MANAGEMENT OF RISK IN DELIVERING COMPLEX RESEARCH AND DEVELOPMENT PROJECTS

A Thesis Submitted by

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ABSTRACT

Risk management continues to be a major feature of the project management of large construction, engineering, technological, and research and development projects in an attempt to reduce uncertainties and to achieve project success. Managing risk is an important task in identifying and quantifying the uncertainties inherent in complex research and development projects. Managing such risks better aids minimization of threats and maximization of opportunities in such projects, and therefore better assists such projects to realize their potentials while minimizing exposure to potentially adverse outcomes.

Working in Research and Development Centre of the United Arab Emirates Armed Forces is challenging as new developments are continues since the tasked projects include a high degree of risks which may potentially interfere with successful completion of these projects. Therefore, a scientific approach and developing process improvements for identifying and managing the risks that exist in these projects are needed within the context of the UAE environment.

Thus, this study outlines a research of *Management of Risk in Delivering Complex Research and Development Projects*. The research is based on a real case study focusing on risk management in the *Research and Development Center of the United Arab Emirates Armed Forces*. Although managing risks of R&D environments have been studied for many years, researches on risks associated with R&D of military environments are still relatively low and almost scarce in the UAE, giving importance to such a study to fill in the literature. This will fill a void in the literature, where current studies fall short of studying these risks in the UAE Military. The benefits yield a theoretical framework for managing risks that fits R&D in the UAE military and similar R&D environments.

The thesis highlights the research purpose, objectives, and motivation together with the statement of the problem, the current status of the proposed research organization, and the research questions. This is followed by a literature review and theoretical background of risk management in general as well as in R&D, military, and UAE, and, consequently, the significance of the proposed research. Then, a brief of methodology aspects along with

the research ethics is presented. The obtained results and findings are then presented followed by its discussions, and, therefore, yield to highlight the conclusion and recommendations grasped.

The main research findings grasped that the risk factors along the risk mitigation methodologies of complex research and developments projects of the armed forces tend to be as same as with civilian R&D projects although there is always a place for new and updated practices and methodologies. The research results and discussions led to the development of a risk model for the UAE R&D projects in the environment of the armed forces.

This risk model, the results, and the limitations of this study may provide new openings to interested organizations, students, and researchers in future qualitative and quantitative studies to test, update, and generalize the model to the wider R&D community in the UAE.

KEYWORDS

Project, Complex Project, Project Management, Risk Management, R&D, Armed Forces, UAE.

CERTIFICATION OF THESIS

This Thesis is entirely the work of Badr Alshehhi except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

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PUBLICATIONS

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ABBREVIATIONS

The table below describes various acronyms and abbreviations that have been used throughout this thesis.

AF	Armed Forces
APF	Adaptive Project Management
APM	Association for Project Management
CE	Concurrent Engineering
COTS	Commercial Off The Shelf
DEMATEL	Decision Making Trial and Evaluation
EDIC	Emirates Defence Industries Company
EM	Engineering Management
FMEA	Failure Mode & Effect Analysis
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
HR	Human Resource
ISM	Interpretive Structural Modelling
ISO	International Organization for Standardization
KPI	Key Performance Indicator
NATO	North Atlantic Treaty Organization
NIST ATP	National Institute of Standards and Technology Advanced Technology Program
NPD	New Project Development
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMP	Project Management Plan
PPM	Project Portfolio Management

PRINCE2	Projects IN Controlled Environments
PRM	Project Risk Management
QUT	Queensland University of Technology
R&D	Research and Development
RDC	Research and Development Center
RDCUAEAF	Research and Development Center of the United Arab Emirates Armed Forces
RFMEA	Risk Failure Mode & Effect Analysis
RM	Risk Management
RMF	Risk Management Frameworks
RMP	Risk Management Plan
SDLC	Software Development Life Cycle
S&T	Science and Technology
SPS	NATO Science for Peace and Security Program
STO	NATO Science and Technology Organization
SWOT	Strengths, Weaknesses, Opportunities and Threats
TOPSIS	Technique for Order Preference by Similarity to the Ideal Solution
TRL	Technology Readiness Level
UAE	United Arab Emirates
UAE DOD	UAE Department of Defense
UAEAF	United Arab Emirates Armed Forces
UK	United Kingdom
USA	United States of America
USQ	University of Southern Queensland

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1. INTRODUCTION

1.1. Overview

Project management is a framework to successfully develop new services, products, processes and in the form of a mechanism for successfully applying change within the organization. There are primarily ten knowledge areas that are needed for successfully executing a project (Snyder, 2013). Risk management is one of these areas that can be applied to the process groups of Initiating, Planning, Executing, Monitoring/Controlling and Closure. As per the Project Management Institute (PMI), project risk is an uncertain condition or event that has a negative or positive effect on the objectives of a project (Hayes, 2016).

There are uncertainties and risks at every stage of Research and Development (R&D) projects through the product lifecycle (Gassmann and Han, 2004). Therefore, management of the risks is an important challenge for the R&D project managers (Liu and Han, 2014; Moehrle and Walter, 2008). In addition, the close linking of project risk management with the success of the project is acknowledged across the world (Perera et al., 2014). This emphasizes the role of effective risk management for increasing the success rates of the R&D projects. Uncertainties in the R&D projects from a variety of sources can possibly antagonistically influence the success of the projects (Jalonen, 2011; Sicotte and Bourgault, 2008). Apparently, the expansive number of sources of such uncertainties infers countless project risks along with the adverse effects. Ignoring various uncertainties and risks involved with complex R&D projects are directly linked with lower success rates of projects (Van Zyl, Du Preez, and Schutte, 2012). To enhance the success rates of such tasks, the project managers are required to apply particular strategies and methods that will enable them to recognize and deal with the uncertainties as adequately as possible.

Risk management keeps on being a noteworthy element of the field of project management for extensive development, building, and innovation. R&D projects extend helping hand to manage the uncertainties and for achieving project success. Risk management is a critical undertaking in recognizing and evaluating the uncertainties intrinsic in complex R&D projects (Carbone and Tippett, 2004). Management of such

risks better guides minimization of the risks and maximization of the associated opportunities in such undertakings. Thus, it assists in complex projects in realizing their potential to minimize exposure to the prospective adverse results.

Several studies have been conducted for the identification of distinct risk management techniques and tools. These tools can be used by New Project Development (NPD) and R&D project managers for the management of uncertainties in an effective manner (Teller, 2013). Studies have put forward two main risk types, namely, unambiguous risks and ambiguous risks. Unambiguous risks are those risks that are related to consumer marketing and acceptance while ambiguous risks are the ones that take place when the difference of opinion exists in relation to the project management and the organization. In view of this, these studies set forward a rundown of prescribed activities that the R&D project managers could use to aid to better recognizable proof and administration of basic project risks. The studies recommend that project supervisors should consider ambiguous risks since they can possibly affect the project's success.

Academic literature additionally distinguished two principal kinds of risks in R&D projects (Van Zyl, Du Preez, and Schutte, 2012). These risks have been classified as external and internal. The risks which initiate from the organizational, technological and operational aspects of the project have been grouped as internal. On the other hand, the risks that emerge from the supplier and market aspects have been categorized as external.

Risk management continues to be a major feature of the project management of large construction, engineering, technological, and research and development projects in an attempt to reduce uncertainties and to achieve project success. Managing risk is an important task in identifying and quantifying the uncertainties inherent in complex research and development projects. Managing such risks better aids minimization of threats and maximization of opportunities in such projects, and therefore better assists such projects to realize their potential while minimizing exposure to potentially adverse outcomes.

Thus, the focus of this study is on the management of risk in delivering complex research and development projects within the United Arab Emirates Armed Forces. Even though the management of risks related to the military environments has been studied for several years, studies on the risks pertaining to research and development of the military

environments are still comparatively low and almost negligible in the UAE. This gives value to such type of study for filling in the literature. The research is based on a real case study focusing on risk management in the Research and Development Center of the United Arab Emirates Armed Forces.

This chapter highlights the research purpose, objectives, questions, problem statement, and motivation together with the implications of the research to theory and the wider community of practice. This chapter sets forward the basis upon which the literature review rests, as well as the methodology, results, discussion, and conclusion. Finally it explores further the components and information about the findings of this scientific quest in the field of project risk management practices in the UAE.

1.2. Focus of the Study

This section will explain the scope of the research at hand, its purpose, objectives, and the rationale behind the researcher's interest in seeking this scientific quest.

1.2.1. Research Scope

Identifying project risk management practices within complex research and development projects in the United Arab Emirates Armed Forces will form the boundaries of this research. The vicinity of the United Arab Emirates Army will form the physical boundaries of this research. Project managers, military leadership, and customers of these intended complex projects will be involved in the study. The researcher had reviewed risk management literature and identified the gaps that support the quest of this research effort.

1.2.2. Research Purpose

The purpose of this study is to analyze the underlying risks which are involved in the complex research and development projects within the working environment of Research and Development Center of the United Arab Emirates Armed Forces (RDCUAEAF). The aim is the identification and construction of an R&D risk management framework, which reflects the effect of risks on the large-scale R&D projects in the UAE environment. The understanding of the stakeholder's perception of the risk

types recognized in the development work is at the center of the research so as to develop the suitable risk framework.

UAE is observed to be a unique environment wherein socio-economic, religion, tradition, and culture impact work environments. The effect of such elements, as per the perspective of the stakeholders, along with the elements that arise from their viewpoints, have constituted the foundation elements to the development of a risk framework for the study. On the basis of this analysis, the adoption of this framework will result in the generalization of the outcomes for the desired population.

1.2.3. Research Objectives

There are five main objectives of this research as following:

- **Objective 1:** The first objective is to identify the challenges and risks which have been occurring within the various projects developed in the RDCUAEAF.
- **Objective 2:** The second objective is to explore stakeholders' views on how to manage these risks, what socio-economic determinants affect their decisions when managing these risks, and what factors they think have an impact on the risk management processes by noting their point of views in interview sessions.
- **Objective 3:** The third objective is to analyse the collected data and extract emergent themes in order to be used to achieve the fourth objective.
- **Objective 4:** The fourth objective will be developing a framework of R&D Risk management practices.
- **Objective 5:** The fifth objective is to recommend a risk management process to identify, measure, and control these risks, and apply improvements to the selected risk management processes. The recommendation will draw the lessons learned regarding the identification and management of the risks in similar complex projects and its applicability in similar departments and organizations in the Armed Forces, the UAE, and the region.

