whole process, whenever I faced a setback, I tried to use it as an opportunity. For example, my initial interview attempts failed in the data collection process. That created the opportunity of designing a multiple case study of two big-budget projects of the European Union. While analyzing the report, I started collecting information in an Excel file. However, it did not seem right, and I dug deep to find another solution. I found that coding can be done in pen and paper, MS Word, or with qualitative research software. After evaluating all these methods, using dedicated research software seemed beneficial. It also enabled me to code and journal the whole coding process better.

Construct Validity

For the construct validity of a case study research, data triangulation from different data sources is highly recommended. Other data sources can be derived from interviews, participant observation, transcripts, or reports (Gibbert & Ruigrok, 2010). However, I did not do the data triangulation process. I used reports from European Union's projects for this study. I could not interview any of the project stakeholders of the projects or become a participant. I used different reports on various project artifacts in this research, but they were publicly available reports on the EU's website. I could not get access to any other reports of these projects except the publicly available ones. I was also a solo researcher in this project and did not have communication with other academics independent of the project to review the draft of this study. However, all my collected data, research process, and literature review were shared with my supervisor for his constructive feedback.

I established a transparent chain of evidence throughout this thesis paper so that any reader can understand my thought process and how I went from the primary research question to the conclusion of this research. In Chapter 4, I presented all my findings in such a manner so that any reader could understand the phenomenon of this research. In the current chapter, I illustrated my approach to the research problem, the rationales behind the design of this research, and all the other procedural nuances. This way, I established my evidence-based construct validity for this research.

Internal Validity

Throughout the research, I ensured that my research framework was overtly obtained from existing literature (Gibbert & Ruigrok, 2010). I read through relevant, high-quality papers and books on conducting qualitative research and followed the procedural guidelines for my case study. As this research aimed to understand the critical components of uncertainty management in the innovation process and whether uncertainty management is an integrated or a dedicated process, this study dived into the current best practices of innovation project management. From the analysis on the surface level and empirical observation, five critical themes arose which had a similarity with the literature review of this study. It demonstrated that focusing on these critical components of project management has a proportional relationship with uncertainty treatment in innovation projects. A

strong theme (stakeholder engagement) arose from our analysis of the case study data in the treatment of uncertainty from our selected cases; however, this theme was not considered a critical component of uncertainty treatment in most existing innovation management literature.

External Validity

Case study research does not provide statistical generalization; thus, providing commonly understood "generalizability" is impossible in such a study (Gibbert & Ruigrok, 2010). However, this case study has illustrated analytical generalization throughout the process. I took a nested approach to conduct this study, meaning I selected two case studies within one organization to ensure homogeneity. At the beginning of Chapter 4, I detailed the selected cases' budgets and timelines to illustrate the selected projects' magnitude. I also briefly mentioned the objectives of this project. Both projects aimed to create novel technological solutions for in-field operations and training of emergency response personnel. The magnitude of the projects expanded the horizons of uncertainty generation and treatment components, and the development of novel technological solutions satisfied the innovation project management paradigm.

Reliability

The reliability of qualitative research comes from transparency and replication (Gibbert & Ruigrok, 2010). I maintained careful documentation and clarification of the research procedures to ensure transparency in this research. The data from the analysis process was presented as it came by rather than putting too much theoretical inference in it. All the data presented were appropriately cited. I also used several visualization techniques from my understanding of the data to make information more compelling for the reader.

3.5: Ethical Considerations

Though secondary data sources were used in this research and no interviews, participant observation, or confidential documents were analyzed, I actively followed the guidelines for research ethics in social sciences and humanities (NESH, 2021). They were relevant for ethical assessments in some of the areas of the study.

The first ethical consideration in this study was the relevance of the research. I actively addressed the uncertainty treatment paradigm in innovation projects by providing concrete suggestions on practical implications. I asked relevant research questions, created a straightforward research design, and did a comprehensive literature review of existing research to illustrate the justification of my findings and suggestions.

The second ethical consideration was the quality of the research. As mentioned in the previous section, I focused more on this research's construct and internal validity than external validity and reliability, as this research was a qualitative case study. I mentioned why I could not perform data

triangulation for construct validity; however, I structured a transparent chain of research processes in this paper for a deep understanding.

Though I used publicly published reports by European Union on their website, I respected their data ownership. All the data presented in this research have been appropriately cited. For both projects, a total of forty-six project-related reports were analyzed. While collecting and analyzing data, relevancy per the research problem was thoroughly considered.

3.6: Potential Limitations of The Study

Some of the limitations of this research were already discussed previously, like the lack of data triangulation (Gibbert & Ruigrok, 2010). The data source of this case study was only the public reports from the European Union's website. I did not have any access to conduct any interviews or study any internal reports (lessons learned documents) regarding this project. Therefore, it may impact the construct validity of this research.

Another limitation of the study is that only two cases were analyzed for this study to understand the phenomena of uncertainty treatment of innovation projects. Both selected cases had robust governance structures, significant budgets, and sufficient resources provided by the European Union. The projects also connected well with the academic researcher, who provided valuable directions throughout the timeline. These elements made solid rationales for the case selection. However, it can be argued as a substantial limitation of this study. This research did not consider innovation projects from tech startups with limited resources and market access. It also did not take radical innovation projects from current market players where innovation speed is critical for the company's continuous growth. The nuance of uncertainty is so versatile that it is tough to pinpoint the treatment factors only by doing a case study of two large-budget projects with the best resources.

I am also aware of the limitations that might arise from my personal bias and experience. As I have technical project management background and have worked with current best practices of risk and uncertainty management in innovation projects, I might have a little unconscious tendency to relate the phenomenon with my current knowledge rather than seeing things as they are.

4: FINDINGS

This thesis explores the critical areas of uncertainty, measures the impact, and identifies the best practices for managing uncertainty in different phases of radical innovation projects. I have done a case study analysis of two successful projects of the European Union's Horizon 2020 initiative- RESPONDRONE and ASSISTANCE. The goal of the RESPONDRONE was to create a fleet of drones with multiple synchronized missions for disaster response which would help the first responders in a critical disaster rescue operation. The overall budget of this project was € 8 257 937,50, and the project completion time was 3.25 years. The ASSISTANCE project aimed to build an advanced training platform merging virtual, mixed, and augmented reality to help the first responders enhance their operational capabilities in different critical scenarios. The budget of this project was € 6 393 691,25, and the project completion time was 3.25 Years. The research method used for this study was thematic analysis, and the qualitative data analysis software "Delve Tool" was used for thematic coding.

In this chapter, I will render the findings of my thematic analysis. After doing a qualitative inductive coding of all the data from relevant reports from these two projects (Risk and Opportunities Register, Project Management Handbook, Communication Plan, Exploitation Strategy and Business Plan, Final Dissemination Report, Final Project Report, Governance Structure, etc.), five themes have arisen associated with the treatment of uncertainty in innovation projects. The key themes from this analysis are-

- Technology and Innovation
- Communication and Collaboration
- Adaptive Project Management
- Stakeholder Engagement
- Risk Management

Each of these themes exhibits direct relationships with the successful management in different areas of uncertainty in a radical innovation project.

Best practices and guidelines recommended by Delve have been followed to safeguard this qualitative thematic analysis's validity and reliability. It includes creating a codebook, organizing codes into categories and subcodes to let the theme emerge, and practicing reflexivity. First, I have read through all the relevant project reports and extracted the necessary data to address this thesis's research questions. Then I labeled the data into relevant codes in an open coding approach. Open coding is an initial round where the approach is loose and tentative. Here, I have broken down the qualitative data into discrete extracts and labeled them. After labeling all the relevant data into codes, I have done a thematic analysis on them. Here, I have tried to figure out the pattern from the codes created in the previous open coding approach and unify the patterns under one single code to generate an integrated theme. Throughout this process, I have been reflexive about how the data has been collected, the choice of data collection methods, and how the information has been analyzed and reported. Throughout the process, I have maintained a reflexive journal

describing how I am making the meaning of data, the reasons behind that interpretation, and any revisions necessary. Additionally, I have consulted with my thesis supervisor on the data collection method and analytical approach to ensure that my research direction and interpretations are aligned with the research problem and well supported by solid data.

The findings presented in this chapter provide us with a deep insight into the critical areas of uncertainty in a radical innovation project. It also gives us a better understanding of the interrelated components of managing the effect of uncertainty.

4.1: Technology and Innovation

The success of a radical innovation project is often directed by developing a groundbreaking new technology and its advancements. Developing new technology creates opportunities, addresses challenging problems, and offers creative and dynamic solutions. After doing a detailed thematic analysis of RESPONDRONE and ASSISTANCE, it has surfaced that a few critical components of technology and innovation played a significant role in the potential and success of these projects. We will look deeper based on some subthemes under the "Technology and Innovation" umbrella. The subthemes identified in this analysis are- Technology Adaptation and Integration and Innovation Management.

Technology Adaptation and Integration

Both RESPONDRONE and ASSISTANCE was a large scale technically complex project. Both had various dependencies throughout the project lifecycle, increasing the technical uncertainties for these projects. RESPONDRONE aimed to build a fleet of UAVs (Unmanned Aerial Vehicles) for emergency management operations. These UAVs would collect different kinds of situational data from the scenario and help the first responder team to make an effective strategy. The ASSISTANCE project sought to develop a virtual training simulation software to help the first responders get field-level skill development training quickly, safely, and efficiently. The simulation software would use novel technologies like Virtual, Mixed, and Augmented Reality. Building large-scale systems requiring software and hardware resources and seamless integration is technically challenging. Also, with the rapid change in the technological world, using the relevant software and hardware and continuous upgradation that would not become obsolete in the short term created a different challenge area.

In the RESPONDRONE project, different software upgradation happened over time to ensure seamless data collection, connectivity, and unlocking new features. In RP1 (Reporting Period 1), One of the essential tasks was to ExpressIF GUI (Graphical User Interface) Update. This update aimed to create a Windows-like web server for ease of use, decrease the load in the web server and decrease the server communication, resulting in more privacy and data security. Several more web applications were built and integrated into this GUI, like weather forecasts, video analytics, etc. However, the development and integration plan did not go in a straight line. The project team

decided to use BLAZOR, a new web application development framework by Microsoft. The reason for using this framework was that it allows C# (programming language) codes directly into the web browser. The challenge happened from Microsoft's side. Due to the Covid-19 pandemic, Microsoft faced some product development delays with the Blazor though the development team of the RESPONDRONE was ready. The release of BLAZOR happened phase by phase, and the development team of the RESPONDRONE also matched themselves with the rhythm of that and progressively developed their ExpressIF GUI.

Another critical task was to update the whole ExpressIF software suite. This update was to get 3D spatial reasoning to help develop DTM (Digital Terrain Models) based on field data in an emergency scenario. During this upgradation process, the team had to continuously port the code to the latest C# language and runtime version. As a result, they started the project with .net framework 4.7 and finished with .net 6 frameworks.

A critical task of the RESPONDRONE development team was to design and validate virtual reality training packages to operate the fleet of drones in different emergency scenarios. However, over time it became evident that developing a VR (Virtual Reality) training system was not sustainable because VR simulation training has to be scenario-specific (Fire, earthquake). Also, VR technology was unfamiliar among first responders, so another training would be required to train them how to use the VR training simulator. The project team realized that it would be creeping the scope of the RESPONDRONE project, and therefore, collectively, they decided to build an e-learning platform to serve the project's purpose better.

Creating a secure distributed network with a shared web meta-database that would ensure adequate emergency response at the EUROPEAN level was one of the critical concerns for RESPONDRONE. This cloud database needed to be accessible to all involved stakeholders (National Authorities, FR organizations, and the public) to ensure the situational awareness and efficiency of the first response missions. This web-based cloud platform-building idea was generated when the consortium discovered that internet connections are not always available in emergency response scenarios. Even when it becomes available, connecting remotely to do operational work takes some time. It created a whole challenge for the RESPONDRONE project. If the drones could not fly in the disaster area and provide necessary information beforehand due to a lack of internet connectivity for the first responders, they would not be beneficial. Therefore, the development team pivoted to creating a web-based cloud platform and a fleet of sensor-based UAVs that will partially have their own data storage and processing system. This approach was helpful because a web-based cloud platform is easily accessible remotely. In real-time operations, especially in a crisis scenario, connecting to the internet may take some time due to different uncertainties. That is why they built the fleet of drones with their own data storage and command management system to partially run operations and store data at the beginning of the operation.

When the internet connection could be established with the cloud server, it would automatically backs up all the data in the cloud storage for appropriate dissemination (Union, 2022, p. 62-64).

The "ASSISTANT" project's technical reports showed that it focused on creating a complete VR (Virtual Reality) training simulator for all kinds of first responders worldwide. The VR simulator would cover training modules for natural (earthquakes, floods, etc.) and artificial disasters (chemical plant meltdown). The development and implementation were divided into four software modules: Augmented video fusion module, Chemical Hazard Module, Damaged Assets Location and Routing, and portable SA (Situational Awareness) platform. The deliverables in each module were based on comprehensive research of the first responder's needs. The development team collectively agreed on all the subtasks in each module and used their scientific and technical expertise to build advanced algorithms behind each module. As the technology was novel for the development team, there had also been a learning curve for them. Identifying the developed modules satisfying the first responders' needs was also essential. That is why the development and testing of each module happened simultaneously in this project. Based on the feedback from each testing phase, the development team has corrected their course of action to be better suited to meet the need of the first responders (Villamor, 2021, p. 15, 36, 58, 73, 88).

One of the critical technical adaptations in this project happened when new logical interfaces integrating new sensors and platforms needed to be developed to create the ASSISTANCE SA Platform in the GESTOP (Operatives Management) System. A SAS (Sensor Abstraction Service) platform was built by different microservices and a persistence layer on Mongo Database. The microservices in the platform offered a Rest API (Application Programming Interface), a DDP (Datagram delivery protocol), and a service bus with NATS (Network Address Translation) protocol. DDP protocol on web sockets enabled the platform to interact directly from the web sphere, and NATS protocol supported the satellite service that created the ecosystem for the "ASSISTANCE."

The platform also offered metric services to track the changes in data over time. This information was stored in a time-oriented database such as InfluxDB. It also offered a management interface, a 3D KPI, and a mapping visualization to position the sensors and view their properties. The consortium built a new software connector so SAS can be connected as software through a CITRIC connector. They also developed an MQTT server to send all the collected by the sensors and store it in a MongoDB ASSISTANCE Database.

On the hardware development and integration part of the project, a PIAP Gryf all-terrain mobile robot was modified with necessary mechanical and electrical integration, such as sensors, effectors, and communication modules. This UGV (Unmanned Ground Vehicle) was modified on top of the base platform and software. No changes were made in the base platform or software in the scope of the "ASSISTANCE" project (Carvajal, Esteve, Robles, et al., 2020, p. 14-15).

Innovation Management

Innovation management is a crucial process for successfully developing a radical innovation project. Adaptation of new technology happens rapidly in innovation projects. However, if the adaptation and development of new technology do not happen systematically, considering the impact on the other part of the projects, the whole project gets exposed to failure. Therefore, innovation must be managed diligently and systematically to bring the best results from a project. In the RESPONDRONE report, innovation management was treated as a separate task under the observation of an Innovation Board (Union, 2022, p. 97-99). The primary objective of this task was to create an innovation process that would ensure the development of a new market for RESPONDRONE and commercialize the product in the first responder service industry. Key achieved milestones for this task were the following:

- Creating a legal framework for the project and future commercialization.
- Conducting behavior studies to understand public perception and create public acceptance.
- Analyzing the market for gathering market intelligence to create appropriate commercialization techniques.
- Engaging technical and business stakeholders to create a business plan for future business options with RESPONDRONE implementation. The technical team took the insight from the business team to understand the market demand and end-user needs; they had their full autonomy to define the necessary product development backlog items to satisfy the project's time, budget, and scope.
- Conducting group and individual discussions among all partners to build a roadmap for RESPONDRONE implementation beyond the project lifecycle and commercialize the product.

In the ASSISTANCE project, the innovation management process was to set up a technology watch tool to conduct periodic searches about the exciting topic in the market defined by the partners. The search parameters were fine-tuned in three project phases by analyzing market trends and innovations. Whenever an exploitable result was discovered, competing solutions were developed early to maximize the result (Carvajal et al., 2022, p. 15). This project also took a very risk-focused assessment approach while identifying the different components of the innovation process. A structured what-if analysis was done to identify the point of failure in different areas of innovation and their consequences. The focus area of this analysis was obsolete technology, failure to meet the need of first responders, delays in technological development, and insufficient resources for technological Development (Amon, 2020, p. 11). The key identified consequences of this failure points were as follows:

- If the technological advancement in the current first responder industry superseded the project's technological development, the project results would no longer have any scientific or business benefits.
- If the technological approach chosen for a pilot did not satisfy the field requirement of the first responder, then either the approach or the pilot needed to be modified.

- If a development delay happened, it would impact the other part of the project, which may impact the project schedule.
- If resources were not adequate in quality and quantity for the project development, then the whole technology development would be delayed or unavailable.

Overall, the RESPONDRONE and ASSISTANCE project emphasized the significant role of technology and innovation in these projects' success. Rapid technological adaptation, continuous integration, and risk-based innovation management process were the significant variables in the success of these two large-scale innovation projects.

4.2: Communication and Collaboration

Effective communication and collaboration are critical success factors for a radical innovation project. Both RESPONDRONE and ASSISTANCE aimed to implement novel technology to change how the first responder industry manages operations, and front liners sharpen their skills in emergencies. In such a large-scale international project, special teams from around the world with diverse expertise contributed to achieving project milestones. Communication and collaboration were essential to achieving success in these projects. In the reports of RESPONDRONE and ASSISTANCE, different elements of effective communication and collaboration emerged, which can be categorized into three subthemes –

- Cross-functional communication, Product awareness, and Shared team vision
- Transparent and Proactive Communication
- Team Collaboration and Knowledge Sharing

Cross-Functional Communication, Product Awareness, and Shared Team Vision

In the RP1 of RESPONDRONE, one essential task was to develop the TMM (Traffic and Mission Management) tool. It was important because it would have received mission requests from the front-end components, processed them to find a proper UAV placement trajectory, and reported them back to the front end. Over time, the TMM would be the critical trajectory-finding algorithm for the RESPONDRONE fleets. However, things did not go as planned. During the TMM development in RP1, covid 19 restrictions happened worldwide. So, the advanced TMM development plan was in jeopardy and had to be modified. All the WP partners arranged and performed regular online meetings to ensure the timely progress of the TMM development despite the COVID-19 restrictions (Union, 2022, p. 33). The COVID-19 restrictions also impacted the development of the ASSISTANCE project's different modules. They maintained strong communication with the whole consortium and increased the number of bilateral contacts to detect early warnings of potential problems (Amon, 2020, p. 19). If the COVID-19 situation were going to impact the pilot inductions, contingency plans would have been developed by communicating with all the necessary stakeholders and work package leaders. Emphasizing continuous communication played a crucial role in this project. For every risk and opportunity that might appear in the project, there was a strong communication plan to formalize the aspects of that. If a risk or opportunity was identified by any project participant at any time, they first needed to discuss

it with their colleagues and then the TL (Team Leader)/WPL to get clarity on the situation. If the uncertainty remained, it would be forwarded to a Risk Manager. The risk Manager would first determine whether it could be handled or might be registered for further mitigation with the PIC (Project Implementation Committee) (Amon, 2019, p. 15).

Creating product awareness for the general public, internal and external stakeholders, and end users was one of the most challenging tasks in both projects. The RESPONDRONE communication plan focused on creating a dialogue with the public to raise awareness, promote the service and create a positive perception reflecting the product's benefits. As there were many different policies regarding using UAVs in different countries, it was essential to convince the policymakers of the usefulness of using a fleet of drones during the crisis with appropriate analytics of efficiency, response time, and budget. Therefore, different exploitation events were organized, and an open day was planned for all the internal and external stakeholders to watch the live operational demonstration of the RESPONDRONE. However, the live demonstration did not go as planned due to COVID-19 restrictions. Therefore, only a few key stakeholders attended the live demonstration. However, the demonstration was recorded and shared with all the internal and external stakeholders for viewing (Gerstenfeld et al., 2020, p. 8-13).

The same strategy was implemented in the ASSISTANCE project as well. Various communication strategy was used to create end-user awareness, communicate progress with internal and external stakeholders, and convince policymakers of the benefit of it. The purpose of creating a user community was to establish a broad dialogue to understand the requirement of the end user at the field level. These inputs of the end users were later used for the further modification and development of the product. Engaging end users in the development process helped them create awareness beforehand among the community, which later helped them to accept the final product. National workshops, conferences, exhibition fairs, and open access to research were organized to keep internal and external stakeholders during the project lifecycle. Many dialogues happened with policymakers to showcase the benefits of the project's outcome for the society, industry, and user community (Arias et al., 2020, p. 15-17).

In such a large-scale project like RESPONDRONE and ASSISTANCE, it is imperative that all the teams have an identical product vision and that their work is getting done cohesively. These clarifications and visions must be identified in any project's initiation phase. In the RESPONDRONE project, an initial mockup meeting was held in TEL AVIV with all the technological partners. The purpose of this meeting was to finalize the functional design and divide the workload and responsibilities among the partners. Another 2-day design thinking workshop was organized for testing the design, where end users (first responders) also participated with the technological partners. The end user's input and feedback were significant elements for confirming the initial mockup requirements. All the information from the initial mockup meeting and design thinking workshops were used to create the final product mockup. After the final mockup design

was ready, a kickoff meeting in Madrid included research institutes, universities, policymakers, and FR organizations from 12 EU and NON-EU countries. The primary purpose of this meeting was to get the project teams acquainted with each other, understand their roles and responsibility clearly, and share a unified product vision throughout the project lifecycle. The consortium had extensive discussions regarding project planning, addressing challenging questions, and working in separate groups for the same vision to ensure a shared understanding (Union, 2022, p. 28-30).

In the ASSISTANCE project, the kickoff meeting was held in Valencia in May 2019, and the first plenary meeting was held in Rome four months later. Many different plenary meetings were held during the project timeline at different intervals. Some plenary meetings in the project's first phase happened at three weeks intervals. It was influential in the first phase in creating a shared understanding of the project among the different team members and addressing the complicated questions early, which could hinder development in the project's later phases. Six months interval plenary meetings were mainly to track the project's progress and address any new risk or opportunity that may impact the product development and project timeline (Carvajal, Esteve, & Pérez, 2020, p. 13).

Proactive Communication and Dissemination Plan

As RESPONDRONE was a disruptive technology, it posed a high-risk perception among the public. Therefore, in RP1, the project consortium built a dedicated communication team to build a unique project identity and propagate its achievements and activities beyond the scientific and commercial audience. The communication team of the RESPONDRONE created an iterative communication plan which would be reviewed on a need basis. The communication strategy for this project was adaptive and focused on continuous active involvement with project partners, stakeholders, and end users. Some key objectives and methods to achieve those objectives were described in the communication plan. The key objectives were-

- Informing the project partners, stakeholders, and end users of the latest development of the project
- Raising awareness among the appropriate audience about the RESPONDRONE products and services
- Actively engaging all the necessary parties in the design and development of the process.
- Demonstrating the European collaborative approach in achieving scientific excellence and addressing societal challenges

The communication plan of the project was built on five elements of adaptive strategic communication- Purpose (Why), Messages (What), Key Audiences (Who), Methods (How), and Time (When). The following figure provides a visual representation of the adaptive communication plan:

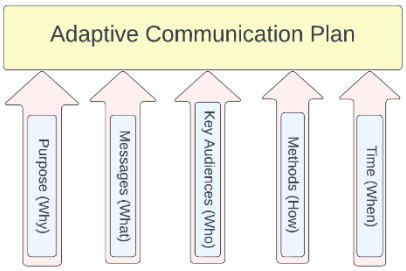

Figure 3- Elements of Adaptive Communication Plan

As we can see, the plan started with the why question. Why was communication needed? If needed, what would be the message, and for whom? How and when would the message be delivered? Every element of the communication plan was outlined with specific activities. The activities were reviewed periodically, and changes were made if necessary (Gerstenfeld et al., 2020, p. 6).

The RESPONDRONE website (https://respondroneproject.com/) was launched and had a representative profile in different social media (Facebook, Twitter, LinkedIn) projects. A publicly accessible blog post was launched in addition to the website and social media presence. In the blog post, updated project brochures were shared for understanding and providing the latest information to the interested parties. This Communication approach benefited the RESPONDRONE project in several ways. As the project brochures and latest information were shared with the interested parties, a wide range of expert opinions and inputs from different European interested parties came in. A project-specific advisory board was formed with four independent international experts who provided unbiased feedback and guidance on the project. For example, The Bavarian Red Cross (Germany's first response company) cooperated closely with RESPONDRONE and became a part of the advisory board. It helped RESPONDRONE to achieve public acceptance quickly from its initiation to the complete development phase by making it well known in the Public Protection and Disaster Relief Community (PPDR). Various online personal events and scientific research papers were published to create awareness about the project among laypeople (Union, 2022, p. 23-24).

The communication and dissemination strategy for ASSISTANCE aimed to maximize the project impacts towards knowledge creation, technological advancements, and societal benefits. Therefore, a structured communication plan focused on key objectives and target audiences was vital. The key target groups for the design of structured communication plans were-

- End users
- Local, National, and International Authorities
- Public and Private security agencies
- Policy Makers
- Standardization Bodies and Scientific Professional Community
- General Public

The end user's acknowledgment and acceptance of the project objectives and outcomes were the key success indicator for the project's communication plan. Acceptance of the project benefit among end users also minimized lay people's risk perception on using a novel technology. Local, National, and International authority's involvements were necessary for the project's mission, vision, and progress so that operational impediments could be identified and solved easily in the project's implementation phase. Policymakers and security agencies were informed to protect the project assets and related activities. Standardization bodies helped validate project outcomes through safety standards for operational use in live operations. Their involvement also created a positive perception among laypeople of the project's outcomes. Involvement with other researchers and engineers ensured that related R&D domains of the project were not getting duplicated. Access to the scientific publications ensured that most of the deliverables were accessible as an open knowledge source to lay people through the project website.

As the project had different target groups, communication and dissemination tools were used to develop the communication plan throughout the project lifecycle. An "ASSISTANCE user community" was established to involve different first responder organizations as they would be the primary end users of the project. The purpose of this community was to create extensive awareness among the end users, which was the primary foundation for the future uptake and acceptance of project results. The project logo, templates for presentation, and other dissemination materials were created to create the project's professional identity. The project public website was created to share the project-related general information, results, achievements, and public deliverables among all the project partners. In addition, social media accounts were also established across different platforms for information dissemination. High-quality dissemination and advertising materials were created using a standardized format to distribute at meetings and events. Dissemination videos, annual newsletters, and media-related actions (press releases, interviews) were conducted regularly to create public acceptance and awareness. Liaisons with research groups helped maximize the project's impacts and cultivate new synergies. Dialogue with policymakers, stakeholders, and citizen's associations helped to showcase the benefits for the society, industry, and user community (Arias et al., 2020, p. 12-17).

Team Collaboration and Knowledge Sharing

In a complex, large-scale radical innovation project, different teams work in the various part of the project. Therefore, all the teams must have a shared vision about the product and deliverables and constantly collaborate during the product development lifecycle. If teams work in silos rather than collaborating, it always poses a considerable risk that the development work may become irrelevant to the project objective. In the RESPONDRONE project, a design thinking workshop took place in November 2019 to finalize the product's functional design. The technical team of RESPONDRONE and the end users of RESPONDRONE (first responders) participated in this design thinking workshop. First responders shared their experiences, challenges, and learnings from emergency operations. As a result, the RESPONDRONE team identified a broad set of

features crucial for the project's success because first responders need those for on-site operations. The role of team collaboration in the project's success was so significant that the design thinking workshop was on hold till November to ensure the first responders' participation. Summer and Autumn is fire season, and it is a busy season for the first responders; therefore, they could have only participated after the fire season ended (Union, 2022, p. 29). In the "Assistance," a private collaborative workspace and a secured file repository were developed by UPVLC. It was available to each partner of the project. The workspace allowed secure information exchange among project partners, maintaining security compliance for some project deliverables (Carvajal, 2019, p. 10). A project coordinator helped teams find quick solutions to problems by engaging the project partners in result-driven discussions. To ensure team collaboration, the project coordinator took appropriate decision-making and conflict-resolution procedures (Amon, 2020, p. 15). In the testing phase of the VR simulator, first responders from different organizations participated, used the training simulator, and provided evaluation and feedback. The feedback from these participations helped the ASSISTANCE team to set new milestones for the project's success (Carvajal et al., 2022, p. 17).

The analysis of RESPONDRONE and ASSISTANCE projects emphasized the significance of communication and collaboration in managing uncertainty within radical innovation projects. Under the umbrella of communication and collaboration, cross-functional communication, product awareness, shared team vision, transparent and proactive communication, team collaboration, and knowledge sharing emerged as critical uncertainty management factors. Interestingly, all of these elements had an interconnected relationship among them as well. The significant success factors for these two projects were the effective establishment of necessary communication channels, a result-driven team toward a shared vision, and a continuous flow of knowledge sharing. The following network diagram will help to illustrate the complex nuances better-

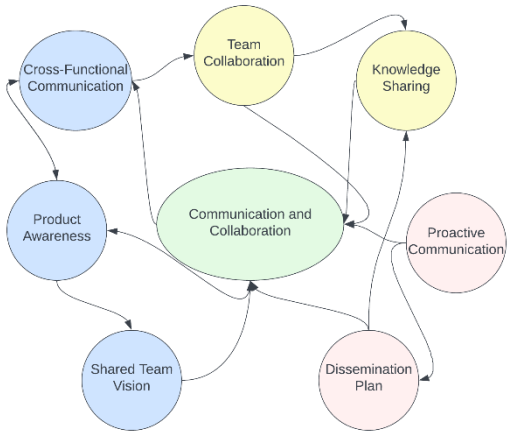

Figure 4- Network Diagram Illustrating Interconnectivity of Communication and Collaboration Elements

As we can see from the figure, every element of the communication and collaboration sphere had one-way or both-way interconnectivity. If we notice carefully, it is interesting to identify that

cross-functional communication increased product awareness, and the increment of product awareness also created solid cross-functional communication. Product awareness also influenced shared team vision, and cross-functional communication increased team collaboration, eventually leading to knowledge sharing. A proactive approach towards communication led to a better dissemination plan and thus also enhanced knowledge sharing among the project team and stakeholders.

To sum up, the interconnectivity of different communication and collaboration elements provided both projects with fluidity to craft context-based communication plans, resulting in better project dissemination, transparency, and shared team orientation.

4.3: Adaptive Project Management

Efficient project management plays a significant role in achieving success while navigating through the mine ground of uncertainty in radical innovation projects. From the analysis of RESPONDRONE and ASSISTANCE, adaptive project management surfaced as a critical success component for both projects. However, adaptive project management was not only about a specific methodology. Several vital components played an added role in forming adaptive project management. The subthemes of adaptive project management that arose from this analysis are-

- Agile Project Management Methodologies
- Result Driven Planning
- Dynamic Leadership and Decision Making

Agile Project Management Methodologies

A collaborative project demands effective and flexible management practices. Large-scale radical innovation projects like RESPONDRONE and ASSISTANCE had many teams working on various technical, business, and communication challenges. In addition, external uncertainties like COVID-19 also disrupted the initial project development plans. In such scenarios, a closed project management methodology like “waterfall” would severely threaten the project's success. Therefore, a lightweight and flexible project management methodology helped these projects progressively achieve their milestones. In RESPONDRONE, a modified agile project management method was developed, inspired by the Scrum framework. Scrum is valid for any complex project with many changing variables and requirements. Scrum is lightweight, simple to understand (yet difficult to master), and solves complex problems in small and simple increments.