1.2.4. Study Motivation

The priority goal of most military R&D investments is to enhance warfighting capabilities, which takes into consideration such components as humans, organizations, and equipment. These capabilities range from something as simple as the ability of a soldier to fly an Unmanned Aerial Vehicle, to something as complex as the ability to develop a Future Combat System and to participate in joint urban operations.

Although military innovations always remain confidential (Paret, 1989), it no longer remains the privilege of a handful of industrialized, wealthy nations, and its belief that military's R&D will release and persist a new wave of proliferation (SIPRI, 2018). R&D activities can be characterized as complex, interdependent, responsive to sudden research environment changes, and heavily reliant on expert judgment in order to maintain quality, relevance, and performance (Energy Facility, 2010). Process improvement is historically considered as a critical element to the success of an organization or business.

Therefore, the motive for this research, based on data collection and analysis, is the researcher's quest to discover and develop process improvements for identifying and managing risks that exist in the Research and Development Centre (RDC) projects in which it can be applied to similar complex projects in this environment and other related environments and organizations. The researcher, being part of this organization, has witnessed a need for such inquiry, that will not only lead to an improved risk management practice and prompt an enhanced hazard administration process, but will also save precious resources, expertise, and expenditures by minimizing threats and maximizing the success of such projects. The researcher opts to make a scientific and practical contribution not only to the UAEAF but also to offer his knowledge of shared and collaborative learning with other government agencies throughout the UAE and the Gulf Cooperation Council (GCC) region. To conduct this research effectively, it is important for the researcher to be among the main UAE subject matter experts who are managing risks at this level in complex projects in a country with scarce human resources but that lack the proper specialization in the field.

1.3. Statement of the Problem

1.3.1. Organization Background

The Armed Forces (AF) of the UAE are based in the capital of the UAE, Abu Dhabi. The AF has primary responsibility for the defence of all the seven Emirates (Wikipedia, 2018) in addition to participating in the United Nations peacekeeping operations. The UAEAF has grown significantly over the years and due to its modernizations efforts, it has acquired the most modern weapon systems, from a variety of foreign countries, mainly France, USA, and the UK (Wikipedia, 2018). Meanwhile, the UAE has begun to produce a greater amount of military equipment in a bid to reduce foreign dependence and help with national industrialization (Wikipedia, 2018). In 2005, the AF established a new unit, the RDC, to handle the R&D concerns of the AF. Over the years, the RDC has been going through development and its structure and organization has been changing in order to amass new capabilities and adapt to new global technology trends.

Consisting of approximately 200 personnel, the RDC is one of the most diverse engineering and scientific research organizations in the UAE and especially so within the UAE Armed Forces. The mission of the RDC is to provide scientific knowledge, technology, and expertise in engineering and environmental sciences in support of the UAEAF to make the Armed Forces safer, better, and up-to-date with ever-changing technology.

The RDC's vision is to bring technology and innovation to the country by bringing research and development into potential areas which are important to the advancement of the country and welfare of the people, in addition to aiding the development of a more diverse economy and away from one that is dependent on oil. RDC is continuously cooperating with local and international industries, academic institutes, as well as with private and government sector partners to implement new ideas that will help the country in general and the Armed Forces specifically.

Furthermore, the RDC conducts its main mission, namely doing R&D for UAE's military in support of the soldiers, military installations, and the Corps of Engineers' civil works mission. Since RDC is the first R&D organization in the UAE, it also provides these services to UAE federal agencies, state and municipal authorities, and with local and foreign industries through innovative work agreements.

1.3.2. Organization Current Status

Working in RDCUAEAF is continuously challenging as new requests, developments are in daily demand, and its associated projects require a variety of resources and expertise. Further, they include high degrees of uncertainties and risks which may potentially interfere with successful completion of these projects. Therefore, potential risks ascend which threaten the successful completion of the projects, and in some cases, these projects fail to deliver their basic outputs due to these risks.

One of the typical examples of the RDC complex projects is that UAEAF has purchased a huge fleet of military vehicles with basic structures without any installed configurations. UAEAF tasked the RDC, through an arrangement with each end-users of these vehicles, to integrate different types of configurations consisting of different kits and armaments. Specific configurations were installed for each set of these vehicles. For example, for a predetermined number of these vehicles, RDCUAEAF has installed the following equipment:

- Different types of communication systems from multiple international manufacturers.
- Different types of weapon systems, from different countries.
- Lots of basic mission-related equipment such as display units and munitions which are either sourced locally or from overseas.

As a result, RDC has been placed in a situation of high uncertainty with very special, expensive, and complicated military vehicles which have complex subsystems, tasked with R&D activities to integrate different system configurations of different standards from different countries, and communicate with end-users, suppliers, subcontractors, licensing and legal authorities, and team each with different countries, cultures and perceptions, to deliver efficient and reliable products that meet the expectations of the UAEAF. These complexities form risks that need to be addressed in such projects.

It is noteworthy that the lower rate of adaptation of formal Project Risk Management practices leads to ineffective project performance (Mojtahedi, Mousavi and Makui, 2010). There are many variables used for project risk management studies including tools, techniques, structure, perspective, outputs, goals, agility and adaptability

(Mikkelsen, 1990). However, the presence of different risk management guidelines, frameworks, and standards do not provide any kind of assurance that the organizations will apply their processes and principles adequately. Many project risk management processes possess rigid frameworks and thus project managers cannot adapt to the project conditions effectively, and/or observe them as being too costly or complex, using a weak structure that lacks innovative techniques and tools for increasing the depth of the analysis. The UAE has been fairly recent player in the field of complex projects, with the military taking the lead initiative in this effort.

Given the former issues with risk management for complex projects, there is a lack of understanding of project management practices and culture to address these risk factors and the region-specific factors that impact upon risk management practices within the UAE.

Therefore, a further look into improving the processes and systems of identifying and managing the threats that exist in these projects and the projects' environment is required. There is a need for a scientific approach, to uncover user perception of risks associated with such complex endeavour, and the elements that impact the management of such processes within the context of the UAE environment. This will fill a void in the literature, where current studies, to the best of the knowledge of the researcher, fall short of studying these risks in the UAE Military. The benefits and recommendations will yield a framework of managing risks that fits UAE and neighbouring Gulf countries which share culture and traditional values.

1.4. Research Question

1.4.1. Main Question

Are current RDCUAEAF risk management strategies adequate and sufficient for the management of complex projects in a military research organization?

1.4.2. Sub-Questions

- **RQ1:** What are the main risk factors, from the point of view of impact and likelihood of occurrence, in the undertaking and delivery of current RDCUAEAF complex projects?

- **RQ2:** What is the effectiveness of these risk factors with respect to the completeness, accuracy, validity and correctness of the execution, testing and delivery of complex projects undertaken by RDCUAEAF?
- **RQ3:** Are current RDCUAEAF procedures and practices adequate for managing the risks in complex projects in a significant military research organization?
- **RQ4:** What innovative risk management approaches can the management of RDCUAEAF use to effectively manage and control the risks associated with the undertaking of complex projects in a military research organization?

1.5. The Contribution of the Research

The importance of this study stems from the important impact of the results and recommendation have on the community of practice within the project management profession. The research can make a probable contribution to the body of knowledge, the practice of project risk management, and a regional impact as following:

1.5.1. Contribution to Theory

This study contributes to the body of knowledge in project risk management by filling the gap in the literature when it comes to risk management practices of complex projects within the UAE Armed Forces. The findings suggest best practice examples and approaches gleaned from the academic and industry literature of risk management performance of complex R&D projects.

1.5.2. Contribution to Practice

The research at hand contributes to the practice of risk management by establishing a framework of risk management practices in the UAE, where local and cultural factors have an impact on those factors. Also, the study recommendations for best practice when it comes to project risk management serve as a guide for military organizations in the UAE for successful implementations of both current and future project undertakings. The recommendations draw upon the lessons learned regarding the identification and

management of the risks in similar complex projects and its applicability in similar divisions and organizations in the Armed Forces, the UAE, and the region.

Furthermore, the study anticipates that the findings of this focused research will provide more perceptive and practical solutions for the stakeholders of complex R&D projects in the domain of risk management as follows:

- It will assist the RDC higher management to integrate and align the risk management methodologies within the organization's strategies, policies, and practices.
- It will enable RDC project managers to identify, at an early stage, and manage risks through the project lifecycle.
- It will enhance customer's awareness and participation in innovation to reduce the risks of unmet customer needs.
- It will assist other organizations in UAE, both in government and private sectors, to identify and manage risks associated with their projects and environments.
- It will assist multinational private or state-sponsored organizations in the army and defense industry to understand the nature of risks associated with R&D projects carried in the Armed Forces within the UAE.

1.5.3. Contribution to the Wider Community

This study has implications that can be applied not only within the UAE but across all the other GCC countries including Saudi Arabia, Bahrain, Oman, and Kuwait. The rationale behind this is that many of the cultural and social factors exploited in the study are shared between these countries. Thus, this study should give other Armed Forces personnel in the GCC countries a picture of the factors impacting upon complex R&D projects and best practice and procedures to manage such risks.

1.6. Summary

UAE risk management terminology has been introduced with a focus on the social and local practices to manage these risks. The focus of the study showed the main aims and purpose of the current research as well as the rationale behind this research. The

current research problem has been presented followed by the research question and the benefits of the study to theory and practice. The next chapter will shed light on risk management literature in complex projects.

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2. LITERATURE REVIEW I: RISK MANAGEMENT

After the introduction of the subject and stating the problem and the research question, the study moves to discuss the theoretical background of the subject at hand. This chapter examines the relevant information related to the various aspects of the research topic, including a theoretical perspective on project management and risk management and reviews of the related literature.

2.1. Theoretical Perspective

2.1.1. Project

Since the start of the new age of the modern world, many definitions and perspectives have defined projects and their related activities. One of these comprehensive definitions was established by (Berkun, 2005) who defined a project as "a carefully defined set of activities that use resources such as money, people, materials, energy, space, provisions, and communication to meet the predefined objectives". Others have referred to a project as a unique set of coordinated courses of action, with a definite beginning and ending that is undertaken by an organization or individual to meet particular objectives within predefined parameters of cost, schedule and performance (Davidson Frame, 2014; Turner, 2006).

PMI (2017), on the other hand, has expanded the definition, defining a 'project' as "a temporary endeavor undertaken to create a unique product, service, or result. The temporary nature of projects indicates that a project has a definite beginning and end. Projects can also have social, economic, and environmental impacts that far outlive the projects themselves". Another definition of a project is "a temporary organization that is created for the purpose of delivering one or more business products according to an agreed business case" (AXELOS, 2017).