The Scrum framework is based on three roles, four events, and three artifacts. In Scrum, teams are self-organizing and cross-functional to optimize flexibility, creativity, and productivity. The roles are- Product Owner, Scrum Master, and Development Team (Perrela, 2020, p. 12).

All the events in Scrum are time-boxed, used to create regularity and minimize the need for unproductive meetings. Events in the Scrum framework are- Sprint Planning, Daily Scrum, Sprint Review, and Sprint Retrospective. Artifacts in Scrum showcase work or value to provide

transparency and room for inspection and adaptation. This transparency of information and value creation improves the shared understanding among team members.

However, the Scrum framework was not used directly in developing and implementing the RESPONDRONE project; therefore, the framework was modified to satisfy the project requirements. This modification was possible because Scrum is an open-source framework that allows room for modification based on the industry and project needs.

The first issue with the Scrum framework in RESPONDRONE was the scalability of the framework. Scrum is mainly developed for intracompany development teams where the in-house development team simultaneously focuses on single projects/products. However, the RESPONDRONE project was much more heterogeneous. Teams working on H2020 projects had additional responsibilities in their companies/ research organizations. In addition, the global pandemic hit shifted most of the meetings and managed remotely. There was also a time-zone variation as many development team members were in different parts of the world. Therefore, the "Daily Scrum" event of the Scrum framework was replaced with a "Weekly Follow-Up" (Perrela, 2020, p. 13).

Usually, development works in Scrum happen in sprints. A product owner creates a product backlog, the work breakdown for completing a project. Then in a sprint planning meeting, the development team, in the presence of the product owner and scrum master, chooses the possible items from the product backlog that can be finished in a sprint. These items are then put into a sprint backlog, where they are described as a "User Story." Development teams then work on these user stories in one sprint. Usually, one sprint is 1 or 2 weeks, based on the workload (Schwaber & Sutherland, 2020). However, in RESPONDRONE, this timeline was modified. Initial sprint durations in the project were one month, and the duration got modified based on the workload in each sprint meeting (Perrela, 2020, p. 13).

A critical challenge in RESPONDRONE was creating and choosing compelling user stories that boosted the project development in the right direction. RESPONDRONE had different users in different phases of operations, i.e., commanders, first responders, decision-makers, and system integrators. Therefore, a priority number was assigned in the user stories that helped the development team understand which work to pick first. After picking the top priority use stories for development, user stories were often further broken down into more descriptive components. This approach helped the development team identify the key development features and moved the project in the right direction (Perrela, 2020, p. 14-19).

A project management handbook detailing the platform's development and overall project coordination was published in ASSISTANCE. The primary purpose of the handbook was to establish strategic control of each WP (Work Package), coordinate the project activities, and ensure

quality control and appropriate standards. This approach was necessary to reach project objectives within the triple constraints of the project- Budget, time, and scope. It also ensured the project could adjust itself by altering any constraints' elements while ensuring quality.

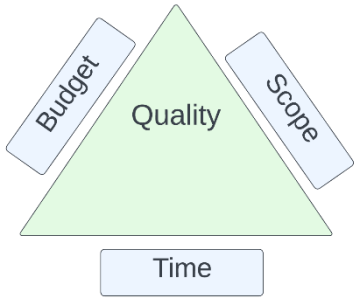

Figure 5- Triple Constraints of Project Management

The figure above illustrates the nuances of the triple constraints of project management in ASSISTANCE. As we can see, the quality of the project depended on three variables- Budget, time, and scope. If a project's budget needed to be changed for any reason, it would impact wither project's scope or time. If the project scope needed to be changed for any reason, it would impact the budget or time. Finally, if the project's delivery time were changed for any reason, it would impact its budget or scope.

RESPONDRONE required a well-structured organization to ensure good work division among project partners, proper information flow, and decision-making processes. Though the technical development part of the project was crucial, the efficient and responsible management procedures for the administrative and communicative work added significant value to the project's success (Carvajal, 2019, p. 10-12). Some of the vital project management activities were-

- Coordinating the project management activities at the consortium level
- Ensuring overall legal, contractual, ethical, financial, and administrative management of the consortium
- Creating and maintaining a shared workspace repository to ensure adequate knowledge and communication management
- Managing the project-related innovation activities at the consortium level

The establishment of the project organization was a joint agreement signed by all the project partners at the project's initiation phase. In order to eliminate the unnecessary management bureaucracy, ASSISTANCE followed a simple management structure where discussions and decisions were made at the plenary level with the consensus of project partners. However, for complex decision-making problems, a high-level project steering committee (PSC) was formed, complying with the CA (Consortium Agreement) and H2020 rules. PSC was the highest decision-making body, and a subset of PSC was established, named PIC (Project Implementation Committee). PIC was responsible for implementing and overseeing the project plan. It also coordinated the technical work among the work packages. Much of the management and coordination-related work was the responsibility of the PC (Project Coordinator). PC liaised

between the European Commission and ASSISTANCE project consortium. He ensured the overall project coordination, appropriate technical project outputs were generated, milestones reached, and deliverables were timely produced. He also kept an open eye to identify external risks, threats, and uncertainties that may impact the project's successful outcomes (Carvajal, 2019, p. 13-14).

The PC also established the project management office at the beginning of the project to handle all the administrative activities and keep the internal and external information flow running between different project parts. Whereas the administrative and financial information flow was very formal and structured, the technical information flow was less formal and horizontal. It helped the different project teams collaborate without bureaucracy and quickly and effectively solve technical challenges (Carvajal, 2019, p. 15).

Quality assurance and control were among the most significant success elements of ASSISTANCE. It was carried out by regular self-assessment in the periodical plenary meetings by all the project consortium members. In addition, PIC (Project Implementation Committee) also regularly monitored the self-assessment cycles and proposed corrective actions if necessary to achieve the project milestones. The project activities were monitored with the highly adopted iterative principle- PDCA (Plan-Do-Check-Act) by reflecting relevant project specifics of collaborative EU projects and different ISO management standards. Project controlling happened by considering different internal project elements, i.e., project deliverables and milestones status, regular work progress, and status of project resources and inventories. However, the project coordinator always had an open by of external factors that may impact the project's progress and outcome, i.e., market change, technological changes, etc. The project coordinator and quality manager consistently followed the PDCA principle throughout the project lifecycle to ensure progress and successful outcomes (Carvajal, 2019, p.19-20).

Result-Driven Project Planning

As both projects were large-scale and had many different components that needed to be integrated simultaneously in real-time, proper project planning was a critical success factor. However, result-driven project planning is not a one-man show. As both RESPONDRONE and ASSISTANCE had multiple project teams, stakeholders, and end users, all of the actors needed to be agreed on the project deliverables and the definition of success. It was also essential to understand how the current emergency rescue operations work so that the development of such novel technologies could be integrated into the current operational processes and systems seamlessly. Otherwise, neither the project's development was possible nor would it have been successfully implemented and commercialized later.

In the RESPONDRONE, interviews were conducted with the project's end users according to the three emergency management stages- preparation; assessment and coordination; response, and recovery (Amirkhanian et al., 2021, p. 7). After that, end-user mapping was done to identify all

the relevant actors in a first response activity, their relations, and dependencies. The analysis of the interviews and mapping were used to develop a standardized operational process flow and system maps for end-users that represent a unified emergency response process and end-user organization's emergency management system structure. The following figure illustrates a standard operational process flow in an emergency management operation that had been developed based on the research of the project team on their end-users' operational system-

Figure 6- Standard Operational Process Flow from RESPONDRONE End-User Research and Relational Mapping

The figure portrays that in a standard field-level emergency operation, the emergency team's first intake comes from the emergency cry-out help seeking an incident call. The call then gets dispatched to the necessary operational units to respond. Emergency units rush into the incident area for their first physical field-level assessment. The assessments work as the input for the operational planning. When the operations are on the run, continuous investigation and reporting happen on what is working and what is not. Those reports continuously go through a feedback loop as input for the whole process, which helps the emergency response team continuously upgrade its operational strategy.

After developing the standard process flow, the research team developed narratives to explain the differences between the standard process and field operational procedure. It helped the project development team to understand the field operations' need well and develop the product roadmap that would be best fitted to improve the field-level operations. This end-user research and knowledge generation helped the project team set quantifiable objectives and key results. It also helped them understand what was achievable and what was not and what kind of technology and feature development would best suit the first responders in critical operations.

On May 20-22,2019, RESPONDRONE held its kickoff meeting in Madrid. All 19 partner organizations participated in the meeting, including research institutes, universities, policymakers, and SMEs from 12 EU and NON-EU countries. The purpose was to become acquainted and build strong support and collaboration during project implementation. The governance structure, project deliverables, and definition of success were finalized in this kickoff meeting with the consent of each project partner and relevant stakeholders. End users organizations also participated in these meetings. Research organizations presented their finding from the analysis of current emergency management operational procedures, and the development team shared their product roadmap to implement the system into operational management. End users organizations evaluated those research findings and technological strategies and shared their input on improving them to address the challenges in field operations. The shared team dynamics and product vision among partners

and end users helped to develop a project plan where progress was quantifiable and transparent. It also helped the project teams to respond to changes quickly (Friedrich, 2019).

ASSISTANCE also had a similar approach in the knowledge generation process. Desk research was performed by subject expert project consortium members focusing on the different areas of technological development in ASSISTANCE. End-user interviews were also conducted, and the combination of desk research and end-user input was used in developing the project deliverables and success matrices.

From the analysis of the project proposal, which was based on different hypothetical scenarios, lists of technological problems were developed to be addressed and solved in the ASSISTANCE. The problem lists were grouped as chapters and discussed with the project consortium (technical partners and end users) to refine them into more actionable items. After the refinement, specialized partners were assigned to work on the different items from the list based on their expertise. A questionnaire draft was created for the end user's input based on two questions- what technology do they currently use, and what technology would they like to use? The draft was available as both- web-based and document-based. The answers from the questionnaire provided some fascinating insight into the project scope. The project consortium periodically discussed these insights to identify the risks and opportunities in changing the project scope. If the consortium agreed on any idea that might add significant value to the project's final deliverable, it would be added to the refined project scope (Maciaś, 2019, p. 14-15).

A kickoff meeting was held in Valencia on May 07-08, 2019, for ASSISTANCE. The whole project consortium attended the meeting. The consortium discussed and agreed on the project deliverables, success criteria, quality control procedures, and risk management approach that would be carried out throughout the project. The kickoff meeting helped the consortium agree on what the project would look like in its different stages. It also developed a shared understanding of the project vision and shared team dynamics to handle the complex technical nuances of the development work (Carvajal, Esteve, & Pérez, 2020, p. 13).

Dynamic Leadership and Effective Decision Making

Adaptive project management involves dynamic leadership and effective decision-making throughout the project lifecycle. The analysis of this research revealed that both projects embraced the idea of dynamic leadership to address the continuously changing nature of project development and structured governance to establish work delegation and effective decision-making.

RESPONDRONE established a governance structure in the project's early initiation phase, and all the project consortium members approved the structure in the kickoff meeting. The internal structure comprised six roles- Project Coordinator, General Assembly, Project Executive, Work

Package Leaders, Task Leaders, and Innovation Board. The external structure consisted of- Stakeholders forum and an advisory board (Geister, 2019, p. 5).

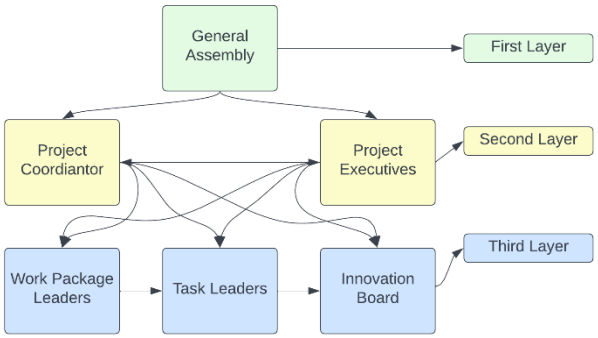

Figure 7- RESPONDRONE Governance Structure

From the figure above, it is evident that the ultimate authority of the project was the General Assembly. Any decisions that could not be sorted out at the other level of the governance structure were forwarded to General Assembly, which made the final call. In the second layer of the structure were the Project Coordinator and Project Executives. Project Coordinator was responsible for the overall project's progress monitoring and continuous reporting, while the Project Executives were responsible for the daily management of the entire project. Then, the Work Package Leaders and Task Leaders were in the third layer. Work Package Leaders were responsible for the daily management of the work packages, and the task leaders were responsible for the management and implementation of each task. An innovation board was established and responsible for daily innovation management and exploitation activities throughout the project lifecycle.

All the tasks in the project were assigned to a Task Leader with appropriate team members. Tasks were grouped into different work packages assigned to Work Package Leaders. Both the Project Coordinator and Project Executives monitored the work package developments. Project Executives were a constant support system for the Work Package leaders and Task Leaders who helped remove impediments to achieving daily milestones. Project Executives usually consulted with Project Coordinator if something needed higher supervision or insight. However, the governance structure was not a rigid vertical one. It went both vertical and horizontal ways. It was possible because of the transparency of work progress reporting in the shared documentation repository accessed by all internal project team members and internal communication channels. It ensured that the project team members were not working in silos and that everybody came to a shared collaborative mindset to understand each other's work towards the final project vision. The hybrid integration of vertical and horizontal structures gave the project flexibility to move fast and established the power dynamics of each role for effective decision-making in a complex, uncertain scenario (Union, 2022).

The ISO 31000-Risk Management Guidelines inspired the ASSISTANCE governance structure. The project created the Risks and Opportunities Management Policy (ROMP), and it was linked to a risk and opportunities register that occurred or anticipated to occur during the project (Amon, 2019, p. 11). Risk and opportunity management was defined as a constant iterative process of planning, identifying risks and opportunities, assessing for mitigation plans, implementing them, and monitoring them throughout the project life cycle. The risk manager headed the ASSISTANCE project management team. He was responsible for managing all the risks and opportunities identified during the project and finding an appropriate resolution.

The ASSISTANCE governance structure was built on the risk and opportunity owner role, who took responsibility for management actions associated with a particular risk or opportunity. The following management tree provides us with a visualization of the governance structure-

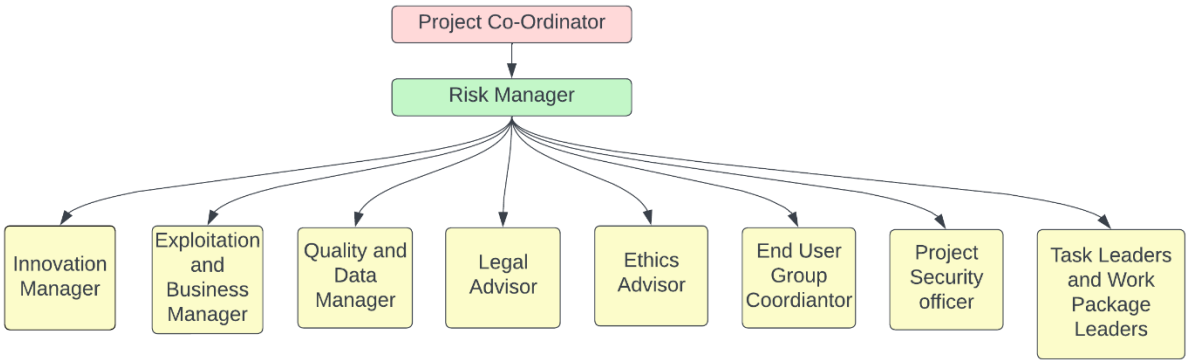

Figure 8- ASSISTANCE Governance Structure

From the figure, it is distinct that depending on the nature of the risk or opportunities, the risk manager appointed "Risk or Opportunity Owner" from any designated managers or leaders. The "Risk or Opportunity Owner" became responsible for all the management actions associated with the specific risk or opportunity. Though the risk owners took all the management actions, the risk manager was responsible for all actions or decisions. He was also responsible for regularly updating the risk and opportunity register, generating risk matrices for the project team, and verifying consistency between the mitigation plan and the calendar. It was also imperative that all the project consortium members and stakeholders were appropriately communicated with all the identified risks and opportunities.

The horizontal governance structure of the ASSISTANCE reduced the project's bureaucratic complexity of decision-making. It also gave flexibility to each risk owner to take appropriate actions needed to address a specific risk or opportunity. The environment of embracing dynamic leadership and responsible decision-making enabled the project to adapt to any changes quickly (Amon, 2019, p. 12-13).

To sum up, the analysis of RESPONDRONE and ASSISTANCE illustrates adaptive project management's impact on project success. Embracing agility in project management, proactive result-driven project planning, dynamic leadership, and flexible decision-making structure gave both projects the to move and respond to change faster. It was vital because both projects worked on developing complex distributed systems where the market and technical uncertainty happens fast.

4.4: Stakeholder Engagement

Efficient stakeholder engagement is a critical success element for innovation projects. This theme explores how stakeholder engagement was tackled and accomplished in RESPONDRONE and ASSISTANCE. It focuses on identifying stakeholders during the project initiation, involving them in the planning process, getting periodical feedback in the development phase, and using collaborative communication channels throughout the project lifecycle.

Stakeholder Identification and Analysis

Stakeholder identification and analysis was an integral part of RESPONDRONE and ASSISTANCE. Both projects were large-scale complex system development where different stakeholders had different interests. If all the stakeholders were not identified in the initiation phase and their interests were not considered in the project planning, the project outcomes would pose an enormous risk of becoming irrelevant for the unidentified stakeholders. That would not bring any successful outcomes for these projects in the long run. Both projects identified the relevant stakeholders through systematic processes like stakeholder mapping or analysis. This approach allowed the project teams to prioritize their tasks and tailor communication strategies to address the needs of each stakeholder.

In RESPONDRONE, stakeholder mapping was established as a task, and a task leader was assigned for the completion. A set of questionnaires was prepared and sent to end-user organizations to gather information about all the relevant stakeholders involved in emergency management in different countries. The questions were set to identify national, regional, and local emergency management authorities and map the relationships with international stakeholders (Union, 2022, p. 26). Some identified stakeholders were individual, while others were collective user groups. The identification and mapping process identified that the stakeholders would include representatives from public, policy, industry, education, and research/scientific end-user groups. Different stakeholders had different interests in the project objective, and the stakeholder mapping and analysis process helped to identify those interests and create them as objectives in the project planning. The key identified stakeholders in RESPONDRONE were- Opinion leaders and regulators, the scientific community, security and defense-related equipment manufacturers, technologies and integrators, media, emergency response authorities, policymakers, and the general public (Gerstenfeld et al., 2020, p. 8-10).

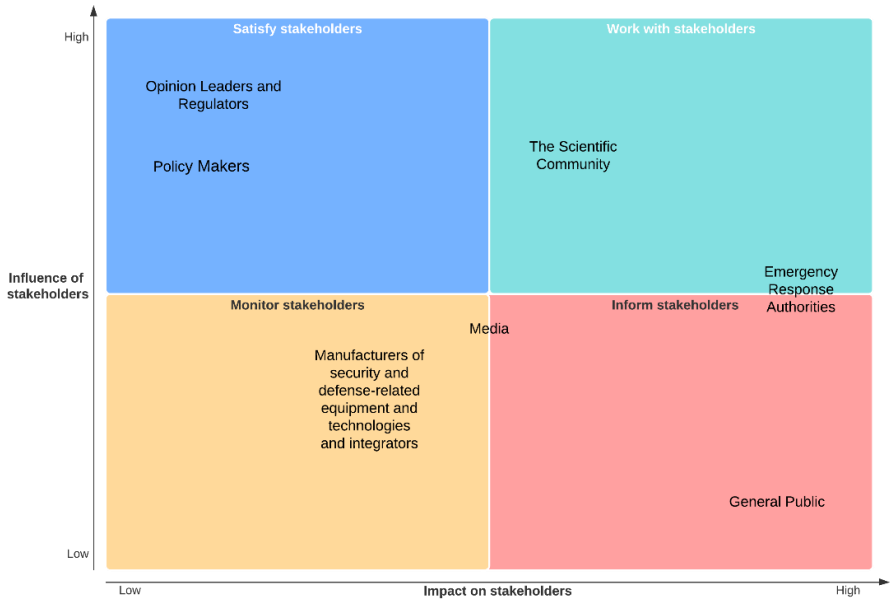

Figure 9- Stakeholder Mapping for the RESPONDRONE Project

Based on the stakeholder's influence and the project's impact on stakeholders, a stakeholder mapping has been done in the above figure. Here, on X-axis, the impact of the project outcomes on stakeholders has been shown from a low to high range; on Y-axis, the influence of the stakeholder on the project has been shown from a high to low range. The mapping demonstrates that opinion leaders, regulators, and policymakers had the most substantial influence on the project with the lowest impact on the project outcomes; therefore, the communication strategies were crafted to satisfy them.

Interestingly, emergency response authorities and media had some cross-functional influence and impact on the project. The impact of the project outcome on emergency authority was very high, and they had a moderate influence on the project. Therefore, they lay between "work with stakeholders" and "inform stakeholders." Continuous integration and experience gathering from emergency response authorities in the project planning helped the project to set the right achievable milestones. When milestones were achieved and a minimum viable product was built, they were informed and invited to the demonstration phase of the RESONDRONE (Union, 2022, p. 90).

Another engaging stakeholder in the project was the media. They had a moderate impact and influence on the project as the media was part of the strategic communication channel to build perception and awareness among the general public throughout the project lifecycle. Therefore, they lay between "monitor stakeholders" and "inform stakeholders." Media was continuously informed about the project's progress; however, they were closely monitored to ensure that disseminated information about the projects was correct, and they were helping to amplify the project results to all audiences (Gerstenfeld et al., 2020, p. 10).

ASSISTANCE also had an almost similar type of identified stakeholders like RESPONDRONE; however, in ASSISTANCE, stakeholder mapping is different based on their influence on the project and the impact project would have on them. A total of 4 stakeholder groups were identified and prioritized in ASSISTANCE to create strategic communication and dissemination plan. The first group was end-user groups. End-user groups' acceptance and acknowledgment was a key milestone for ASSISTANCE as it opened new channels of business expansion for the project. End-user groups comprised numerous first responder organizations (Medical Emergency Services, Firefighters, Law Enforcement Agencies, and Civil Protection). The second group was the security, regulatory, and government organizations, which validated the project development process and associated legal issues. The third group was the scientific/technological professional community. The knowledge gained on ASSISTANCE needed to be shared with the research and development community to ensure scientific publications and avoid duplication of efforts. The fourth group was the general public. Public acceptance and positive perception were crucial to ensure that people understood the project's benefits and avoided misperceptions towards technological advancements in security. Unlike RESPONDRONE, though media was not categorized as a stakeholder in ASSISTANCE, the role of media was significant in the overall communication and dissemination throughout the project lifecycle.

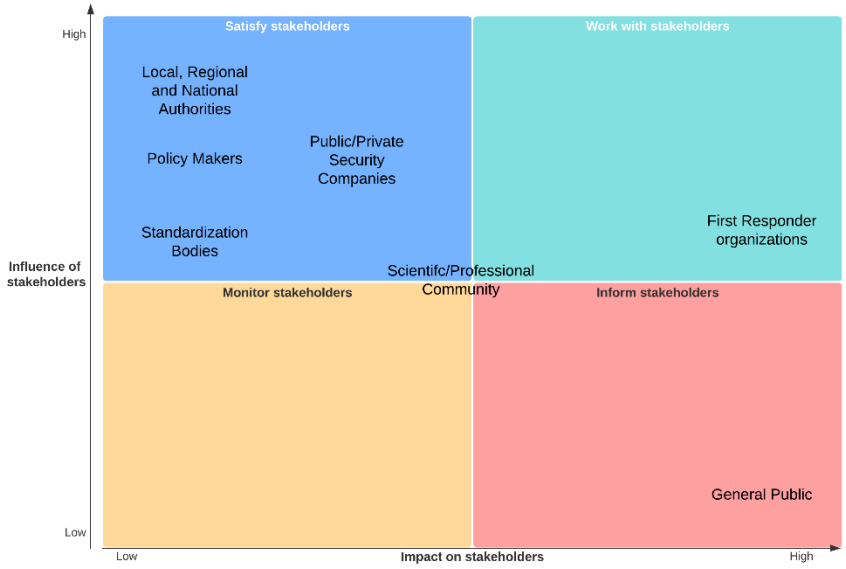

Figure 10- Stakeholder Mapping for the ASSISTANCE Project

From the illustrated stakeholder mapping, it is visible that satisfying all the associated regulatory authorities at the local, regional, and international levels was vital in ASSISTANCE, just like RESPONDRONE. This project also worked closely with the different first responder organizations to ensure the technology development is relevant and valuable for the end users. Interestingly, the scientific/professional community lies in all four areas of the power grid. It is because the knowledge from ASSISTANCE was shared continuously in the scientific community. The scientific community ensured efforts were not duplicated and helped the project team make the

right technological choice. They also did extensive open research and published research papers based on the knowledge from ASSISTANCE. This open practice and access to knowledge helped build a positive public perception of the project (Arias et al., 2020, p. 12-13).

Stakeholder Involvement and Feedback

Engaging stakeholders to ensure public support, satisfy regulatory guidelines, and solve the operational problems of emergency management organizations was crucial for both RESPONDRONE and ASSISTANCE. As RESPONDRONE was a new, innovative, and disruptive technology, it often created fragile public acceptance by using drones for operations. Therefore, the project's designated communication team focused on creating a project's identity for laypeople by creating websites and representative profiles on social media (Facebook, Twitter, LinkedIn). The project also maintained a public blog on the project's website giving regular updates on the project's progress (Union, 2022, p. 23).

Utilizing the experience of a wide range of end-users from different parts of Europe, RESPONDRONE successfully tackled the public acceptance-related issues regarding drone technology. It also established a project advisory board with four subject matter experts who provided project-specific advice, guidance, and feedback for the successful implementation of the system. The project consortium conducted a public acceptance study regarding drone technology in six countries (France, Netherlands, Greece, Bulgaria, Latvia, and Armenia). The objective was to identify the benefits and barriers of public acceptance regarding drone technology. The survey result concluded actionable recommendations to enhance the acceptance of drone technology among laypeople (Slaughter & Dam, 2022, p. 8).

RESPONDRONE also involved different professional organizations in the relevant fields in assisting them in adapting the product and technology. They also involved the scientific community in validating their generated knowledge through open research and publication. It helped the project to create positive public acceptance by providing accessible knowledge of the project's technology. It also helped the project development team to gain insights and directions from experts in the scientific field. Both knowledge generation and knowledge sharing helped the project team develop the best minimum viable product (MVP).

The project partners in RESPONDRONE took all the opportunities to communicate, disseminate and raise awareness among industrial, regulatory, and end-user partners about the project results and benefits both during and after the project. In the initial planning of the RESPONDRONE, members from different first responder organizations (end-users) were included. The project team members shared their current knowledge of emergency operational management systems and proposals for addressing the problems with technology development. However, the first responders identified different grey areas in the presented knowledge by the project team and gave them perspectives on the intensity of the field operations. The project team used those feedback to refine

the planning to make the product development best suited to address the need of the first responders. The open conversation between the project team and end users created a collaborative mindset and gave the project team a clearer product vision. After the initial product development, the project team arranged a live demo of the drone operations where the first responder organizations participated and helped the project team understand the product's relevancy with operational needs. In addition, end-user feedback was gathered on creating value propositions and business models. The practical knowledge of the market from the end user feedback helped the project team to make proper time estimations, product roadmap, and investment strategies for the project's future development (Union, 2022, p. 25, 99).

The ASSISTANCE project's risk and opportunity analysis identified stakeholders' engagement as both risk and opportunity. A risk statement established that a lack of involvement of end-user stakeholders might create miscommunication between end users and technical partners. It might result in project outcomes becoming irrelevant to the end users. This concern came from the end user surveys, and the impact would have been disastrous for field-level operations. Therefore, a permanent feedback loop was established to prevent misalignment between user needs and platform specifications. The feedback was produced by arranging sufficient interaction opportunities between the development team and end-user groups through telcos, meetings, and workshops. In addition, whenever a project milestone was achieved, end-user groups were involved in the final testing to provide necessary modification inputs (Amon, 2020, p. 18-19).

The involvement of end-user stakeholders also created a few opportunities for the project. The drone tech 2019 conference allowed the project to gather more information about end-user needs, innovative technology, and dissemination strategy. It also promised to connect to the dedicated training platform for female firefighters in The Netherlands. It helped the project team to generate the needs and opinions of female firefighters and decide on the proper gender dimension of the project. It also created an opportunity for market expansion in VR training technology. The more comfortable end users would get with the training simulation by VR technology, it would create the opportunity to generate other types of training simulations for them shortly (Amon, 2020, p. 26-27).

Regulatory stakeholders' involvement, like public authorities, security agencies, policymakers, and standardization bodies, helped the project to implement legal and ethical frameworks. As the project scope involved different partners in various regions, the project outcomes and operational activities needed to follow all the regional, national, and international laws. It also helped the project avoid unintentional legal nuances and interruptions during development. In addition, the scientific community's feedback helped the project team to generate new insights for technological development. The research and feedback also helped the project to build positive perceptions among laypeople (Arias et al., 2020, p. 12-13).

Collaborative Communication Channel

Both projects used different communication tools to ensure effective communication among all the project teams and interested parties and to disseminate information meaningfully. The choice of communication tools was based on the target audience. In RESPONDRONE, the first communication-related task was to develop an individual project identity and brand that would be successfully used on all the project products, communications, and outputs. The project identity creation was accomplished by using a dedicated project website. The project team maintained the website during the project timeline and would be for three years. After that, the website maintenance activities would be handed over to the consortium.

The RESPONDRONE logo and communication templates were created and provided to all project partners to build a brand. The logo and the templates were the standard communication and reporting tools for all the project-related internal and external communications. Communication templates include- PowerPoint presentation templates, Deliverable report templates, Meeting minutes templates, Letterhead, and Videos. In addition, RESPONDRONE created various graphical products like posters and marketing brochures. The purpose of the graphical products was to create awareness and a community of RESPONDRONE through different public conferences and scientific events.

The RESPONDRONE website played a critical role in regularly disseminating project-related updates. The website had six dedicated tabs- about, partners, the system, resources, news and events, blog, and contact us. The information shared through these six tabs covered all the areas of the project progress, achieved milestones, resources used, and media coverages of RESPONDRONE. It ensured project transparency and enhanced public trust to build positive perception.

RESPONDRONE also created nine newsletters throughout its lifecycle delivered to targeted professionals updating them about upcoming news and updates. The project also maintained an active presence on social media channels (Facebook, Twitter, LinkedIn) by creating dedicated accounts. Critical project-related progress and updates were disseminated through these social media channels to create awareness among the maximum number of general people.

RESPONDRONE arranged two live demonstrations, including all the project partners (technical and end-users), to orchestrate the project's progress. Due to the restrictions of the Covid-19 pandemic, many project partners could not attend the live demonstration event. The project team used ZOOM as an alternate communication channel to include the project partners in the live demonstration. Last but not least, RESPONDRONE participated in different scientific and technical workshops throughout the project timeline to present its findings and challenges and gather feedback from the subject-matter expert. It enabled a continuous learning process for the project team members and enabled them to create a better product (Gerstenfeld, 2022).