Projects can take place as a standalone function or can occur within programmes or portfolios. Typically an organizations mission is to manage programs, which are sets of multiple projects. AXELOS (2017) has defined a 'program' as a temporary, flexible organizational structure created to coordinate, direct, and oversee the implementation of a set of related projects and activities in order to deliver outcomes and benefits related to

the organization's strategic objectives. **Appendix A** summarizes the main areas of difference between a project and a programme.

Some of the projects vary, one to another, even though on a fundamental level all projects are different in nature as each has its own objective. Some of the projects require a small number of resources, cost, and space for completion. On the other hand, there are some complex projects, which are different in nature from traditional projects. In the current modern world, projects have been conveyed from its simple form to include, relationship, communication, and integration with many organizations. Such of these include joint ventures, collaborative research, intergovernmental projects, and partnerships (AXELOS, 2017).

2.1.2. Complex Project

Complex projects, as in **Appendix B**, differ from traditional projects due to their large scope, high cost, and size – and such projects include structural, technical, directional, or temporal complexities (Remington & Pollack, 2007). There are many other definitions for complex projects, one of which was set out by the Queensland University of Technology (QUT), Brisbane, Australia who defined complex projects as those that (Caietti, 2017):

- Are characterized by uncertainty, ambiguity, dynamic interfaces, and significant political or external influences; and/or
- Usually run over a period which exceeds the technology cycle time of the technologies involved; and/or
- Can be defined by effect, but not by solution.

2.1.2.1. Complex Systems and Project Complexity

A complex project typically comprises several different and overlapping phases, includes cultural implications and interactions with several suppliers and teams from various cultures, and has many stakeholders with a number of customers or end users each with different perceptions and plans for the project (Kerzner & Belack, 2010). The complexity of the project is still highly contested within both professional and academic

worlds, and some projects don't conform to best practice in project management (Remington, 2011). The challenges for these type of complex projects include the successful delivery of the outcomes in the short term in addition to ensuring that outcomes are sustainable and provide business and community benefits in the long term (Remington, 2011).

Evidence from research and practice points out that leadership for these complex projects differs considerably from leadership for simple and more stable projects (Remington, 2011). Complex projects include an unusual degree of uncertainty and unpredictability, contain new technologies, involve a large number of stakeholders and institutions, and extend over a long time scale. Thus, the project manager must make decisions in an environment in which many of the critical factors are outside the project team's direct control.

Project complexity is dynamic and may vary with the maturity of each organization (SHRP2, 2015). Although the project's scope may be uncertain in the early stages, the project team must develop solutions to satisfy external stakeholders who can affect their ability to achieve the complex project's objectives.

According to the researchers, there have been various difficulties in defining the theory of complexity (Turner, 2006), and no researcher has a unique definition for the term complexity.

The term complexity can be defined as a system which is considered to have a multifaceted structure with variations. According to the researchers, the complexity is the final dependence on the ultimate outcome which is based upon favorable primary conditions (Turner, 2006).

2.1.3. Engineering / Technology Management

Engineering Management (EM) is the application of the practice of management to the practice of engineering. It builds on the foundation of management topics in accounting, finance, economics, organizational behavior and organizational design, which assist in dealing with operational and organizational issues related to managing innovation and technological change. Likewise, it brings together the technological problem-solving

ability of engineering and the organizational, administrative, and planning abilities of management in order to oversee the operational performance of complex engineering driven enterprises (Wikipedia, 2018). Thus, the desires of EM come from the side it aids in understanding technology driving the business today and technology that will change the business in future, in addition to treating research and development as an investment, not as an expense to be minimized (Wikipedia, 2018).

2.1.4. Review of Different Project Types

In general, projects are designed to solve a problem or to derive benefit from an opportunity. Every project has a purpose with some clearly defined objectives and aims that are set out to generate clearly defined outcomes. Their motivation is to settle an "issue", and this includes division of the needs in advance. A project is aimed to recommend at least one solution to the problem. Projects are realistic and sensible and their objectives must be achievable, which implies considering both the prerequisites of funding and staffing. Projects are constrained in time and space, they have a start and an end, and in addition, they are executed at a particular place and in a certain setting (Lock, 2005).

Projects are formed with many different sets of arrangements. They can be simple, complex or extremely difficult. Project approaches include different arrangements and usage abilities and include different accomplices and players. Projects are, in general, collective. Projects are the result of the aggregate undertaking. They are controlled by groups, and include different accomplices and look for the necessities of others. Projects are one of a kind and come from new thoughts. They give a particular reaction to a need (issue) in a particular setting and they are inventive. Projects are an enterprise, each undertaking is unique and notable, and they generally include some vulnerability and hazard. Projects can be studied. They are arranged and separated into quantifiable sections, which must be available for assessment. Projects are comprised of stages that are unmistakable, identifiable stages (Cicmil and Gaggiotti, 2018).

The typical theory of projects has been developed on the basis of two dimensions, namely, complexity (or system scope) and technological uncertainty (Carbone and

Tippett, 2004). There is other research that discusses additional dimensions like market uncertainty and the pace of its growth (Essling, 2014). This study, however, will be focusing mainly on the dimension of technological uncertainty, which are amongst the key dimensions that have been observed to differentiate among the project management practices. The underlying technological uncertainty has been categorized mainly into four levels (de Hek, 2002):

- **Type A:** This includes low-tech projects that are dependent on the well-established and existing technologies. The typical examples of such projects include building according to plans, road building and construction projects, wherein it is required by the contractor to rebuild the existing product. The projects that are included in this category need no new development work, their resource planning and architecture are all conducted before the implementation phase of the project, and the preliminary work usually leads to detailed material lists, drawings, specifications and plans (Zwikael and Ahn, 2010). In relation to such types of projects, the products are basically shaped along with their designing before the formal approval and the start of the project's implementation phase.
- **Type B:** This includes medium-tech projects that make use of existing technologies. However, they are observed to incorporate certain new features or new technologies which were not existing in the past. Some of the examples of such types of projects are modifications and improvements of the existing products or derivatives, along with the development of a new generation of products within stable industries such as heavy equipment, automobiles and appliances. Even though the majority of the technologies utilized in these types of projects are not completely new, some testing and development works is needed. Also, as should be expected, there are certain changes that get included in the initial design.
- **Type C:** This includes high-tech projects that are fit for situations wherein the majority of the technologies used are new, however, they exist. These types of technologies get developed before the inception of the project, and later on,

efforts are made to integrate them early in a single product. The majority of defense industry development projects are included in this type along with the new generation of computers and the products belonging to the high-tech industries. When the new technologies are incorporated for the first time, they typically result in products which did not exist in the past (Winer and Bernstein, 1997). In addition, it has been found that the management and execution of such type of projects are completely different from the ones that have lower levels of technological uncertainties. These projects are observed to be characterized by longer design periods, developing, testing, and redesigning (de Hek, 2002).

- **Type D:** This includes super high-tech projects that are highly dependent on the new technologies which cannot be found at the time when the project gets initiated. There is clarity in mission, however, the solution is not known while the technologies remain unavailable. For this purpose, the non-existing technologies have to be innovated during the key project execution period. Such projects are found to be relatively rare, and are typically carried out by large and few companies, or government organizations (Wang and Yang, 2012). Amongst the popular example is the Apollo, the Moon-Landing project. The project was initiated in 1961 and had well-established timetable and mission. However, no technology existed to carry out such a task as no one had a clue how to get to the Moon at that time.

2.2. Project Management

Project management is the discipline of organizing and managing resources in such a manner that the project covers all the familiar elements and complete within predefined objectives under all the predefined constraints (Cavaleri and Reed, 2008). The important thing about project management is that it is a convenient methodology that adapts to any size of project or program. The tools and methodology that are used are similar in all projects (Newell, 2005). Project management typically includes the planning, delegating, monitoring and control of all aspects of the project, and the motivation of those involved,

to achieve the project objectives within the expected performance targets of time, cost, quality, scope, benefits and risks (AXELOS, 2017). Hence, the project management objectives are to manage cost, timescale, quality, scope, benefits, and risks (AXELOS, 2017).

The primary thing to understand about any project management is that it is a structure that can be applied to almost any project of any size. However, as shown in **Appendix C**, the overall project management depends on the demand for the project and its complexity. Every project uses some tools and methodologies that can be used in other projects as well, with the changes as per the nature of the project on which the project management is performed (Ulku, 2004). The project management ensures that the team involved in the project are aware of the steps and phases of the project and understand what and when to do what must be done.

2.2.1. Project Management Triangle

Projects need to be performed and delivered under certain constraints. Traditionally, these constraints have been listed as "scope," "time," and "cost", which are referred to as the "Project Management Triangle". Each side of the triangle represents a constraint, where one side of the triangle can’t be changed without affecting the others. A further refinement of the constraints separates product "quality" from “scope”, and turns quality into a fourth constraint (Cicmil and Gaggiotti, 2018).

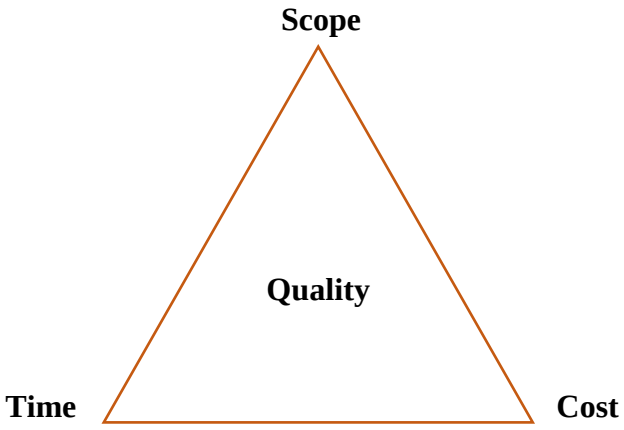

Figure 2-1: Project Management Triangle

(Source: Cicmil and Gaggiotti, 2018)

- **Time-bound project:** A scoreboard for a renowned tennis competition must be done in time for the opening coordinate, regardless of whether it costs more than foreseen and the show of some optional data, for example, the speed of the administration, should not hamper the project.
- **Cost-bound project:** A nearby expert lodging improvement may need to shorten the number of lodging units and may even overwhelm the first development program. However, the task cost can't be surpassed since the lodging award dispensed by the local government for this kind of advancement had been settled already.
- **Scope-bound project:** A weapons producer has been contracted to plan and make another sort of rocket launcher to meet the customer's execution specifications in terms of range, accuracy, and rate of flame. The scope should not be changed regardless of whether the project is deferred to do more tests and the cost has expanded.

2.2.2. Project Management Frameworks

There are many frameworks that govern the discipline of project management. Of these frameworks, PMBOK, PRINCE2, in addition to APF, are the most popular in the field.