ASSISTANCE also used almost the same communication channels and strategy for dissemination and communication. However, they had some additional scopes in their communication strategy. The project also created its visual identity, like RESPONDRONE, by creating a website, logo, and templates and distributing it to all the necessary project partners. It maintained an active social media presence to maximize public acceptance and transparency. Regular press releases and interviews were done, and dissemination videos were produced illustrating the project's objectives, goals, and scientific and practical benefits. The project teams attended relevant scientific conferences and workshops regularly to create a strong liaison with the scientific community and gather their valuable feedback.

Unlike RESPONDRONE, project newsletters were published annually to present information regarding the progress, results, and achievements to all the interested parties in ASSISTANCE. Another interesting communication channel in the project was the end-user community. The community building happened by fostering a solid representation of end-user organizations in the project consortium, coordinating them, and participating in different external activities. It helped to create massive awareness and paved the path for future acceptance and opportunities (Arias et al., 2020).

To conclude, the analysis of RESPONDRONE and ASSISTANCE demonstrates stakeholder engagement's importance in project success. For active stakeholder engagement, they need to be identified and prioritized first. The identification and prioritization process gives an idea about the level of involvement required by each stakeholder in the project. It also helps to create the appropriate communication plan for the targeted stakeholders and maintain a collaborative and engaging environment.

4.5: Risk Management

Risk management is a crucial success factor for radical innovation projects. It allows project teams to identify, assess and mitigate known risks. It also helps the project team to build resiliency to deal with uncertainty by generating strong knowledge about known unknowns and unknown unknowns. This theme explores the critical risk management approaches in RESPONDRONE and ASSISTANCE: Risk Identification and Assessment, Risk Mitigation Strategies, and Risk Monitoring and Control. Combining these processes enabled the project team to address uncertainties and ensure effective project delivery.

Risk Identification and Assessment

A good risk management process begins with early identification and assessment of potential hazards, exposures, vulnerabilities, and social perceptions (IRGC, 2017). It helps to set the boundaries of risk or system and identify the risk's technical or perceived causes and consequences. In large-scale novel technological system development projects like RESPONDRONE and ASSISTANCE, risks and uncertainties arose from market, technical, organizational, resource,

legal, ethical, etc. Therefore, a comprehensive risk management approach was crucial in these projects. The IRGC Risk Governance framework and ISO 31000- Risk Management Guidelines inspired both projects' risk management.

RESPONDRONE used the pre-assessment techniques, risk appraisal, and risk characterization from the assessment sphere of the framework to generate strong risk knowledge in different project areas (Figure 2). In addition, it used risk evaluation techniques and risk management measures from the management sphere of the framework to decide on the risk-related actions where communication, stakeholder engagement, and proper context were the heart of the whole process. The purpose was to reduce the likelihood of potential risks or uncertainties as much as possible.

This project's key WP2 (Work Package) objective was to inspect and identify the critical risk factors in the first response process. After the identification, a risk assessment was done based on thorough literature reviews and standard practices. It helped the project team build a holistic risk model with a detailed analysis of all potential risks and their consequences. Both generic and area-specific threats were considered in the identification process, and an assessment was done based on their likelihood and impact level as the development of the implementation of RESPONDRONE was large-scale and international, regulatory risks raised from the international, national, and EU (European Union) level. As a drone is a flight technology, other air traffic laws and regulations exist worldwide. Not complying with those laws would put the project in danger of violating regulations and might have faced regulatory charges as well. That would affect the project's time, budget, and scope. In addition, it was using drones for emergency services that needed to comply with other regulations. Emergency service is mission-critical and has a lot of humanitarian aspects in it. There are civil protection rights in emergency operations. The challenge is that drone technology is identified as a military technology for strategic warfare and military surveillance. Therefore, the project team needed to find the middle path to how military technology could be safely used in civil operations by not violating civil protection rights. Not only from a legal point of view, but it was also imperative for social concerns. If people were not well informed about how military technology would be broadly used for civil operations in the time of their extreme vulnerability, it posed a massive risk of negative risk perceptions, which might hamper the project's success (Dumortier & Vandezande, 2019, p. 10-27).

Another drone technology usage-related risk was complying with the data protection regulation while conducting drone surveillance. According to Article 8 of the European Convention on Human Rights (ECHR), the right to privacy is a significant human right. Later, informational privacy was developed from the OECD (Organization for Economic Co-operation and Development) guidelines on privacy protection and cross-border data flows. Later, the GDPR (General Data Protection Regulation) was regulated to handle individual privacy protection in the EU area. As the RESPONDRONE was a cross-border project with different parts in different areas of the world, complying with all these regulations was extremely necessary. There might be

instances of the RESPONDRONE where the operation might happen in one country, and the data processing might happen in a different geographical location. The survey and field data would be flown over the cloud for computing and processing in the operational process. All of these information flows and operational nuances had to comply with all the applicable laws and regulations of the different countries across different regions.

Another key risk factor for the RESPONDRONE was the project's relevance to the target market. The development period for the RESPONDRONE was three years. The period was long enough to make the technology obsolete for the target market as some other competitors were already in the drone business and were creating state-of-the-art commercial drones for different purposes (DJI Drone Products). In addition, there were also risks of declining the adoption of technology by the first responders because of its novelty. No matter how technologically improved the product was if the first responders did not feel comfortable with the novelty of the technology, then the project objectives would not be achieved.

The nuances of technical complexity in this project were also another significant factor. RESPONDRONE had different technical components that needed to be synchronized to implement. Some technical issues were new to the development team members, and they had to learn new frameworks and technologies from scratch. This project's need for innovation speed made this task more critical and increased the risk exposure. Innovation speed was critical to ensure timely project delivery; however, the team members needed sufficient time to understand new technologies and frameworks to be integrated into the project. If the development team did not get enough time to learn the necessary things, the development might have been delayed; however, if the project delivery did not happen in time, the project might lose its market value. Therefore, the technical need for the project indicated that any new technology needed to be learned and implemented by the development team quickly and efficiently (Union, 2022, p. 61-64).

This project had team members from different parts of the world and different organizations, exposing the project to some organizational and resource-related risks and uncertainties. Handling different project teams worldwide was critical, and delay in one component of the project would have a domino effect on other parts of the project. Team members in this project were usually people from different organizations who had work accountability in their workplace. Any changes in their workplace or some urgent priorities would catastrophically impact the team member's development work for this project. During the first year of this project, the COVID-19 pandemic happened, and it changed many common practices that were usually a standard for this kind of large-scale project. The first impact of the covid delayed some of the project's work packages like platform integration and software updates (Union, 2022).

ASSISTANCE had a more structured risk reporting inspired by the ISO 31000 – Risk Management Guidelines. They maintained a risk and opportunities register throughout the project lifecycle,

which was drafted and updated three times. Several risks and opportunities were identified in management, innovation, end user, business, security, and other areas. In addition, the following chart provides a comprehensive summary of the identified risks and opportunities in ASSISTANCE.

Area	Risk	Opportunity
Innovation	Obsolete Technology	Possible use of ATMON FL (New Sensing Technology) sensor for design purposes
	Technology and First Responders need mismatch	Security Research Event (SRE2022)
	Technology development delays	
	Insufficient resources for technology development	
End User	The final results are not as expected by end users	NL (The Netherlands) platform for female firefighters
	Lack of female end users	Renewed interest in VR (Virtual Reality) training due to pandemic
		Demonstration with robots and electric cars
Business	Insufficient exploitation of results	First Responders participation
Management	Partner performance issues	NA
	Planning issues	
	Collaboration issues (Conflict Resolution)	
Security	Unauthorized access to the repository	NA
Other	Global Pandemic	NA
	Turkey increases its military conflict	
	Unable to fly drones in Turkey	
	Drones' arrival delay/stoppage due to Turkish customs procedures	
	Robots' arrival delay/stoppage due to Turkish customs procedures	

Table 1- Risk and Opportunity Analysis Data for the ASSISTANCE Project

The above chart shows that identified risks in innovation, end user, business, and management were almost similar to the RESPONDRONE project (Table 2). This project also posed the risk of being technologically obsolete and irrelevant for the end users, developing delays and resource insufficiency. In the end users area, the project had the risk that the final project outcome would not satisfy user requirements, and a lack of research data from female end users might reflect on the product design. In the business area, there were risks of insufficient market exploitation due to delayed project delivery or better technology of competitors. In the management area, there had been risks of improper project planning, team performance, and collaboration. Unlike RESPONDRONE, this project had no GDPR issues as it did not work on surveillance technology and collected data from the emergency response scenario.

However, data collection happened when users practiced with the technology; however, they were not personal data; they were only user data reflecting user experience and pattern. Still, it was essential to secure those data, and there was always a risk of unauthorized access to those data repositories. The impact of covid 19 was similar on both projects; however, ASSISTANCE posed

additional risks due to a military conflict in Turkey as many of its drones and robots were supposed to be delivered from there (Amon, 2021).

Risk Mitigation Strategies

The key to effective risk management is to evaluate the risk to create a risk profile with an appropriate risk rating. In RESPONDRONE, the project team interviewed the wildfire first responders to understand the nuances of the operational complexity and management techniques in emergency response. The critical questions in these interviews were based on the first responder's reasoning methodology, data collection techniques, and decision-making philosophies. Based on the answers to the questions, the three most critical aspects of the operation arose- evaluating the risk for each disaster block, estimating the spreading of wildfire, and pinpointing the area of water dropping. These identified aspects allowed the project team to define the technical requirements and resources needed for the development. This approach helped the project team address the project's market, technical, and resource-related risks and uncertainties (Union, 2022, p. 62). The project team also evaluated the risks of the legal and ethical issues and their consequences on the project. They published two dedicated reports only on identifying different legal, ethical, and security issues related to the project and how they may impact it.

The identified risks in the previous section for RESPONDRONE projects are listed below-

Risk Number	Risk
R1	Drone flight-related risks at the national, international, and European levels
R2	Usage of drones in emergency service-related risks
R3	Drone surveillance-related data protection violation risks
R4	Drone surveillance-related adverse social perception related risks
R5	Obsolete Technology
R6	Project outcomes and end-user needs mismatch
R7	Resource shortage for technological development
R8	Technology development delays
R9	Project Collaboration
R10	Covid 19 Pandemic

Table 2- Identified Risks in the RESPONDRONE Project

A 3x3 risk matrix can help to visualize the identified risks and their risk rating based on their probability and consequences in the RESPONDRONE.

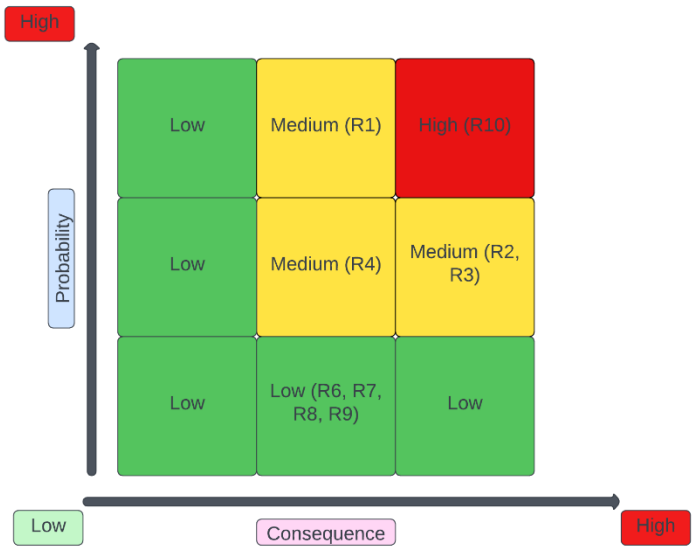

Figure 11- Risk Matrix for the RESPONDRONE Project

If we look at the risk matrix, it is visible that the high probability and high consequence risk for this project was the COVID-19 pandemic (R10), which was also reflected in the project report. In the final report, all the significant delays happened due to the sudden outbreak of COVID-19 at different work packages. However, the project team was nimble enough to address these changes. It implemented necessary mitigation strategies like virtual communication tools, virtual data repositories, and virtual conference tools in the shortest possible time, keeping the project afloat even with all the restrictions of COVID-19. As the project was well planned, researched, and communicated, the probability of technical, market, and resource uncertainties (R6, R7, R8, R9) were very low though their consequences were medium. Therefore, they stayed in the green tier of the matrix. Drone use, Drone flight, and Drone surveillance-related risks (R1, R2, R3, and R4) stayed in the yellow tier as they had medium to high probability and consequence in the project outcomes. Therefore, the project team decided on a set of deliverables required for the project in the first reporting period. The deliverables allowed the project team to analyze and design a roadmap for how, when, and where the drone flights needed to be operated. Based on the analysis, the project team examined the legal frameworks for running this project. The legal grey area was though drone flight was restricted in many areas, this project was designed for first responders in emergency management services. Many legal frameworks in EU areas permit drastic measures during emergency response. Therefore, drone flights could run without breaking the law during emergencies. The project team continuously researched the applicable laws and framework to address these legal issues and worked with the EU consortium to develop a policy recommendation for the RESPONDRONE project (Union, 2022).

ASSISTANCE created its 5X5 risk matrix to rate the identified and registered risks in their risk and opportunity register in innovation, end user, business, management, and security (Table 1), with medium consequences and very low probability, management, and innovation-related risks

stayed in the middle of the green zone. With very low probability and consequence, Turkey's flight and resource-related complications stayed on the left side of the green zone. However, the risks of increased military conflict would put the project's outcomes in a medium-risk zone as many drones and robots were sourced from Turkey for the project development. Another risk with medium consequence was if the project outcomes failed to satisfy the end user requirement. It would have made the whole project obsolete and wasted time, money, and technology. The most critical risk for this project was the outbreak of COVID-19. The restrictions associated with the COVID-19 pandemic was making project management hard, and the high probability of new restrictions and consequence associated with the restriction made the project timeline vulnerable. Therefore, the project team needed to monitor the pandemic-related updates constantly and make responsive plans to satisfy the movement restrictions during the pandemic (Amon, 2021, p. 12-13).

The key risk mitigation strategy in ASSISTANCE was setting up an action plan with small, sequential, and measurable steps to address risk. The action plan determined the scopes and boundaries of the tasks, time and resources required, expected outcomes and dependencies, responsible owners, and impact on other external factors. However, the action plan was not rigid to these factors only. Risk owners could fix their action plans in the context of the risks. There was always a chance that mitigation strategies for a specific risk might not work. In such a worst-case scenario, ASSISTANCE had contingency plans to minimize the impact of the risks (Amon, 2019, p. 21-22).

Risk Monitoring and Control

The final part of effective risk management is monitoring the identified risks and mitigation strategies and putting strategic control in place to implement the actions. The analysis in this study revealed that both project teams had to monitor and control systems to track the risk status of the identified risks throughout the project lifecycle. Regular risk review and progress assessment were integral to the risk management process, and feedback from the implemented mitigation strategies ensured their effectiveness. The iterative monitoring and control process allowed the projects to adapt the risk management process over time.

As illustrated in the previous section, RESPONDRONE faced different risks over the project timeline. One of the critical risks was the legal and regulatory risks of operating drone flights. Therefore, the project team constantly monitored the changes in the EU regulatory framework to proactively identify any policy change that may threaten the project and quickly change the project direction to comply with new laws. Operating a fleet of drones in an emergency response scenario is technically complex. Fine-tuned airspace and traffic management was the key to running a smooth operation. The strategic approach to this risk was to integrate the use case knowledge of the first responders on operational complexity and integrate a holistic risk model into the operational concept of RESPONDRONE. Therefore, higher-level monitoring was established for

air traffic management, and the central tactical team was responsible for detecting uncertainties and initiating warnings (Union, 2022, p. 13,32).

The project consortium established a deliverable review process to monitor the project's progress, risks, and mitigation strategies. It safeguarded the high quality of the submitted deliverables. The review process happened in three phases and started a minimum of four weeks prior to the final submission of each deliverable. The review process was interconnected with the lead author, draft reviewers, WP (Work Package) leaders and partners, project coordinator, risk, and administrative managers. It ensured transparency in the review process. The review process was flexible and nimble. If any party missed a deadline in any review phase, they had a float to work on the rest of the document while the reviewer reviewed the work done so far. It gave the review process agility, and potential reporting delays did not become a significant obstacle (Union, 2022, p. 105).

The project had constant monitoring throughout its lifecycle by different project partners and project executives. The initial plan was to arrange biweekly conference calls between different work package leaders and project executives to ensure seamless monitoring and robust control. However, the initial plan was disrupted by the COVID-19 pandemic, and new corrective measures needed to be implemented for monitoring and control. One necessary change was the increased use of virtual meetings. It caused significant delays in the project deliverables, and the arrangement of a virtual work setup required additional resources and budget. However, project teams shared team vision on the project deliverables, nimbleness made the necessary changes happen quickly, and virtual team integration, monitoring, and control processes were established (Union, 2022, p. 109).

ASSISTANCE maintained a waterfall chart to regularly monitor the identified risks and opportunities. Both the reduction in risk and increment in opportunities were noted in the chart after completing a mitigation activity. It gave the project team a clear visualization of how the mitigation activity had performed and whether it needed to be changed. In addition, they used risk visualization for overall project risk monitoring to understand the project’s progress and whether it is operating at a safe risk level.

Furthermore, ASSISTANCE established reporting and review process of all the project deliverables. The reporting usually took place at the plenary; however, if the project consortium demanded more reporting on any specific deliverable, the reporting process could do that. The project consortium also established a review process to ensure the ROMP's (Risks and Opportunities Management Policy) overall suitability, adequateness, and effectiveness. ROMP was reviewed before each deliverable report, and the risk manager conducted the quality control of the ROMP. Any changes in ROMP needed to be discussed with the PIC (Project Implementation Committee) to identify and rectify the potential impact of any changes (Amon, 2019, p. 24-25).

Altogether, the analysis of these two projects highlighted the importance of robust risk management practices in innovation projects. A proactive approach to risk identification and analysis, crafted risk mitigation strategies, and constant monitoring and control of each project work package and overall project progress resulted in the successful delivery and integration of both projects.

To conclude, this chapter portrays the critical findings from the thematic analysis in the context of uncertainty treatment in innovation projects conducted on the selected EU (European Union) projects- RESPONDRONE and ASSISTANCE. The analysis has revealed five key themes for uncertainty management in innovation projects: Technology and Innovation, Communication and Collaboration, Adaptive Project Management, Stakeholder Engagement, and Risk Management.
The findings illustrate that technological adaptation and integration foster innovation, and systematic innovation management drives the project toward success. Effective communication and collaboration across project stakeholders construct shared team dynamics and crafted communication plans for specific project audiences, ensuring appropriate information dissemination and knowledge sharing. Result-driven project planning, dynamic leadership, and agile project management methodologies like scrum give innovation projects the suitable instruments to deal with the changing nature of innovation projects. Stakeholder engagement allows the project team to identify the appropriate development requirements, and the stakeholder feedback works as a compass to move the project in the right direction. Robust risk management practices safeguard the project from unforeseeable events and build resiliency among the project team to prepare for the worst. These findings are essential for organizations working on radical innovation projects to survive in the competitive market. The key themes from this analysis give an organization a roadmap for capability enhancement in navigating the uncertainties of innovation projects.

5: DISCUSSION

The themes from this research analysis are an exciting starting point to engage in an appealing analytical discussion. In this chapter, I will examine the main research question of how radical innovation projects can better navigate and treat the unknown territory of uncertainty. This chapter is divided into two parts. In the first part, I will discuss the research questions in light of the RESPONDRONE and ASSISTANCE analysis and the literature review's perspectives. The purpose is to clearly understand what strategies worked in real life for RESPONDRONE and ASSISTANCE and how much they answer our research questions for this thesis. Later, I will discuss whether the strategies are replicable for radical innovation projects or are case specific. This discussion will be done through the literature review's innovation, risk management, and decision-making perspectives. Finally, I will propose a unified conceptual toolbox for better treatment of uncertainty based on the knowledge generated from this research and existing literature.

In the second part, I will reflect on a few puzzling aspects of this research. Most previous literature indicates customer integration in the idea and development process does not add value to radical innovation projects. The rationale behind the argument is that customers lack sufficient knowledge about disruptive technology's impact. So, their feedback can sometimes even harm the creative process of designing such a technology. However, the analysis of this research indicates something very different. Customer engagement was an integral part of both RESPONDRONE and ASSISTANCE. The same goes for the implementation of standardized rules and procedures. The synthesis of existing literature suggested that due to the dynamic nature of radical innovation projects, standardized rules and procedures hinder the innovation process. However, from the analysis of RESPONDRONE and ASSISTANCE, it is evident that both of the projects had a robust governance structure. However, it does not mean the structure was rigid and hard to navigate. The governance structure was fluid and flexible, yet it was structured. I will discuss potential reasons for such a dilemma and reflect on some perspectives to look at it.

5.1: Unveiling the Reflective Landscape

Throughout this thesis, we have explored the multifaceted nature of uncertainty in radical innovation projects. The literature review highlighted various perspectives, including innovation, risk management, and decision-making, shedding light on the complexities and challenges that arise in the face of uncertainty. Problematic aspects such as a long incubation period, standardized rules and procedures, non-existent market and market unfamiliarity, fuzziness in the fuzzy front-end, project team, and dynamic shifting capability and selecting the right project leader have been identified, underscoring the need for a comprehensive approach to uncertainty treatment.

The research gap in the existing literature led us to develop an analytical direction focusing on identifying areas of uncertainty, measuring their impact, and proposing a unified toolbox. The detailed discussion of the research questions, reflections on the findings, and integration with

existing literature will unravel the complexities of uncertainty treatment in innovation projects. The aim is to pave the way for enhanced project success and foster a climate of innovation in today's rapidly evolving landscape.

5.2: Illumination of the Unknown: A Journey of Research Reflection

Uncertainty in any situation is complex, nuanced, and terrifying. It is like navigating a boat in uncharted water. You never know what awaits you in the next step and how it will impact you. Now, let's put it in the context of innovation projects. The journey is more arduous and more complex. Now you are trying to find a hidden treasure in an unknown territory navigating uncharted water. However, you are not sure if the treasure is out there. Still, you want to try it because of the reward; you are investing your time and resource with the knowledge that the quest may fail drastically.

Now what can one do for such a treasure hunt? Can he reduce the situation's complexity, dangers that may lie ahead in his journey, and reasons that may fail him drastically in his quest? The answer is no. One can only better equip himself with the necessary knowledge, tools, and experience to complete this journey. One can only know the history of other people trying to commit such a dare, learn from their experiences, identify the critical aspects from where dangers may arise, and equip himself with better boats, navigation, and survival tools.

The purpose of this research has been exactly like that. Here, I have explored how a radical innovation project can navigate in the uncharted territory of uncertainty. I searched for the critical areas of uncertainties, their impact on the project's success, and which tools and frameworks can give the project a better chance of survival.

Decoding the Unknown: Exploring Critical Areas of Uncertainty

The first critical question of this research is what are the critical areas of uncertainty in a radical innovation project. The very nature of the uncertainty indeed tells us that it is impossible to understand all the aspects of it. However, this approach to understanding uncertainty is vague and does not offer solutions. My point is that I accept that uncertainty has a limitless boundary, but all of the uncertainties can not arise in an innovation project simultaneously, and the impact of all kinds of uncertainties can not be the same. There must be some common areas where radical innovation projects face the uncertainties most, and their impact is detrimental to the project's health.

The first uncertainty area I would like to focus on is the technical uncertainty. Let us look at the findings from the analysis of RESPONDRONE and ASSISTANCE. The first theme that arose from the analysis was technology and innovation. Both projects were large-scale and technically complex. The projects had many dependent and independent variables. Different types of technologies were used and developed in smaller portions and later integrated into the development

of the whole system. Such an integration process is never easy. Technical development in today's rapidly changing world is fast. One platform or framework used to develop a particular software or interface can suddenly become obsolete in its next update. The complexity does not end there. If that platform gets changed, it also necessitates the design and integration change of the whole platform. Different software versions fix bugs that must be aligned with the whole system. Both projects underwent different software upgradation throughout their whole project lifecycle. Some of the project work was delayed due to these nuances. In one instance, the RESPONDRONE team even had to wait for Microsoft's release of the BLAZOR web application development framework by Microsoft so that they could integrate their C# codebase directly into the web browser.

The complexity did not end there. The technical project team was challenged with a vast learning curve in ASSISTANCE. The ground-up build of a VR (Virtual Reality) training platform, integrating different kinds of new sensors and logical interfaces, and collaborating with different databases created a considerable challenge for them. The project team was unfamiliar with all the technical nuances and thus needed time to learn the frameworks and tools to develop and integrate.

One can claim that these complexities are known facts in any technical project. New software upgrades will be released; what is so uncertain about that? So it is instead known risk factors than uncertainties. I want to argue by stating that though technical changes may identify as a known risk factor, it is an uncertainty in the context of a specific innovation project. The rationale behind this argument is that a development team cannot know when the subsequent upgradation will be released and what changes it will bring to their codebase. If the change is too radical, how long will it take them to understand, learn and implement them? How will that affect the project delivery deadlines? How will the delay in project delivery deadlines impact the project's budget? How will it impact the project's relevance in the market? There are just too many questions that no project team can provide a concrete answer to beforehand.

I want to focus on the knowledge from the existing literature now, which satisfies the observation from the study. It is established that the nature of technology and market, innovation, and industry is a critical success for radical innovation projects (Balachandra & Friar, 1997). Technical complexity is hard to steer; therefore, it is crucial to determine where to put the focus. The combination of technical and market uncertainty has also been labeled "Suicide Square" (O'Connor & Rice, 2013). It is because rapid technological changes expose an organization to strategic ambiguity to achieve the project goal. The impact of technological changes on resource allocation, budget, and delivery deadlines can threaten a project's survival over time.

The second uncertainty area I would like to focus on is the market uncertainty. In both projects, market uncertainty was identified as a critical factor. Different project and risk management techniques were implemented to address them. The innovation management of both projects developed the commercialization and business planning centered around addressing market

uncertainty. RESPONDRONE had a dedicated innovation management board for creating an innovation process to ensure the project's integration into the market. In the innovation process of ASSISTANCE, the technical team continuously took insights from the business team to understand the market and looped the insights back into the development process. Both of the projects repeatedly showcased their concern about the changing market needs. From idea generation to quality assurance, both projects embraced adaptive project management, allowing them to change direction according to market demand. Focus on market uncertainty also helped the projects to select the proper development procedures, choose the right technical tools and create a comprehensive business plan.

The question is why a radical innovation project's market uncertainty is critical to identify while the project's purpose is to develop something new for the market and the probability of failure has been considered. I argue that every radical innovation project aims to create or disrupt a market so that organizations can achieve financial growth. Organizations invest their technical and financial resources to develop a radical product for a long time. If the market uncertainties are not appropriately identified, it exposes the project to failure to a large extent. If the market uncertainties are not identified on time, the project may be irrelevant by the time the development phase is done; competitors can enter the market with the same product type, or the market itself can be diminished. If the possibility of such uncertainties is not identified early, the organization may continue to invest its resources in the wrong project and exposes itself to a significant financial loss.

Let's lean back into the existing literature to gain some support for my argument. O'Connor and Rice (2013) described high technical and market uncertainty as a suicide square for an organization. Rapid technological advancement creates market disruption and changes customer orientation at any time. The strategic ambiguity in such a scenario puzzled the organization to take appropriate uncertainty treatment procedures. Interestingly, no universal methodology exists for a company to handle market uncertainties (Oconnor, 1998). There are indeed some common strategies like gathering market intelligence, understanding market familiarity, and identifying market location; however, not everyone is related to all kinds of innovation projects for different organizations. Therefore, the identification strategy must be crafted on a project basis for successful product development. Another notable observation is that market uncertainty complexity does not just end in the initiation and planning phases of the project; it revolves around the whole project lifecycle. In the fuzzy front end of a product development process, identifying a product's value offering is much more important than gathering market intelligence on how customers may react to the product. However, in the project's later phase, such information is valuable for developing product commercialization and business plans (Thanasopon et al., 2016).

The third uncertainty area I would like to focus on is organizational uncertainty. If we look at the analysis data of RESPONDRONE and ASSISTANCE, it is clear that the organizational

uncertainty of both projects was very high. It is because of the complex structure of both of the projects. Both projects had team members from different parts of the world working together. Though the EU funded the project, not all the team members of these projects have been EU employees. EU outsourced different work packages to professionals in multiple locations worldwide. Such diversified locations of team members made the work progress tracking challenging for the assigned task leaders and work package leaders. Most of the team members were also part of different companies where they had different priorities. Keeping the team members motivated and aligned with the project goal was challenging and exposed the projects to uncertainties. However, it is evident that despite such complexity, the project milestones were achieved at an incremental speed. It was possible due to both projects' robust yet fluid governance structure. Both projects had a transparent chain of command and responsibility distribution, ensuring everybody knew their role and expectations. The governance structure gave the project team members an internal support structure to lean on while facing challenges. However, the process was not rigid. From the observations shared in the communication and collaboration theme (Chapter 4, section 4.3), it was distinct that the governance structure fostered cross-functional and proactive communication for creating a shared team vision, knowledge orientation, and collaboration. It created a safe place for the team members to generate ideas and foster innovation.

One of the most considerable external organizational uncertainties for both of the projects was the outbreak of the Covid-19 pandemic. Though the impact of the pandemic was in all the areas of uncertainty, putting it in the context of organizational uncertainty gave an overview of all of them. However, both project teams orchestrated their dynamic organizational capabilities to tackle the uncertainties due to pandemics. The outbreak happened during the first phase of both projects, which did not allow team members for physical meetings to share project updates. Virtual solutions (Virtual meeting apps, cloud document repository, live streaming platform) were implemented and adapted quickly to tackle the situation and ensure project progress. It went beyond the project team members associated directly with the project. To specify, RESPONDRONE planned a live demonstration for the end users after the initial development phase. As pandemic-related restrictions made physical gathering impossible, a few project team members did the demonstration and arranged live streaming for the associated stakeholders. The recording of the demonstrations was then shared in a cloud-based file-sharing space for any associated interested parties.

Let’s recline to the existing literature now to support my observations. O'Connor and Rice (2013) introduced organizational uncertainty as a different category while developing their unified matrix model to quantify uncertainty. Organizational aspects like location, value chain maintenance, workforce outsourcing, and project internal support structure can significantly impact a project’s future direction. Thus, these uncertainties need to be identified and treated well. Organizational effort in knowledge gathering and creating a shared space for safe and informal communication also plays a crucial role in an innovation project’s success (McDermott & O'Connor, 2002; Van

Riel et al., 2004). If the organization does not foster the innovativeness of the team members and does not give space for people to share their ideas and try something new, innovation can not happen. Micromanagement of the project team is not an answer while developing a radical innovation project. There are also internal (controllable) and external (uncontrollable) factors of organizational uncertainty. Whether the uncertainty factor is internal or external, if it is not appropriately identified, the treatment plan will not be sound and efficient (Balachandra & Friar, 1997). The organization needs to develop its dynamic shifting capabilities along with the project team (Lee & Kelley, 2008). It is like the wheels of a motorcycle. If both wheels do not move in the same direction at the same speed, the motorcycle will soon hit the wall.