2.2.2.1. PRINCE2

PRINCE2 (Projects IN Controlled Environments) is a structured project management method and practitioner certification program. PRINCE2 emphasizes dividing projects into manageable and controllable stages. It is adopted in many countries worldwide, including the UK, Western European countries, and Australia (Wikipedia, 2018). PRINCE2 has been designed to be generic so that it can be applied to any project regardless of project scale, type, organization, geography or culture. Hence, the strength of the PRINCE2 is its wide applicability and, therefore, it's not the aim of PRINCE2 to cover all aspects of project management. For instance, the following categories are considered to be outside the scope of PRINCE2 (AXELOS, 2017):

- Specialist aspects such as industry-specific, type-specific activity, engineering models, project lifecycles, agile methods, and specific techniques;
- Detailed techniques such as proven planning and control techniques that can be used in support of the PRINCE2 themes; and
- Leadership capability, motivational skills and other interpersonal skills.

2.2.2.2. PMBOK

PMBOK (Project Management Body of Knowledge) is a set of standard terminologies and guidelines for project management resulting from work overseen by the Project Management Institute (PMI). As stated by the (PMI, 2017), the PMBOK contains the standard for managing most projects of the time across many types of industries. **Appendix D** shows a graph of an overview of project management knowledge areas and project management processes as provided by PMBOK (PMI, 2017). These areas include the management of a project's integration, scope, time, cost, quality, human resource, communications, risk, procurement, and stakeholders.

2.2.2.3. APF – Adaptive Project Framework

APF (Adaptive Project Framework) is a structured and systematic process that allows the gradual improvement of decisions and practices, by learning from the outcomes of the decisions that have been taken at previous stages in the project (Wysocki, 2010). APF is a framework for generating a unique and dynamic management approach to be used on the project. The success of that approach is measured by the delivered business value. Project managers are in charge of the approach, meaning they need to understand the situation and adapt their approach and techniques (Wysocki, 2010). The main characteristics of the APF are that it succeeds on change, learns from discovery, and is customer-driven, as it places the customer as the central figure who decides on the project's next step/s and has the power to completely change the project's direction (Wysocki, 2010).

2.2.3. Project Portfolio Management Tools

Another increasingly popular technique of managing projects and evaluating investment options is the use of Project Portfolio Management (PPM) tools. PPM software originated in the business world, influenced by the growth of project management as a specialized knowledge area and the increasing use of complex, structured processes to perform it. These tools help users to plan and evaluate projects, as well as help decision makers to estimate the absolute and relative rewards of a series of possible projects (Sciarretta et al., 2008). Ideally, PPM tools are embedded with the following four functions (Sciarretta et al., 2008):

- **Analysis:** Link objectives to vision, goals, priorities, and capabilities, and identify gaps and risks.
- **Selection:** Identify and select the best mix of investments to achieve capability goals and objectives across a portfolio.
- **Control:** Ensure investments within portfolios are managed and monitored to determine whether to continue, modify, or terminate.

- **Evaluation:** Measure actual contributions of a portfolio towards improved capability and support adjustments to the investment mix.

Many commercial PPM tools focus on the control and evaluation of the portfolio. However, superior PPM software assists users with the initial analysis and the selection phases of project management, the requirements of the control phase during implementation, and the evaluation phase upon project completion. Such of these known tools are PALMA, ExpertChoice, and Equity (Sciarretta et al., 2008).

2.2.4. Phases of the Project Management

As per the PMI (2017), every project goes through five phases during project management. These five phases of project management are the following:

- Conception and initiation;
- Definition and planning;
- Launch and execution;
- Performance and control; and
- Project closure.

2.2.4.1. Project Initiation

This is the beginning of the project, and the objective of this stage is to characterize the project at a wide level (Mir and Pinnington, 2014). This stage normally starts with a business case. This is the point at which the project manager examines whether the project is worthwhile, achievable and if it should be attempted.

2.2.4.2. Project Planning

This is one of the most crucial phases in project management. In this phase, the project manager defines the scope and budget of the project (Essling, 2014). In this phase, the project manager along with the project team, develop the work breakdown structure. Also, the project manager develops the communication plan which is very important for the success of any project, in addition to defining SMART (Specific, Measurable,

Attainable, Relevant and Timely) goals and describes them in front of the project team (Moore, 2017).

2.2.4.3. Project Execution and Implementation

In this phase, the initial expectations of the project after completion are decided. It comprises of several frequent meetings involving topics such as status reports, improvement updates, execution reports, and various others. The first meeting usually indicates the beginning of the project execution stage, where every member involved in the project is made aware of their obligations (Cicmil and Gaggiotti, 2018).

Project execution phase involves several tasks (Orangescrum, 2018):

- *Team development:* Project managers or champion bring individuals and develop a team.
- *Assigning resources:* Once the team is developed, the project manager assigns the work to every team member.
- *Executing project management plans:* The project manager executes the previously developed project management plans.
- *Procuring management:* The project managers accumulate and manage the required resources.
- *Project management manages and directs project implementation:* It involves managing and directing project implementation.
- *Setting up a monitoring system:* The project manager develops a monitoring system to track the project. It is critical for the completion of the project.
- *Project assignments are executed:* The project manager is required to manage the project tasks, which are developed at the starting of the project.
- *Stating meetings:* The project manager holds meetings and addresses to the team members. This is the phase where the team members understand the project in depth.
- *Updating the project schedule:* It involves updating the project schedule. It is necessary as several challenges occur during the project.

- *Adjusting project plans as required:* The project manager adjusts the project plans as per the improvements identified in the project monitoring process.

2.2.4.4. Project Monitoring

Project monitoring is important because it helps project managers in identifying the key improvement areas which prevent any damage to the whole project. Without project monitoring, no project manager can ensure the validity, reliability, and accuracy of the plans, methods, and resources used in the project. This is tangled in with estimating project progression and execution and guaranteeing that everything is happening lines up with the task administration design. Administrators with the responsibility to utilize Key Performance Indicators (KPIs) to decide whether the project is on track (Orangescrum, 2018).

2.2.4.5. Project Closure

In this stage, the project managers take the projects towards the ending. This stage shows the completion of the project. Once a venture is finished, the project management holds meetings in order to assess what went well in the project and distinguish venture failures (Orangescrum, 2018). This is particularly useful to comprehend lessons realized so changes can be made for future ventures.

2.2.5. Project Management Plan

The Project Management Plan (PMP) is the most important activity in any kind of project. The PMP consists of the documents and plans designed by several processes. The PMP is developed to create the source of information which will work as the standard and the guideline for how the project would be planned, implemented, monitored and controlled (PTR Development, 2006). Hence, from authorization to completion, a project goes through a whole lifecycle where several elements are introduced, which defines the objectives of the project, planning related to the steps required for achieving those objectives, controlling and monitoring of the processes, execution of the work, and finishing the whole project (Ahern, Byrne and Leavy, 2015).

Furthermore, the development process includes the actions necessary to define, integrate, and coordinate all subsidiary plans into the PMP (Barkley, 2006). One of the main purposes for developing a PMP is that not all the projects need all the planning processes, and to the same degree (PTR Development, 2006). Therefore, the content of the PMP will depend upon a specific project and its content will vary depending upon the application area and complexity of the project (Piperca and Floricel, 2012). It is for this reason that the content involved in the PMP depends on the specific project and the contents involved in it, which also vary based on the complexity of the project and the area it would be used after the successful completion.

The PMP is not designed at once. The PMP is progressively elaborated that implies that it is refined, revisited, developed, and updated (Mikkelsen, 1990).

The PMP requires essential knowledge of critical areas and composed of the plans and documents generated by the various processes. Each of these areas contains several components which consist of subsidiary plans and baselines and offer detailed information in managing projects (Orangescrum, 2018). These components typically include (Leach, 1999):

- Baselines for the schedule, cost, and scope;
- Management plans for schedule, scope, cost, human resources, quality, risk, procurement, and communication;
- Requirement management plan;
- Configuration management plan;
- Change management plan; and
- Process improvement.

The PMP is typically developed by the project managers. Project managers follow inputs from the key stakeholders and the project team. PMP is designed in a formal, affirmed document that characterizes how that particular undertaking is executed, observed, and controlled. It can be a summary or a point by point report and may incorporate baselines, management plans, and other planning reports or documents. This

document is utilized to characterize the approach that the project team takes to execute the scope of the project (Cicmil and Gaggiotti, 2018).

As the work continues, the execution of the project is estimated against the execution measurement standard incorporated into the PMP. The scope benchmark, schedule benchmark, and the cost baseline are, in a combined manner, considered as the performance measurement benchmark (Essling, 2014). In case while the work on a project is going on and another work requires attention, then the project manager has to tackle both the scenarios by making changes accordingly.

The project managers invest a significant measure of time and effort guaranteeing baselines are accomplished, and the sponsor and the organization get the full advantages of their tasks. Apart from the proper planning, the abilities of the project manager likewise lie in productively controlling the task and making sure project deliverables are on track and that the undertaking is finished as per the PMP (Joslin and Muller, 2015).

2.2.6. Risk Management

2.2.6.1. Risk

Risk can be referred to as an uncertain event or condition that, if it occurs, has a positive or negative impact on project objectives (PMI, 2017). Several researchers and practitioners involved in project management be certain that most risks have an adverse impact on any project and its overall performance (Walker, 2008). In a way, various researchers have different opinions regarding risks as there are circumstances where a project has been positively affected by any uncertainty or risk and others have not. Thus, the word "risk" has traditionally been utilized to allude to any kind of unpredictability related to the outcomes (Miller, 1992). **Appendix E** presents an example of typical project risk categories.

Risk management is the efficient way to deal with the recognizable proof, appraisal, assessment, and positioning of the related risks. These risks can occur after the allocation of fundamental resources for monitoring, controlling and minimizing any negative effects of the undesirable events (Perera et al., 2014). Proof has shown that numerous successful

firms understand the advantages that risk management offers to enhance success and project management (Carbone and Tippett, 2004).

2.2.6.2. Risk and Project

Although risks can be good things as they can generate opportunities, especially in R&D, they are typically related to potential harm to the key assets. These types of assets are observed to be: environment, reputation, information, production, materials, and human health and life. Potential losses of assets means the existence of an uncertainty related to the severity scale and whether the loss will be becoming a reality or not. In everyday life, the terms ‘uncertainty’ and ‘risk’ are utilized randomly. As per Smith and O’Connor’s study, the differences between the terms are stated as uncertainty involving both potential positive outcomes (opportunities) and potential losses (threats) (Smith and O'Connor, 1972).