The fourth uncertainty area I would like to focus on is resource uncertainty. Resource uncertainties repeatedly surfaced in the analysis of both projects. It is a reflection on conceptualizing the gravity of the problem. The technical complexity of both projects made them very aware of the necessary software and hardware resources. Identifying the necessary resource was an integral part of the early phase of the project and innovation management. In the later phases of the projects, regular status reporting of project resources happened as a part of the quality control. Both projects were transparent about their budget, resource collection, and allocation. A separate "resource" tab was assigned to disseminate the resource-related information on both projects' websites.

The transparency assurance approach related to resources in both projects provides an interesting observation. Resource-related uncertainty does not impact the project's development process or teams; it can also impact public trust. Let me explain how. If the resource-related uncertainties are not appropriately identified in the early stage, during the project lifecycle, teams will face many roadblocks, and it will make a dent in the project budget. When the information is shared publicly, it can create skepticism among the general public about the project's benefits. Their point of view can be that resource allocation changes and budget problems indicate that the project team does not understand the nuances of the product themselves. If they do not understand what they are developing, how can they ensure that it will be helpful for the general public in the real world? Therefore, project leaders must become selective, strategic, and dynamic about resource allocations to ensure that changes are addressed immediately and that room for skepticism does not arise among teams or the public.

Let's incline to the existing literature now to support my observations. Resource uncertainty was also categorized as separate and organizational uncertainty by O'Connor and Rice (2013). The term resource has a broad spectrum. Therefore, defining what is considered a resource in a particular project is essential. Generally, resource uncertainty includes project budget, team member competencies, and the adequacy of the resources. The team members' sufficient project budget, resources, and technical competencies are more of a black-and-white matter. Either you have it, or you do not. If you do not have it, a separate mitigation plan is required to address those challenges. However, that is not the discussion point in this paragraph. The critical element that accelerates

the uncertainty is putting team members' dynamic competencies in the context of resources. The subjectivity of the element makes it harder to identify whether it is a resource in the project or a process that will generate dynamic capabilities at a team level (Lee & Kelley, 2008). All the resources in the world will not make sense in a project if there is not an established process to optimize them and generate value.

In contrast, as stated in the problematic aspects of the radical innovation project (Chapter 2, Section 2.4), too many processes and procedures hinder project innovation and perspectives of embracing uncertainty. So, the key is to maintain the sweet spot where a small quantity of chaos will foster the team's innovativeness; however, if necessary, procedures and processes can bring order in a chaotic situation. The selectiveness mechanism is also fundamental in strategic resource allocation. It helps the project leaders or sponsors decide what amount and what kind of resource is required in a specific project phase. This approach also helps with the optimization of resources to generate value.

Measuring the Unmeasurable: Reflecting on Impact Assessment of Uncertainty

The second research problem of this thesis is finding a way to identify and measure the impact of uncertainty in radical innovation projects. I will first analyze the process of RESPONDRONE and ASSISTANCE to find out what worked for them and then lean into the knowledge of existing literature to find the support for my analysis.

Both project teams knew the software and hardware resources necessary from the initiation phase. It was the most significant uncertainty area for the development of the project. Many other project areas could be delayed if the project team could not access the necessary resource at the right time in the development phase. The problem is that resource-related uncertainties did not just raise internally. It had both possible internal and external factors. For example, in the ASSISTANCE risk and opportunities register, the project team identified that the hardware supply might stop suddenly for the project. The skepticism was valid as much of the project's hardware was imported from Turkey, and Turkey had some military conflict then. The project team realized that the impact would be very high in the occurrence of such an event. Therefore, the project team decided on another backup hardware supplier in case of such an event.

Both projects had an integrated impact assessment procedure for uncertainty in their innovation management. It was essential because both projects had different moving parts, and if they were not functioning systematically and cohesively, the impact level on different parts of the projects would be very high. Therefore, project teams brainstormed in the fuzzy front end to identify as much adversity as possible and conceptualize what might happen. The uncertainty impact assessment techniques were systematic yet subjective. Project teams used their experiences to conceptualize the different nuances of particular uncertainty. For example, both projects were highly affected by the outbreak of Covid-19. It created a considerable challenge in both projects'

communication and monitoring strategies. However, it was an external uncertainty that the project team never even thought about in the initial planning phase. Still, they realized the possible impact on different project milestones. Therefore, virtual meeting and file-sharing tools were implemented and adopted quickly to minimize impact.

The project coordinator was one of the key players in uncertainty identification and impact assessment in both projects. A sharp open eye toward the internal and external uncertainties, risks, and threats was essential to ensure the project's success.

An interesting observation from both projects is that uncertainty measure, impact assessment, and treatment were integrated throughout the project in different timelines than a standalone procedure. None of the projects reported any hard and fast methodology or framework for measuring uncertainty's impacts. Uncertainty treatment is subjective and grounded on experience rather than a rigid procedure. The following flowchart will provide better visualization of the process-

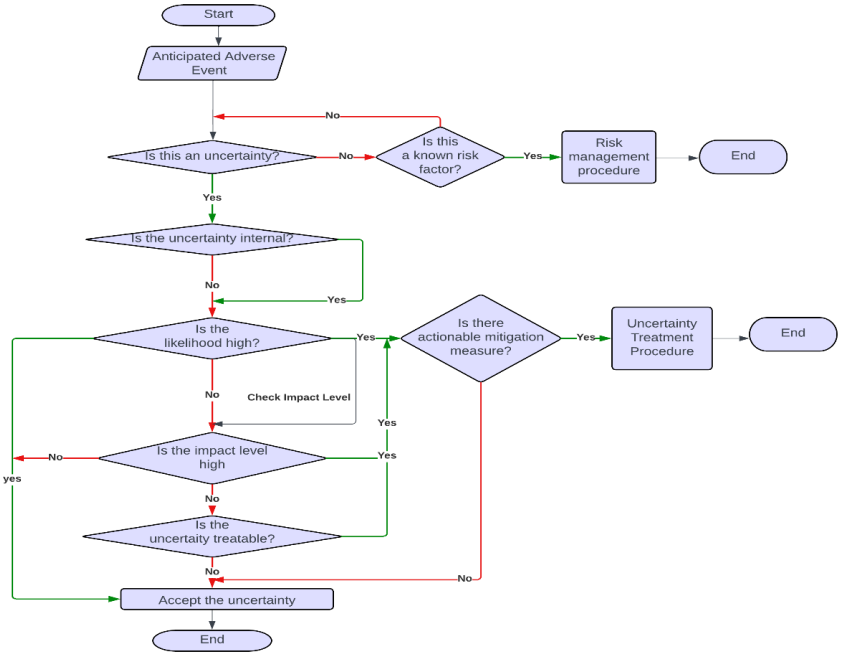

Figure 12- Uncertainty Identification and Impact Assessment Flowchart for RESPONDRONE and ASSISTANCE

This flowchart merely visualizes my understanding of the uncertainty identification and impact assessment process of RESPONDRONE and ASSISTANCE. If an adverse event was identified and anticipated, the dilemma was determining whether it was uncertain or a known risk factor. An established risk management procedure was implemented if it was a known risk factor. If not, then the question was whether the uncertainty was internal. The next step for internal and external uncertainties was determining their likelihood, impact, and treatability. If the likelihood and impact were high and uncertainty was treatable, uncertainty treatment procedures were implemented. If the likelihood was low, but the impact was high, and uncertainty was treatable, uncertainty

treatment procedures were implemented. Uncertainty was treated or accepted if the impact level was low and the likelihood was high. In a worst-case scenario, if an uncertainty had a high impact and high probability yet was not treatable, there was no other option except accepting it. However, no such adverse event happened in both project.

Let's recline to the existing literature now. Ironically, different pieces of literature over various timelines have discussed different dimensions of uncertainty, such as latency, critical measurement, and impact assessment. However, O'Connor and Rice (2013) introduced their uncertainty quantification matrix model based on the synthesis of previous literature. The matrix was three-dimensional, and four uncertainty categories were considered (market, technical, organizational, and resource). The following visualization will help us understand the matrix better.

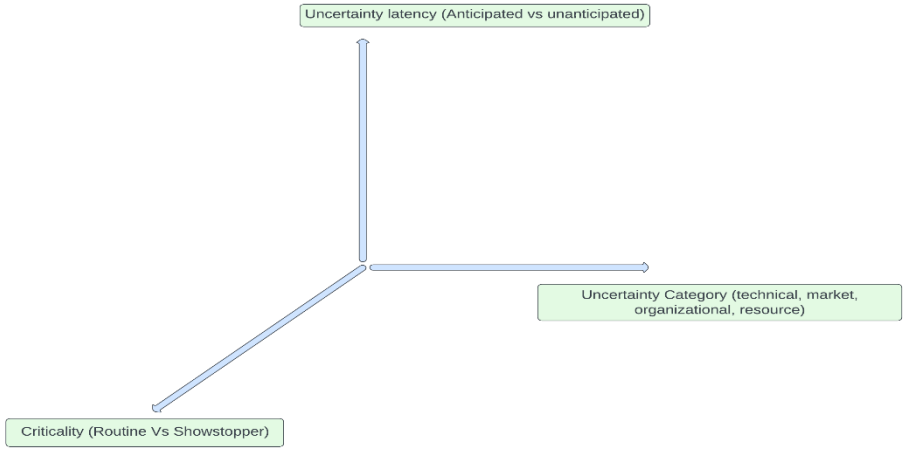

Figure 13- Three-Dimensional Uncertainty Matrix Model

In the X- axis of the model, the uncertainty category is positioned; in the y-axis, uncertainty latency (anticipated vs. unanticipated), and in the z-axis, criticality (routine vs. showstopper). It helps us to identify uncertainty and measure the impact quickly. I will now test the model with an uncertain situation from the ASSISTANCE project. Due to military conflict in Turkey, hardware supply could be interrupted for the project. Let's identify and measure this adverse event in the matrix model. First, we can identify that as it is related to some hardware supply for the project, this is a resource uncertainty. If we look at the latency of the uncertainty, the project team got the news of military conflict beforehand; therefore, if something like the hardware supply disruption happens, the uncertainty is anticipated now. For the criticality of the uncertainty, we can identify it as a showstopper because an adverse event like a military conflict in a supplier country is not regular, and if the hardware supply is disrupted, the project's work progress will be stopped. So final measurement for this particular uncertainty will be resource, anticipated, and showstopper.

Let's measure the same event in the developed hypothetical flowchart (Figure-12) from the RESPONDRONE and ASSISTANCE analyses. If we take the hardware supply disruption due to

military conflict in Turkey as an input in the flowchart, it results in “uncertainty” in the first decision box. In the subsequent decision box, we find that the uncertainty is external. In the next one, we find that likelihood is high as the military conflict has already started, and then we check the impact level, which is also high. In the following decision boxes, we see that the uncertainty is treatable, and there are actionable mitigation measures. So we can implement the uncertainty treatment procedure, which in this case will be having a contract with another supplier in the event of such an emergency.

Interestingly, the three-dimensional matrix model from the O'Connor and Rice (2013) paper and my hypothetical process flowchart from the analysis of RESPONDRONE and ASSISTANCE illustrate the same result in identifying uncertainty and measuring their impact. Both models illustrate homogeneity in the process with each other. Therefore, both models can provide a project team with better impact measurement of uncertainties in the complex paradigm of radical innovation projects.

Navigating Uncharted Water: Evaluating Tools and Frameworks for Uncertainty Treatment
So far, we have built a solid understanding of the critical areas of uncertainty and tools to identify and measure the impact of uncertainty in radical innovation projects. The final research problem of this thesis is to find out the combinations of tools and frameworks for better uncertainty treatment. In pursuing this, I will first discuss what worked for RESPONDRONE and ASSISTANCE and then lean into existing literature for the academics' suggestions. The knowledge extracted from the analysis of this research and existing literature knowledge will be the base for the proposed unified toolbox for uncertainty treatment.

As discussed before, the complexity of uncertainty in a radical innovation project is so nuanced and vibrant that a niche approach for a specific framework or methodology can not cover all aspects. Now one can ask why? I will present an example of a carpenter to illustrate the nuances of the complexity and why we need a toolbox rather than a framework. Let’s imagine a carpenter going to work every day. When he goes to work daily to cut, shape, and install building materials, he does not use one tool to do all the jobs. He uses a chisel set, clamp, coping saw, hammer, joiner’s mallet, marking knife, nail puller, sharpening tools, tape measure, etc. The point is that he uses different tools based on the need and situation. There is no one magical and universal tool that can address all the needs of building construction. Like carpentry, a radical innovation project also needs different tools to handle different uncertainties in different areas.

Regarding RESPONDRONE and ASSISTANCE, both projects had a dynamic approach toward uncertainty treatment in different areas. Cross-functional communication, awareness raising, robust yet fluid governance structure, team collaboration, agile project management, effective risk management, end-user involvement, and project leadership have surfaced repeatedly across both projects when addressing uncertainty treatment. None of the treatment tools have been specified

for one uncertainty area. Tools had dynamic usability in different areas of projects simultaneously. For example, whenever technical project teams anticipated any technical uncertainty, the robust governance structure indicated them to inform the work package leaders. The risk manager would be informed if it were out of their capacity to address. If the issue were out of his capacity to solve, then the PIC (Project Implementation Committee) would be involved. So, the robustness of the governance structure established explicit power dynamics of who does what. At the same time, robustness did not increase any rigidity in the structure. The process was fluid because of the emphasis on cross-functional communication and ambidextrous project leadership. At the same time, the project team also had the flexibility to look for alternative ways to handle the uncertain situation, and new ideas could be generated quickly and shared because of the collaborative and knowledge-sharing atmosphere. It illustrated how one uncertainty needed different tools simultaneously for better treatment and management.

Let's lean into the existing literature for more uncertainty treatment tools. One of the most emphasized tools identified for uncertainty treatment in radical innovation projects has been flexible project management procedures (Alexander & Van Knippenberg, 2014; McDermott & O'Connor, 2002; O'Connor & Rice, 2013; Robbins & O'Gorman, 2015). It has surfaced repeatedly over time that routinized processes and procedures hinder innovation projects' success. Another highlighted tool for uncertainty management is project leadership (Klingebiel & Rammer, 2014; McDermott & O'Connor, 2002; O'Connor & Rice, 2013; Oconnor, 1998; Thanasopon et al., 2016; Van Riel et al., 2004). Uncertainty is complex, and decision making under uncertainty is much more intricate. Therefore, the right project leader with naturalistic decision-making capability is essential. The complexity of uncertainty requires urgent decision making. At that time, project leaders could not always take a classical decision-making approach to option calculation and elimination. They rely on their heuristic for pattern matching and mental simulation to properly judge an uncertain situation (Klein, 2008). In addition, their selectiveness capacity also minimizes resource allocation-related uncertainties; agility ensures flexibility and dynamic capacity building among team members (Klingebiel & Rammer, 2014; Oconnor, 1998). Effective risk management procedures are also significantly crucial in uncertainties. It minimizes the probability of many associated uncertainties and thus ensures project success (IRGC, 2017).

Proposed Unified Toolbox for Uncertainty Treatment

From the analysis of this research and knowledge gathered from the existing literature, it is evident that the complexity of uncertainty can not be contained; it can only be better treated. However, the treatment of uncertainty is multi-faceted, with different variables acting simultaneously. Therefore, the treatment approach is also divergent and non-sequential. In this proposed unified toolbox, we will incorporate all the identified treatment tools from the analysis and literature. It will give us different lenses and multi-faceted strategies to treat uncertainty better. Lastly, we will take one example of uncertainty and test the toolbox to observe how it treats uncertainty.

The identified tools for uncertainty treatment are- cross-functional communication, awareness-raising mechanism, robust yet fluid governance structure, team collaboration, agile project management, risk management procedures, project leadership, naturalistic decision-making capability, team-based dynamic shifting capability, and selectiveness mechanism. The following figure will give us a better visualization of the toolbox-

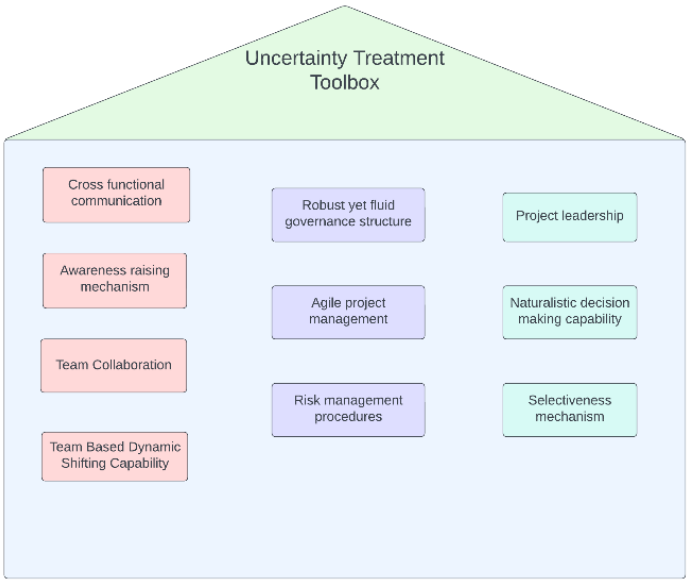

Figure 14- Unified Toolbox for Uncertainty Treatment

Let's test a hypothetical uncertainty now to observe the performance of the toolbox. For example, a software development team suddenly gets the news that the current version of the development platform will go obsolete after the next release in 2 months; however, their development work will need at least six months. As this is an external uncertainty, first, the team will need an awareness-raising mechanism to share the news. First, the concern will be forwarded to the project leader. He will then sit with his team to brainstorm this scenario's possible consequences and solutions. The project team communicates that it is impossible to complete the work in two months with the current team size. However, they offer several alternative mitigation strategies that might be helpful. They can hire more developers to push the development work in two months, they can shift the codebase into a new platform, but it will delay the project delivery time, or the company can talk with the platform vendor to keep the current version accessible for them till the work is finished; however, it will impact the project budget significantly. The project leader can quickly raise the concern to the appropriate parties in the different levels of the governance structure. The fluidity will help address the concern quickly, and the robustness will clarify who can make the final call. After all the discussion and risk analysis, it was decided that the migration to the new platform would happen now, and project delivery dates would be extended. The project team will

now use their dynamic shifting capability to move the codebase to the new platform and familiarize themselves with the new coding environment.

Different toolbox elements can give the project team and leader the flexibility to act fast to address the uncertainty and find a solution. Therefore, we can conclude that a toolbox approach ensures better uncertainty treatment. However, there is always scope for adding further elements to the toolbox. It provides the opportunity for further research on the topic to make the toolbox more resourceful.

5.3: Unexpected Findings: An Intriguing Twist

Two puzzling aspects – the role of end-user involvement and the impact of standardized rules and procedures have emerged from this study that contradicts the idea from the existing literature. Existing literature over time repeatedly suggested that customer input drives a product into an incremental project rather than a radical one. It also hinders innovation (Oconnor, 1998; Robbins & O'Gorman, 2015; Van Riel et al., 2004). The rationale behind this idea is that the radical innovation project aims to bring something disruptive to the market. Such disruptive ideas are generated by the innovators and creators, not the end-users and customers. Therefore, their input will not add value to the project's progress. In addition, literature also suggests that traditional practices with standardized rules and procedures are obsolete in handling the uncertainty level in radical innovation projects, and too much routinization of the project management processes hinders project innovation rather than fostering it (Alexander & Van Knippenberg, 2014; McDermott & O'Connor, 2002; Oconnor, 1998). The logic is that radical innovation projects are more of a creative process than a company's standard day-to-day operations or incremental projects. The project team needs to generate new ideas, test them, fail them, and keep them going until the magic happens. This approach needs the flexibility to move fast, multi-direction, and breathing space to make mistakes. Therefore, standardized rules and procedures can diminish the creative mindset required for a radical innovation project.

Contradicting Perspectives: End-User Involvement

As mentioned before, existing literature suggests that end-user involvement in a radical innovation project can hinder project innovation and drive it into an incremental one. However, from the analysis of RESPONDRONE and ASSISTANCE, it is evident that end-user involvement was a critical success factor for both projects. From the project's initiation till project closing, representatives from the first responder industry and field operators from emergency operations were actively engaged with the project team to share their knowledge of operations. They gave the project team feedback on the viability and reliability of their developed product. Why is this contradiction between the analyzed case studies and the existing literature? I reflect that this contradiction is merely an additional perspective to conceptualize the nuances of a radical innovation project. I argue that whether the end user involvement is a success factor or an obstacle depends on the type of the project, the target industry, the demography where the product will be

used, and also on which phase the end user involvement is happening. For example, in a niche industry like emergency response, innovators and creators can not identify all the requirements of a product used in field operations of extreme scenarios. They can do all the research, collect all the data, synthesize it, and still determine whether the developed product is viable; it can only be validated by people from the industry. No matter how technically developed a product is, it will lose its value if it creates more complexity in the field-level operation than in assisting it. A fleet of drones for emergency operations and a new mobile phone with exciting capabilities do not work in the same demographic. It is also essential to identify in which phase the customer involvement is happening. I agree that in the initial idea generation phase, customer involvement does not add value to any radical project, whether a consumer product like a mobile phone or a complex operational product like RESPONDRONE and ASSISTANCE. Idea generation is the responsibility of the innovators and creators. They must develop a disruptive technological idea to address a complex challenge or penetrate a new market. However, when the industry is specialized, end-users are limited, and the product usage demography is complex, end-user involvement can help the product development in the right direction and help the project move faster in the later phases.

Unraveling the Paradox: Standardized Rules and Procedures

Another puzzling aspect in this thesis is the role of standardized rules and procedures in an innovation projects uncertainty treatment and success. Existing literature strongly argues that the practice of standard rules and procedures hinders a radical innovation project's success and is obsolete in handling uncertainty nuances. However, the analysis of RESPONDRONE and ASSISTANCE reflects that throughout the project lifecycle, they had a robust governance structure, standard communication, project management, and ethical procedures to be followed by all the project members. As discussed in the previous section, though the governance structure was robust, it ensured fluidity for quick response to uncertainty. There was a reflection of some standard procedures and practices in every part of the project to specify who would do what, what to do in a particular scenario, how regular communication and progress reporting would happen, etc. Now the question is, why such a contradiction? I argue that this contradiction gives us a new perspective on radical innovation projects through the lens of project size and complexity. Building a new software or mobile app with 20-40 developers employed within the company and building a complex distributed system of drones and a VR (Virtual Reality) training platform for emergency operations with a globally located team while facing a pandemic is not the same.

I agree that innovation needs some creative chaos, but it cannot replace the role of a standardized procedure in large-scale, highly complex projects like RESPONDRONE and ASSISTANCE. Even the innovative chaos must be systematically controlled among the right people in such a project. For example, RESPONDRONE had a kickoff meeting in the project's initiation phase. The meeting participants were the project team and the first responders of emergency operations. The project team shared their findings and product ideas with the first responders. They shared their feedback

on what would work and what would not. It was a three-day event with many discussions, arguments, and corrections. This meeting was the reflection of the necessary innovative chaos. The meeting was so important that it was rescheduled based on the first responders' availability to ensure their participation. It helped the project team find the proper requirements to add to the project's planning. However, it did not replace the formal communication and reporting processes throughout the project lifecycle. Innovative chaos was a time-controlled procedure that fostered innovative ideas for project development.

5.4: Closing Remarks

This discussion chapter has provided constructive insights into the treatment of uncertainty in innovation projects. The identified problematic aspects in the literature review highlighted the complex nature of managing uncertainty, research gap emphasized the lack of a unified uncertainty treatment toolbox and guided the analytical direction of the study. Through qualitative case studies of two EU projects (RESPONDRONE and ASSISTANCE), this chapter has investigated the areas of uncertainty, measured their impact, and proposed a unified toolbox.

The puzzling aspect of the case study findings is the contrasting role of end-user involvement and standardized rules and procedures. While the literature suggested that they hinder project progress, the case studies demonstrated their positive influence on project success. End-user involvement fostered user-centered design and generated enthusiasm among stakeholders, while standardized rules and procedures provided a solid foundation for decision-making and facilitated collaboration within project teams.

It challenges conventional wisdom and highlights the importance of context-specific factors in managing uncertainty. The implications extend beyond case studies, emphasizing the need for tailored approaches and further research into the optimal level of end-user involvement and the balance between flexibility and standardization in different innovation contexts.

To summarize, this chapter contributes to the existing literature by offering insights into the treatment of uncertainty in innovation projects. It identifies problematic aspects, proposes a unified toolbox, and challenges preconceived notions about end-user involvement and standardized rules and procedures. These findings provide valuable guidance for project leaders and practitioners navigating the complexities of innovation.

6: CONCLUSION

The treatment of uncertainty in innovation projects is a complex and challenging endeavor. This study aimed to find the best approach to address this complex phenomenon. First, the study looked into the existing literature to gain perspectives on innovation, risk management, and decision-making. They all had an interconnected relationship in treating uncertainty in innovation projects. Innovation perspectives from the literature synthesis helped to understand the problematic aspects of uncertainty treatment in innovation projects like long incubation period, standardized rules and procedures, nonexistent market and market unfamiliarity, fuzziness in the fuzzy front end, project team, and their dynamic shifting capabilities and choosing a right project leader for overall project management. Risk management perspectives helped us understand the best practices in innovation projects. They provided us with analytical insight into how risk and uncertainty management differ and whether any components of risk management could be replicated in uncertainty management. The combinations of these perspectives helped us to identify the research gap in the field of uncertainty treatment in radical innovation projects and drive the analytical direction of this study towards finding a better solution to address some of the critical aspects of uncertainty treatment like identification of the uncertainty area, measuring the impact and developing a unified toolbox that covers complex nuances of uncertainty treatment.

The investigation approach in this study was a qualitative multiple-case study design. The case study used a secondary data source (RESPONDRONE and ASSISTANCE project reports). The selected case's large-scale complexity and dynamics were appropriately nuanced to provide valuable perspectives on different uncertainties and their treatment approaches in radical innovation projects. The thematic analysis method was employed to extract meaningful insights from both case studies. It helped us find repeated patterns from both themes, code them, and collaborate the same genre of codes into a group to create a theme that addressed the research phenomenon's complexity. Five themes surfaced on the better treatment of uncertainty from the thematic analysis- technology and innovation, communication and collaboration, adaptive project management, stakeholder engagement, and risk management. The different elements from the surfaced themes helped both selected case studies optimize their uncertainty treatment process and drive the project toward success.

The study was centered around a key research question of how to better treat and navigate the unknown territory of uncertainty in a radical innovation project. It was further investigated in light of three more questions: the critical areas of uncertainty, how to identify and measure it, and what combinations of tools and frameworks can better treat uncertainty in radical innovation projects. The identified themes and knowledge from the literature synthesis were used to address the research questions of this study. It unfolded some exciting perspectives and approaches for uncertainty treatment. Four key areas (market, technical, organizational, and resource) of uncertainty in a radical innovation project were identified, and an impact measurement process flow got developed to conduct the impact assessment of uncertainty in any innovation project.

Finally, a unified toolbox for uncertainty treatment was proposed, integrating the case study's analytical perspectives and mined knowledge from the literature review. In addition, two puzzling aspects (end-user involvement and standardized rules and procedures) of uncertainty treatment emerged from the study. While the findings from the results indicated that the mentioned factors played a crucial factor in the uncertainty treatment and project's success for the selected cases, existing literature considered them to hinder project innovation. Some analytical reflection was added to illuminate this dilemma and provide better perspectives.

On the treatment of uncertainty, the first burning question for any innovation project team is what the most common and critical areas of uncertainty are. This study reveals that though uncertainty has a limitless boundary, not all happen simultaneously in the same project. So, rather than identifying them individually, the study aimed to discover the most common areas of uncertainty generation in a radical innovation project. The analysis of the findings and the literature synthesis narrowed the uncertainty into four critical areas- market, technical, organizational, and resource. Uncertainties in these four areas can throw a project off balance and hit the wall.

The second critical concern for a project team is how to conduct an uncertainty impact assessment. The complexity is in the subjectivity of the concept of uncertainty. The uncertainty reflects the unknown, something that has never happened before. It is tough to do a mathematical analysis of such a subjective topic with probability and consequence matrix. This issue was investigated thoroughly in light of literature and observations from the study. Existing literature suggested a three-dimensional matrix model for impact assessment. A process flowchart for uncertainty impact assessment got developed from the critical observation. Both of the models were tested and projected satisfactory results.

The final vital query is what combination of tools can systematically treat the maximum areas of uncertainty. It has been evident from the existing literature that different project teams use different kinds of approaches toward uncertainty treatment. It necessitates the urgency of a unified model that can be a first step towards a systematic yet nuanced approach to better uncertainty treatment. From the knowledge mining of the literature and the analysis of the reports, ten tools were incorporated into the uncertainty treatment toolbox. The purpose of a toolbox approach is so that the project team and project leaders can use whatever tool is necessary based on the context. The toolbox also provides flexibility to add any new tools based on the need of the project. The toolbox was tested with hypothetical uncertainty scenarios and provided satisfactory results.

The thematic analysis of the two projects through publicly available project reports provides us with five key themes for treating uncertainty in innovation projects. The key themes are- technology and innovation, communication and collaboration, adaptive project management, stakeholder engagement, and risk management. Rapid technical adaptation, integration, and innovation management are essential to better treating technical uncertainty. Cross-functional

communication, proactive approach, team collaboration, and knowledge sharing create a collaborative and positive atmosphere, making the project team more resilient and dynamic. Agile project management methodology, result-driven project planning, dynamic leadership, and project planning keep the project on track and foster the process of achieving project milestones iteratively and incrementally. Identifying appropriate stakeholders from the early phase of the project, involving them, getting feedback, and creating a collective mindset move the project towards the right direction with clear objectives and goals. Finally, identifying and assessing the critical risk factors, implementing mitigation strategies when necessary, and monitoring and controlling the risk factors remove sudden project impediments. It also reduces the uncertainties associated with many risk factors and thus ensures project success.

The importance of uncertainty treatment in a radical innovation project knows no bounds. Because of the disruptive nature of radical innovation projects, they are exposed to many potential known risks and threats during their lifecycle, which significantly impacts the project's success. On top of that, if every area of uncertainty can hinder a project's progress and throw it off its balance, then the whole point of initiating such a project becomes moot. Organizations need radical innovation projects for market growth and long-term financial sustainability. The criticality of uncertainty works as a minefield in the project's success journey. Therefore, the project team needs to learn how to navigate the project through the landmine with their stewardship and necessary uncertainty treatment tools.

Though the importance of this research is significant, and it has been designed following all the rigorous procedures of conducting qualitative research, it has some limitations. This study's two most significant limitations are the lack of data triangulation and variety in the case selection. It is insufficient to illustrate the generalizability of a research phenomenon just by studying two big-budget cases through publicly available reports. It is essential to mention that many complex nuances of the selected cases might be missing due to a lack of access to other confidential project reports and triangulating the data to ensure validity. Also, though the proposed process flow and toolbox have been tested in the study with some hypothetical uncertainty scenarios, it is not a good enough indicator that how its performance in real-life uncertainty treatment will be. More extensive toolbox testing and process flow development are required to justify its performance.

This study can be a stepping stone toward further research in uncertainty treatment. The further research of this study can be a more context-specific approach towards uncertainty which will equip a project team with better and broad perspectives to understand the complex phenomenon of uncertainty. The potential findings from the research can also be used to develop a more comprehensive and resourceful toolbox that will provide better uncertainty treatment and minimize the impact.

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