The direct causes of such losses can be the use of the wrong equipment, wrong/lack of maintenance, errors on the part of operator/s. Most often, the latent sources are poor training or poor maintenance culture, violation of procedures or lack of procedures, and insufficiencies in requirements (Smith and O'Connor, 1972). There are direct causes which are easiest to fix and control. On the other hand, the latent causes are observed to be more complex because of the fact that the relationship between cause and effect cannot be always straightforward (Smith and O'Connor, 1972).

Such losses can occur all of a sudden or there could be delay after the initiating event has happened before its impact is felt (Smith and O'Connor, 1972). Also, it can happen that the losses lay latent inside the system. As the losses are not observed to occur just after the occurrence of the initiating event, there are certain complications associated with the registration of events and system controls. If losses have happened, there must be analysis to determine both the latent and direct causes in order to make sure that the losses do not reappear.

There has been a trend in industry to blame the individuals who are scapegoated as the triggering factor/s (cause/s) of the event, instead of identifying the latent causes (Smith and O'Connor, 1972). Proactive actions must be introduced in order to reduce the latent

causes that will be more efficient in the long run that merely "blaming" an individual. The workers must not be blamed, instead there should be a more open discussion related to locating the correct causes of some incident so that the work environment becomes more positive.

2.2.6.3. History of Risk Management

Winer and Bernstein (1997), in their book *Against the Gods – The Remarkable Story of Risk,* gave some fascinating insights into how the concept of risk management has progressed. From its origins in the Hindu-Arabic numbering framework, created more than eight hundred years ago, to the foundation of the hypothesis of likelihood and basis in quantitative strategies amid the Renaissance years.

A significant part of the progression during these years shapes the premise of a great part of the quantitative hazard administration hypothesis today. Nevertheless, Bernstein's story is set apart all through by the continuous efforts between the individuals who affirm that the best choices depend on measurement and numbers, controlled by examples of the past, and the individuals who construct their choices in light of more subjective degrees of conviction about the dubious future. Vulnerability, furthermore, is viewed as contrary by the individuals who are awkward with subjective probabilities (Chapman, 2006).

Some of the research from the past suggest that risk management can also be relative to current functionality. In ancient times, indicators were more useful to facilitate the evolution. In 1955, modern risk management practices were introduced and also become less limited to the insurance coverage of the market, as this is also determined as a competing protection tool which complements various other management activities (Piperca and Floricel, 2012). As the Second World War ended, most companies were developing differentiated asset portfolios, and with these, developed methods for assessing risk. Self-insurance activity also included creating a correct liquid reserve of resources to cover the losses which might occur from an accident or a negative fluctuation. Risk management is used to lower the financial significance of natural calamities, which is a form of self-insurance (Piperca and Floricel, 2012).

The perception of risk management in the financial sector was transformed in the 1970s, when risk management in the financial sector also became important for various companies - mainly banks and construction companies.

In the 1980s, new revolutionary research in this regard was directed by Daniel Kahneman and Amos Tversky. They built up the Prospect Theory that uncovered personal conduct standards that had never been perceived by defenders of balanced basic leadership.

At the event of any misfortune, individuals are the ones who dare to overcome the misfortune. When they face a similar situation in any other structure, they utilized the "disappointment of invariance" to make decisions (Piperca and Floricel, 2012). These examples were attributed to human feelings, which the researchers also believed through their study that to be responsible for the destruction of self control, and this was accepted as this basis for achieving the objective of basic leadership.

The attitude of the individuals and the associations influence the capability of risk management to convey the desired information accurately. The involvement of the human in the risk management offers an additional layer of quality. This leads to the selection of risk ignorance, which influences each part of the management of risk.

Risk states of mind exist at individual, group, corporate, and national levels. These can be evaluated and depicted, enabling wellsprings of predisposition to be analyzed, and uncovering their impact on the procedure of risk. Despite the fact that the researchers also permitted the considerate and risk managing attitude, is more acceptable as compared to the hypoesthesia, it does additionally accentuate the significance of a people-focused approach on the topic of risk management.

In addition to the immense pressure during the evaluation and subjectivity as mentioned by Zhang (2017), he stated that the risk management investigation directed in the course of the most recent ten years of research in the two schools of the 'management of risk', where 'risk' is seen as a target fact and subjective development. The school in which the risk is seen as a target fact thinks about dangers to serenely exist. Learning delivered from a target risk investigation is the result of reasonable basic leadership. The school in regards to chance as a subjective development considers the risk subjective, built

wonders, with numerous epistemological measurements. In this way analysis of risk is not based on target and characteristic exercises, but rather wealthy in values.

Around the world, breaks, abnormalities, and instabilities give off an impression of being multiplying variables. In such a manner, Bernstein argues that as civilization has pushed forward, as nature's impulses that have made a difference are judged to be less important, the choices of individuals in terms of their potential to make a difference are rated higher. In spite of the numerous crafty devices that have up to this point been made, Bernstein maintains that resistance must still stay uncertain. The book 'Against the Gods – The Remarkable Story of Risk' ends by presenting Chaos Theory. The book also emphasizes its potential commitment to the training of risk administration, because of the hypothesis' inclination towards non-direct reasoning, where the results and outcomes are not balanced to the cause.

2.2.6.4. Risk Management Plan

Almost all projects involve some type of uncertainties and risks. Project management planning only helps in reducing the chances of risks involved in the project. In traditional projects, risk management and proper project management mean that the project will finish without facing any significant challenges (Wang, Lin and Huang, 2010). On the other hand, a complex project is more prone to risk occurrence even after planning of risk management and project management.

Risk management is covered in the second phase of project management, which is project definition and planning. In this phase, the project managers strive for identifying risks. Once they are able to find the risks associated with the project, they start developing plans to mitigate and control these risks. It takes a huge amount of time and energy to develop the Risk Management Plan (RMP). Project managers develop the RMP under the overall process of project management, which is followed in almost every organization that uses RMP (Cicmil and Gaggiotti, 2018).

RMP is defined as the process of determining, assessing and controlling risks associated with a project or work. These risks or threats can originate from a large range

of sources involving legal liabilities, financial uncertainties, strategic management issues, natural disasters, and accidents (Cicmil and Gaggiotti, 2018).

RMP is one of the important plans in project management knowledge. It is a key business process within both the private and public sectors around the world (Turner, 2006). RMP identifies the procedures used to manage risks throughout the project in addition to documenting the approach to risk identification and analysis, how risks will be tracked throughout the project lifecycle, and how mitigation and contingency plans are developed and implemented. Sound and effective implementation of risk management is part of best business practice at a corporate and strategic level as well as a means of improving operational activities (Australian Standard HB 436, 2013).

Risk management includes the processes, as shown in **Appendix F**, concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on projects in addition to the update of these processes (PMI, 2017). Furthermore, the risk management process should be an integral part of management, embedded in the culture and practices, and tailored to the business processes of the organization (ISO 31000:2009, Zwikael and Ahn, 2010). It should not be implemented eventually but should form eventually.

It is, therefore, necessary that the risk management comprises the processes that are involved either directly or indirectly with the planning of risk management, analysis, monitoring, controlling, identification, and response regarding the risk. These processes should also be continuously updated to get the most out of these processes. Effective implementation of the risk management planning also helps in reducing the use of additional resources, which the organization could use otherwise in different projects or areas necessary (Sax and Andersen, 2018).

2.2.6.5. Risks and R&D

There are several organizations have come to comprehend that to get by in the regularly expanding, globalized and competitive marketplace, implementing technological innovations forms an important strategic objective (Teller, 2013). This means Research and Development (R&D) ventures are the sources of performance

improvement (Bedeian, Ferris and Kacmar, 1992) and strategy (Mikkola, 2001) for organizations (Hosseini et al., 2016; Wang, Lin and Huang, 2010). Be that as it may, the execution of technological innovations with the aid of R&D ventures isn't without difficulties. These undertakings are overflowing with uncertainties and risks at each stage of the product lifecycle (Gassmann and Han, 2004). Therefore, dealing with the risks is a critical test for the R&D project managers (Moehrle and Walter, 2008). Moreover, the close relationship between the project's success and project risk management is broadly recognized. This gives importance to the focal part of viably managing risks for increasing the success rates of the R&D ventures.

Uncertainties within the R&D venture originate from an extensive variety of sources that can possibly antagonistically influence the success of a project (Sicotte and Bourgault, 2008). A large number of these sources show that adverse effects develop from the risks involved in the project. Not dealing with the risks related with such sources of uncertainties in the R&D ventures have verifiably brought about lower success rates (Van Zyl, Du Preez and Schutte, 2012). To enhance the success rates of the projects, the project managers must make use of particular strategies and methods that will enable them to distinguish and deal with these uncertainties as adequately as could be expected under the circumstances.

2.3. R&D

Research and Development (R&D) has been well established across different industries since the early 20th century. Definitions vary from business to business and nation to nation, but the primary idea is to capture the creation of new knowledge to be used in products and processes.

2.3.1. R&D Definition

R&D, **Appendix G**, refers to the activities undertaken by entities to create new/improve existing products or services or processes. The term R&D covers three types of activities: basic research, applied research, and experimental development (OECD, 2015).

- *Basic research*: is an experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
- *Applied research*: is original investigation undertaken in order to acquire new knowledge which is aimed towards a specific practical objective.
- *Experimental development*: is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to produce new products or processes or to improve existing products or processes.

Research and Development is different from other major activities involved in the operation (Scandizzo, 2001). It is not an activity or process that can be planned or progressed with an aim to reach at a designated time, as R&D does not produce immediate profits. However, this activity is emphasized by focusing on long-term profits. Thus, some of the experts and professionals think that the research and development projects are constantly complex because of the planning and heading of R&D are unclear and revolve around uncertainties (Brink, 2017). Usually, in a complex R&D project, various phases are present, and these phases can overlap on each other several times increasing the complexity further. **Appendix H** shows the typical lifecycle of R&D.

2.3.2. R&D Structures

Typically, research and development departments comprise of entire employed staff towards achieving the single goal where the entire department is working on the R&D and offer collaborative effort for innovation (Sicotte and Bourgault, 2008). However, it is necessary to estimate the risk-adjustment return on the activities involved in the R&D as it is a risky process and involves risk to the capital invested. R&D has no immediate profits and the return on investment is also not clear and hence the more invested in the R&D activities, the more is the risk (Bath, 2005).

R&D has two types of structures, which are used by any country, company or business as per the requirements (Moehrle and Walter, 2008).

- The first structure of the research and development comprises staff members where only those engineers are involved who develop new products (Moehrle and Walter, 2008). In this process, the involvement of research is extensive and requires a lot of patience for bringing something new to the market to gain an advantage over the competition.
- The second R&D structure involves people, researchers, and scientists from different departments or from different sectors of R&D. Those staff members are tasked with applying their research and skills in industrial, scientific, or technical fields. These members of the R&D have the necessary knowledge and work experience regarding the working environment and its objectives. They can either be involved in various activities for various reasons. A reason to do so is to improve an existing product or to make some innovative improvement over an existing product. They are also tasked with the advancement of future products.

2.4. Risk Management of R&D Projects

In line with its nature, R&D is a procedure which is filled with uncertainties, and with uncertainties comes hazard (Doctor, Newton, and Pearson, 2001). New Product Development (NPD) and Research & Development ventures are impacted by various components (Balachandra and Friar, 1997). The levels and kinds of real risks in R&D ventures are impacted significantly by those variables. The aggregate effect of the vulnerabilities related to these components could be interpreted as the primary explanation for the generally low success percentages of such undertakings. Practically speaking, it is the insufficient administration of the risks and uncertainties which lead to ineffective project performance. Apparently, those could be mitigated through the application of highly effectual risk management strategies (Keizer, Vos and Halman, 2005).

Research and development ventures in firms are among the most basic and useful interfaces (Mousavi et al., 2011). Be that as it may, R&D ventures experience the unpleasant effects of the unfavorable impact of an extensive variety of risks. Uncertainties

increase with the involvement of additional components despite its chance to offer innovation to the organization.

Risk management and project management are related in such a way that increases in one means increase in other and vice versa. Thus, risk management is rapidly gaining recognition as fundamental to proactive and responsible project management as R&D projects introduce unique challenges to project management generally and to risk management specifically (Wageman, 2010). The risks related to the R&D projects are more in private sector as compared to the public sector as the former has to think of the risks involved for business as well on failure (Graetz and Franks, 2015).

Managing risks of R&D environments have been studied for many years. Risk management is one of the approaches that have been widely applied in practice (Wang, 2010). In the literature of R&D risk management, several studies have found that applying risk management techniques to innovative R&D projects can improve their success rates to a considerable extent (Wageman, 2010; Wang, 2010; Hoon Kwak and Dixon, 2008). Some researchers performed empirical studies and reported that risk management practices can lead to the success of higher risk projects (Wageman, 2010; Wang, 2010).

An examination surveyed the risk management methods utilized by different R&D firms around the globe trying to distinguish best practices that can be implemented in the R&D of the public sector. Their investigation found that part of these systems are more usable to particular kinds of industries in comparison to other industries. The outcomes were later affirmed in a research study. The current risk management systems are focused on the industry needs, and accordingly, they have been observed to be deficient in adequately dealing with the risks related to the R&D ventures. Thus, several researchers have tried to recognize particular risk management practices which work for R&D ventures (Strain and Preece, 1999).

One such study could distinguish practices, for example, employment of the risk experts along with the utilization of certain analytical tools in relation to risk-based decisions to be productive for the R&D projects (Malhotra, 2015; Leblanc, 2010). A few studies have explored the drivers of, and barriers to, successful R&D project risk management with an inclination towards organizational environment along with the

leadership style. One study inspected risk management in the R&D ventures utilizing a procedure and distinguished an arrangement of particular tools and techniques which can be used for managing risks in the R&D projects in an effective manner, including templates and checklists. The study additionally proposed employing risk experts to facilitate the key risk management process. In any scenario, examinations have shown that potential irregularities remain, due to the involvement of assessments that have a contrasting view, which happen due to the information from different specialists (Malhotra, 2015; Leblanc, 2010).

Additionally, researchers who are engaged in the activities of gaining new knowledge, approaches or practices required in the project management field are also among those who have participated in the researching field of R&D management. Of those researchers who are involved, some have also developed methodologies regarding the risk management, which are effective in improving the success rate in complex research and development projects (Abdul-Rahman, Mohd-Rahim, and Chen, 2012; Mikkelsen, 1990). Others suggested that managers should adopt different quantitative approaches for different levels of uncertainties in addition to using qualitative tools and rely on judgment and experience as uncertainty increases (Alessandri, 2004).

Furthermore, early detection of complex challenges in R&D project risks require a systematic approach, which is present because of the continuous efforts of the researchers in this field. This systematic approach helps the organization, either public or private, to achieve a high success rate in complex R&D projects. Nevertheless, this is not the only methodology available for risk management; various other proposed approaches are present such as knowledge and data management systems and collaboration tools, which help in capturing the experience of the researcher while reducing the risks associated with the R&D projects (Abdul-Rahman, Mohd-Rahim, and Chen, 2012).

In relation to the measurement of the success of R&D ventures, there have been various ongoing studies to recognize particular risk management tools and strategies that can be utilized by NPD and R&D project managers to oversee uncertainties all the more successfully (Mazareanu, 2010; Lehar, 2003). A study led various case studies to discover the sorts of risks that are generally found in the NPD and R&D projects. They recognized

two fundamental sorts of risks: first is, "unambiguous risks" (that are risks related with customer marketing and acceptance); and second is, "equivocal risks", that happen when there is a distinction of conclusion in relation to the project management and the organization (Mazareanu, 2010; Lehar, 2003).

In light of this, they set forward a rundown of prescribed activities that the R&D project managers can embrace to aid the better management and identification of the crucial project risks. They proposed that project managers must consider ambiguous risks seriously since they can possibly undermine the project's success (Mazareanu, 2010; Lehar, 2003). The academic literature review likewise distinguished two fundamental kinds of risks in R&D ventures (Malhotra, 2015). The risks were classified as external and internal. Risks that are known begin from the organizational, technological, and operational parts of the project were observed to be internal while the risks that stem from the supplier and the market angles were observed to be external.

Some of the researchers, on the other hand, favored the participation of customers in the innovation process to achieve the necessary objectives which are as per the customer need, since involvement of the customer will reduce the risks as the process will flow as per the requirement of the customer without any major speculations (Mikkelsen, 1990). Because of the ineffectiveness of the existing risk management methodologies to manage uncertainties in NPD and R&D projects, a few researchers have created completely new and innovative risk management frameworks (Wageman, 2010; Wang, 2010). Once the underlying risks get distinguished, contingency strategies and plans must be created to be applied.

As long as there is a need to do some innovation or new products, there is a need for research and development. Also, as long as there are research and development projects, there will always remain constant risk factors involved with it because of its inefficiency to produce results in a short time and uncertainty regarding the investment (Lehar, 2003). Nevertheless, to mitigate the risks involved in the sophisticated research and development projects, risk management is utilized, which do not actually eliminate the risks involved in these R&D projects but reduces them by managing them effectively.

Therefore, these approaches help in mitigating the risks involved directly with the complex R&D projects by offering risk frameworks, which help in analyzing the risks related to the technological projects. In addition to that, it also offers methodologies, which quantify the technical performance risks so that the identified risks observed throughout the projects can be controlled without facing any significant challenges (Mikkelsen, 1990).

2.4.1.1. Defense R&D

Although defense research is aimed at giving a decisive operational advantage to the forces, most innovations are applied to the output of defense sector. For instance, aviation, radars, and stealth technology are all weapons that made operational differences due to disruptive technologies. In addition, history is full of worldwide commercial successes that originated from defense research, such as the Internet, the microwaves, and liquid crystals (Mauro and Thoma, 2016).

The importance of defense research comes from the fact it is the crucible in which defense capabilities are forged, it is a key enabler towards strategic autonomy, and it is the long-term investment in the ever-changing world in order to keep alive freedom of action, defend the country's values and to preserve its liberties (Mauro and Thoma, 2016).

Nevertheless, there is not much literature available that discusses the organizational risks involved in the applications related to the armed forces. The literature related to the research and development projects in the military is rarer as compared to the information on civilian organizations. A reason for the low number of literature and studies related to these environments is the nature of the defense sector.

The defense sector in any country is the most confidential and mysterious for ordinary people in addition to its secrecy related to the operations and operational activities. In the defense world, military R&D is primarily focused on enhancing capability and reducing technical risk. Therefore, although the military is concerned about enhancing mid-term and long-term capabilities, its main concentrate is on near-term gains to support current operations. Thus, long term R&D efforts complicate the benefits of the R&D investments for military governance, as these benefits may not be seen for many

years, and may be affected by the globalization of technology, unforeseen changes in the threat, and other uncontrollable outside influences (Sciarretta et al., 2008).

Consequently, these aspects have encouraged various researchers to start their research in this field to get more information and idea about the secret operations and activities involved in this field. Keat (2012), for instance, developed a theoretical framework for defense R&D investments under uncertainty. Another case is the program started in the United States of America known as the National Institute of Standards and Technology Advanced Technology Program (NIST ATP), which offers sponsoring proposals related to the high-risk in the research and development projects of the military (Scott, 1996).

2.5. Risk Analysis Techniques

Risk management is an important action for the projects and thus it is important to have a minimum number of certain risk management activities that must be performed efficiently. There are various risk analyses that can be adjusted to a specific issue to help recognize potential risks. All of them have qualities and shortcomings depending upon the application.

2.5.1. Risk Quantification

Quantification of risk in product development is becoming a highly appealing area of interest. Risk Management Frameworks (RMF) have been immensely popular among the research and development programmes because they offer a firm approach for the quantification of risks and construction of the comprehensive mitigation plans. In addition, RMF is able to explain the efficient and effective responses for mitigating risks. Concurrent Engineering is a business approach which links all of the functional areas of a firm like manufacturing, finance, and marketing with the design process, and in which is encouraged by the RMF analysis model (Investopedia, 2018).

Apparatuses and procedures for project risk administration have been created to help project supervisors in past decades, for example, event tree analysis, fault tree analysis, Bayesian risk analysis, probabilistic risk assessment, venture evaluation review technique,

etc. The hidden supposition in the greater part of these procedures and strategies is that past data is accessible with respect to both the risk likelihood and risk effect (Wang and Yang, 2012). For R&D projects, the particular element is that it is an exploratory high-risk evaluation activity, with next to no or no important past experience and past information. Thus, the customary risk of the board techniques dependent on measurable hypothesis are not fitting (Wang and Yang, 2012). Other risk identification methods and techniques which are available globally and can be used in R&D environments include the following (Open Campus, 2018):

- *Expert Judgment*: an extremely useful tool in risk assessment and particularly where relevant data are scarce.
- *Documentation Reviews*: reviewing project related documents such as lessons learned, articles, and organizational process assets.
- *Brainstorming*: done with project-related people who focus on identification of risk for the project.
- *Delphi Technique*: a list of the required information is sent to experts, responses are compiled, and results are sent back to them for further review until a consensus is reached.
- *Interviewing*: conducted with project participants, team, stakeholders, and experts to identify risks.
- *Root Cause Analysis*: determined for the identified risks, which are further used to identify additional risks.
- *SWOT Analysis*: analyzed for the project and thus, risks are determined.
- *Checklist Analysis*: checklist of risk categories is used to come up with additional risks for the project.
- *Assumption Analysis*: Identification of different assumptions of the project and determining their validity, further helps in identifying risks for the project.
- *Risk Register*: a living document that is updated regularly throughout the life cycle of the project. It becomes a part of project documents and is included in the historical records that are used for future projects.

- *Probability and Impact Matrix*: helps in identifying those risks which require an immediate response.
- *Monte Carlo Analysis*: a simulation technique which can be used to evaluate the overall risk in the project.
- *Decision Tree*: takes into account future events in making the decision and helps to analyze many alternatives at one single point of time.

2.5.2. Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a common framework that is used to mitigate the risks involved in the R&D and NPD projects. It is a technique widely used for reducing the associated risks in complex R&D projects, which targets at the failures that can potentially occur in the future, and in addition, it evaluates the impact of those failures on the overall R&D process of the project.

The FMEA approach includes steps to identify every possible error in any design and can be used in project management. It plans to recognize and organize the prospective failure modes before the failures happen and assess the impacts of such failures on the important production process. Furthermore, the working of the FMEA method involves adding more evaluation processes to the traditional evaluation processes. Its strategy extends the customary risk evaluation process through the inclusion of the detection factor in relation to the project risks along with the impact and likelihood factors. The detection factor reveals the ability of an organization to identify an item's fault before the manufacturer send it forward to the retailers or the customers (Gladden, 2008).

While FMEA is utilized to decrease the risks related to the technical aspects of the planning and design processes of the product development, the Risk Failure Mode and Effect Analysis (RFMEA) is utilized to evaluate and investigate risks, mainly within the project setting (Gladden, 2008). The contrast between the two procedures is in the meaning of the important detection technique. In case of FMEA, the detection aspect is appointed a higher value if the organization has no technique for recognizing that an item failure will happen and a lower value on the off chance that they are able to identify the fault. In the case of RFMEA, detection aspect is observed to be the measure of the capacity

to predict a specific risk event so that there is adequate time for planning for the event (Gladden, 2008).

The FMEA technique appears to be acknowledged as a successful methodology within the academic literature, however, their viability in the R&D setting has stayed tricky. The academic literature review reveals that there is an absence of research on these techniques for R&D ventures (Gladden, 2008). Indeed, even the researchers of the accessible case studies have noticed that the result generalization ends up viable simply after the procedure have been reproduced in different settings and for several cases (Gladden, 2008).

RFMEA can be used for project management to identify significant risks (Carbone and Tippett, 2004). The current method can develop remedial solutions for addressing the issues regarding risk management in the R&D projects. Nevertheless, there is a lack of literature that investigates about the effectiveness of RFMEA risk management approach in the R&D projects (Wang and Yang, 2012).

2.5.3. Decision Theoretical Framework

Despite several models and techniques have been developed in literature and applied in practice of risk analysis and assessment, knowledge about risk management is becoming a matter of paramount importance to effectively deal with the complexity of projects. Thus, decision theoretical framework is usually used to take into account the most relevant managerial and operational aspects and scenarios of the project.

2.5.3.1. Decision Theory

Every individual, departments and organization make decisions. In this competitive world, organization can exist when the correct and appropriate decisions are made. Therefore, correct decisions help in successful operation of business. Decision theory is principle associated with decisions. It is an interdisciplinary approach to arrive at the decisions that are the most advantageous given in uncertain environment (Investopedia, 2019). Consequently, decision theory provides a formal structure to make rational choices in the situations of uncertainties. Given a set of alternatives, a set of consequences, and a

correspondence between those sets, decision theory offers conceptually simple procedures for selection (Civil Service, 2019). **Appendix I** shows summary of the three theories of decision making.

The field of decision analysis prescribes a set of analytical tools that help decision makers achieve these desirable characteristics of good decisions. The decision theory includes a set of concepts, principles, tools and techniques that help the decision maker in dealing with complex decision problems under uncertainty (Civil Service, 2019). The framework of the decision theory commonly identifies three types of decision categories (Investopedia, 2019):

- *Decisions under certainty*: an abundance of information leads to an obvious decision.
- *Decisions under uncertainty*: analysis of known and unknown variables lead to the best probabilistic decision.
- *Decisions under conflict*: a reactive approach that involves anticipating potential consequences to the decision, prior to making a decision.

According to Borgonovo et al. (2017), decision analysis process consist typically of four stages:

- The identification of the available alternatives;
- The description of the uncertain consequences generated by these alternatives;
- The specification of the decision maker's preferences among alternatives;
- The computation of the best alternative among those available.

2.5.3.2. Risk Management and Decision Theory

Risk management is fundamentally a decision-making process. Managing risk demands a methodical approach and project risk management is a formalized disciplined approach consisting of a set of processes for decision-making (Baccarini, 2001). Decision theory has been around for a good while, and has evolved to be used on a higher level to describe decision making processes in various fields, such as economics, mathematics and psychology, and could supply several useful tools for improving risk management's decision making process (Versluis, 2014).

The most resemblance is that both risk management and decision theory would not exist without the presence of uncertainties. Risk management attempts to assess uncertainties and prioritize them, which decision theory is able to achieve. Risk management makes decisions to manage the uncertainties, whilst decision theory can prescribe what the correct course of action would be to deal with the uncertainty (Versluis, 2014). By expanding risk management with decision theory, it is possible to suggest a course of action to deal with risks on a quantitative basis. This enables to maintain the distinction between different layers of uncertainty, not only at the risk analysis level, but also at the decision making stage (Versluis, 2014).

2.5.3.3. R&D and Decision Theory

Decisions are the product of management work. Quality R&D decisions are critical for business success. R&D experience has shown that there are many benefits from using a high-quality decision process such as depolarizing high-conflict situations potentially involving strong differences of opinion, and ensuring comprehensive consideration of relevant factors. These benefits come typically from the nominal decision process, the skill and quality with which it is carried out, and learning from past experience, leading to continuous improvement in the decision process (National Research Council, 1999).

Decision research has shown that failure to learn from experience and to apply the lessons learned are of the most prevalent and harmful practices in decision-making. A decision process incorporating some of the best practices should lead to better results. The key decisions for R&D programs are nominally those to identify and prioritize technology needs and to solicit and fund projects in support of these needs, with the aim of helping to achieve goals (National Research Council, 1999).

Through introducing decision theory's view of how people choose between alternative courses of action to management researchers, and by subsequently exploring its value in understanding R&D progress decisions, would contribute to a more in-depth understanding of R&D progress decisions and other management decisions, thus help those who make such decisions (Rutten et al., 2013). Moreover, presenting innovative

methods that enable organizations to diagnose their R&D decision making and identify those practices that, when implemented, will most improve R&D's outcomes.

2.6. Summary

Project's risk management can be used in numerous ways reliant on the complexity of the projects and potential failures. It can help in identifying the key areas where the challenges may occur during the ongoing process related to complex R&D projects of armed forces, and thus reduces them before their occurrence. It also helps in reducing the risks associated with the planning of the project by analyzing the risks associated with the project. Management of complex R&D projects of armed forces is not easy and thus requires methods to ensure their smooth process running and to minimize loss and maximize profits.

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3. LITERATURE REVIEW II: UAE'S R&D UNDERTAKINGS

After reviewing the literature related to the theoretical background of project management and risk management regarding R&D projects, the study moves to look into the UAE R&D environment and important aspects of projects in the armed forces of the UAE.

3.1. United Arab Emirates

3.1.1. UAE Military

Since the 1990s, the Armed Forces of the United Arab Emirates has continued to grow and acquire the latest of the art technology armaments. Contracts with different allies from different countries such as USA, France, UK, and China have been set acquiring modern capabilities in all domains; land, maritime, air, and cyber. Among these capabilities are the fighter airplane F16 from the Lockheed Martin Company in USA, the fighter airplane Mirage 2000 from Dassault in France, and the M-ATV Armed vehicle from Oshkosh Corporation in the USA. Most of these contract articles include transfer of technology and know-how of these armaments technologies to UAE national employees; officers, soldiers, and civilians. UAE nationals have been receiving training and knowledge transfer on most of these weapons both during the development of the weapons and after delivering of the weapons to UAE through technical assistance. Nowadays, UAE Armed Forces are capable of modifying, repairing, and integrating most of these armaments with in-house expertise.

To further develop the economy of the nation in addition to the development of the Armed Forces, UAE government has been launching many UAE defense companies with state-of-the-art defense portfolios. Such of these are Emirates Defense Industries Company (EDIC), Mubadala Holding Groups, TAWAZUN, and YAS Holding. These companies are able to produce defense technologies and compete in the local and international defense markets.

3.1.1.1. UAE Military Research and Development Environment

To enhance its capabilities and acquired weapon systems, UAE Armed Forces has established Research and Development divisions in most of the units. These R&D

divisions have been supported by engineers and experts in order to improve and develop their weapons. To further strengthen the capabilities and expand the knowledge, the Armed Forces have established the Research and Development Centre of the UAE Armed Forces (RDCUAEAF). The main objectives of the RDCUAEAF are to develop the Armed forces systems, create/develop/enhance new ideas, and provide state-of-the-art solutions to the armed forces so that they can better address issues, problems, and challenges.

Work at the Research and Development Centre of the United Arab Emirates Armed Forces is continuously challenging as new requests and developments are part of the daily work environment. Consequently, this kind of environment's projects require a variety of resources and expertise and include a high degree of uncertainties and risks which may potentially interfere with successful completion of these projects. Therefore, potential risks ascend which threaten the successful completion of the projects and frequently these projects fail to deliver their basic outputs due to these risks. As a result, process improvements and systematic practice of identifying and managing the threats that exist in these projects and the project's environment are required.

3.1.2. UAE R&D

There is far less literature available on the research involved in R&D related to the Middle East countries including the UAE. Nevertheless, some information is available about the civilian sector's research and development in Middle East countries (Wam, 2018). The lack of information, even though it reduces the total quantity of information gathered in the research, at the same time, it also increases the prospect of adding new information to the already existing literature on the research and development in the defense sector in Middle East countries.

Appendix J shows an extracted statistical study conducted and published by UIS in 2018 (UIS, 2018). It shows the number of R&D researchers per million people for each year in most countries, and shows either few numbers of researchers or no information in most of Middle East Countries; perhaps due to lack of available data.

Nevertheless, there are many research efforts that exist in R&D in the civilian sector in most Middle Eastern countries, including postgraduate PhD students. For instance, the UAE is the home to around 70 higher learning accredited institutions that involve

international and large public universities active in research activities. So, universities from other parts of the world that are renowned and want to increase their research and development information on the Middle East countries collaborate with the universities of the UAE. This collaboration includes R&D initiatives, innovation, entrepreneurship, and science and technology.

To that extent, to the best of the researcher's knowledge and exploration, not even a single study is present, or even a part of specific research is present, which includes the information regarding risk management in the sophisticated research and development projects of the defense sector. Hence, it becomes more robust to find the information on the research and development projects of the military, which is rarer because of the nature of work involved, some of which is highly classified for national security. It is for this reason that the information available is sparse. The information related to R&D in various agencies is available on such topics as energy and technology but information about the military is more opaque (Wam, 2018).

3.1.3. Foreign Partnerships Strategy

The United Arab Emirates has maintained its close relationship with its allies due to the country's sizeable financial resources. In addition to this, the relationship with the major countries has allowed the country to get privileged access to the top players in the defense industry. The country is in a unique position to discover opportunities related to the military industrial sector that other countries can only think of reaching. Furthermore, the increase of globalization has also helped the country in various ways regarding its overall military transformation.

With the increase of information technology and globalization, the country has witnessed a revolution in its military affairs. The military of the country has opened up for international traders of the defense industry, which has helped the country in overcoming various challenges related to the upgrading of its own defense industry and overcoming the technological challenges within the industry.

It is arguably the imperative of every country to modernize its military power to show its military strength to the world (Paret, 1989). The same is true for the United Arab Emirates, which has both national and foreign policy interests in creating a modern

military industry in the country. The national policy interest is to create a military industry that is capable of competing in the global deference market. An advanced and highly modernized military industry will attract clients from all around the world as well as help the country to upgrade its military strength.

Another reason for modernizing its military industry is to develop the manufacturing capabilities related to arms in order to address a broad range of apparent internal as well as external security threats (Al-Ghafli, 2018). It will also help the country to reduce its high level of dependence on the USA, the UK, and other weapons suppliers globally who are playing a bigger role in the international defense market. An additional reason to increase the defense industry's power by modernizing it is to diversify the economy of the country, increase its prestige in the region, and to increase the credibility of its military as well as to gain diplomatic leverage.

However, it is not the case as the country is not self-sufficient in terms of military power at present and only the modernization of its military power will help the country to become self-sufficient. There are some defense and security areas, such as the need to acquire ammunition and spare parts as well as the existence of potential threats that have made the country take a step towards the modernization of its military force. The research and development in this field has increased due to the modernization of the military forces in the United Arab Emirates. The focus is to get as much knowledge as possible about advanced technologies so as to create a domestic industry.

The country now additionally manufactures, designs, as well as modernizes its communication through the use of electronics, military vehicles, drones, and various other systems. In addition to all this, the country has also managed to upgrade its repair, overhaul and maintenance capabilities in other areas such as the aerospace industry. It has not only helped the country in reducing the operating costs related to various aspects but has also started developing the country as an alternative market for the defense industry.

Additionally, the country has enhanced its military power in terms of competency and training. It is now capable of operating some of the weapon systems that, by comparison with others, appear sophisticated. The country has also increased spending on its defense as a proportion of its overall national Gross Domestic Product (GDP), and has also successfully incorporated and adapted to technological advancements. The addition

of more and more new equipment in the defense sector has increased the strength of the armed forces and helped the country to gain a higher position in regional areas and in global regions.

The increase in strategic partnerships with Paris, London, Washington, as well as with leading international defense organizations for the past several years has offered the country a breakthrough so that it can pursue its defense industrialization more aggressively. However, of all the contributing factors, the factor that has aided the country in modernizing its defense systems the most is the transfer of technology that has contributed most in developing the country's indigenous defense capabilities.

With this continuous effort from the government of the country to upgrade its military and armed forces, the country has projected itself amongst the top twenty military offsets in the international market at least for the upcoming decade (Bath, 2005). With the help of these offset programs, the country has been able to connect its national defense sectors with international producers of defense products, which has also enabled the country to acquire the basic know-how and knowledge of the industry. The results generated are mixed, and for some areas, the results generated are encouraging, which is evident from the establishment of several indigenous industries in the capital of the UAE, Abu Dhabi, and various other locations in joint ventures with multiple global partners.

The modernization of the armed forces is on a successful path towards the industrialization of the domestic military, which depends on the objectives set to achieve and the efforts taken to achieve the desired objectives. The armed forces get the most benefit out of the industrialization of the defense industry. However, it depends on various factors such as effective national leadership, political stability in the country, and sufficient finance, which are all present in the country (Blumenson, 1980).

Nevertheless, to sustain, rationalize, and develop the process in a longer run, the country needs to ensure all the related aspects are in place for the effective implementation of methods and approaches for the industrialization of the military of the country. Even with the continuous research and development and technology support from partners, the country still needs to follow some of the recommendations to enhance the complex systems in its armed forces.

3.1.4. UAE Requirements for Defense Sector

Various factors contribute to the success of a project. The projects aimed at armed forces have specific requirements, and thus these must be presented before undertaking any defense project. Some of the requirements in the defense sector of the UAE are in the following section.

3.1.4.1. Defense Production Policy

The United Arab Emirates needs to focus on what is an immediate priority in the modernization of the armed forces and how research and development can help the country to enhance the strength of the armed forces of the country (Saab, 2014). They have to formulate transparent defense production policies in addition to effective long-term planning related to defense.

The reason for focusing on long-term planning is that it is vital to manage the consistency among the long-term and short-term plans and decisions. The aim of the defense production policy is to develop an environment which encourages a robust, dynamic, and modest defense industry. It will make the country self-reliant as well as offer the country a chance to help neighboring and friendly nations in the defense sector.

3.1.4.2. Technology Shift

The country is working on research and development and the upgrade of its complex defense systems to enhance it with every possible technological advancement to make it a market for the top players of the defense industry (Saab, 2014). However, the UAE as a small nation is aware that working on its own will not offer any great advantage to the country, and so, the United Arab Emirates should accept help and assistance from its experienced partners and allies to increase its armed force's power.

Moving forward in the military equipment market with a diverse approach by producing different military equipment is the necessity of today's world, as diversity has helped several countries to transfer technology from military use to address the areas where it is actually required in the common public world (Saab, 2014). Additionally, the country has to set up training centers that will encourage its nationals to learn and understand the skills related to the profession, which are beneficial for the country in both

short as well as in the long term. It will help the country by making it self-dependent and eventually it will be able to develop an effective defense system.

3.1.4.3. Participation of Private Sector

Almost every industry and government requires the participation of the private sector (Saab, 2014). It not only opens the market for everyone who is interested to do business in that market but it also increases the competition among the involved players, which in turns increases the quality of the products and services that the private firms offer. It also expands the market for international players, which also increases the quality of products and services as well as global reach.

The UAE should allow the participation of the private sector in its military industry. The involvement of the private sector will play a greater role in the upgrading of the country's military, and it will also offer huge funding to play a vital role in the development of the defense industry. However, allowing the private sector to get involved in every part of the defense system is not a good choice, as it can hamper the confidentiality of the activities involved in defense, and, hence, the country should reduce the involvement of the private sector by only allowing them to offer their respective services for the outer aspect of the defense sector. Thus, the country has managed the defense production by making these defense productions fully state-owned (Saab, 2014).

3.1.4.4. Repair and Maintenance

With the increase in the involvement of several players across the world in offering the defense-related equipment to the UAE, the country should focus on providing the necessary training to its national technicians and engineers, which are very few in numbers (Saab, 2014), in order to gain the knowledge required for the operation and maintenance of the modern acquired equipment.

The knowledge related to maintenance techniques allows the other participating nations to monitor the majority of the operational activities of the UAE. Thus, the country needs to focus on the training of its own engineers and technicians to reduce the involvement of any other nation or sharing its operational activities information with other nations. The country, therefore, requires focusing on the training to increase the

capabilities of its technicians and eventually it will also attract the investment from other nations or international investors because of the capability of these technicians and their availability.

3.1.4.5. Clear Strategy and Purpose

The modernization of its military is what every nation wants to achieve (Saab, 2014). However, the majority of these nations take assistance from other military advanced nations without a clear purpose of strategy for a long-term. The UAE is on a similar track. However, it has a strategic approach towards the industrialization of its military and understands the overall functioning of it.

The country should take emphasis on the high-tech equipment and that also on a small scale, which it finds as the best approach to move forward by producing small useful less complex military equipment. This approach is also good if the country wants to achieve the objective of development of its military personnel who eventually will be able to develop high tech equipment for the country's armed forces, without assistance from other nations.

3.1.4.6. Industrialization of Defense Organization

The involvement of foreign partners in the armed forces, including the equipment and other elements, can help in increasing the technology involved in the defense organization of any country (Saab, 2014). The UAE is also trying to increase the strength with its defense organization, which would aid it to reach a position where their defense organization is also among the elite defense organizations globally. It will also increase the research and development within their military thus increasing the strength with their armed forces to tackle challenges easily.

However, a market is only attracted to global players when it is not restricted by any means that create hurdles for free trade (Bath, 2005). Hence, the UAE needs to ensure that its military industrialization is done according to global regulations. For example they should avoid giving all control to few people - where the rulers or the military commanders have the controlling power, as the favored players, those who are friends with rulers will be the ones getting the maximum profits from the industrialization of military, thereby

restricting the involvement of other global players as well minimizing the scope for innovation and the inclusion of new technology in the military to increase the strength of the armed forces.

3.1.4.7. Role of Research and Development

In the past few years, countries have witnessed the downfall of research and development in the global military regarding the overall spending (Saab, 2014). The core reason for this downfall in military spending is the improvement in the overall security situation in the world, which is far better than it was at the time of the World Wars or the Cold War. Now the majority of the countries focus on research and development related to the improvement in the living conditions of the country's people. However, there are few countries that are on the path of increasing their military strength not only to increase their defense supremacy in the world but also to increase their strength as compared to other regional nations.

The United Arab Emirates is also on the same track, and thus it is concentrating on increased research and development capabilities in its defense organizations. Research and development play a vital role in increasing the strength of the armed forces of the country. It not only increases the country's grasp on military technology but eventually increases their influence among neighboring nations. Research and development can help by introducing technology that both civilians, as well as the military, can benefit from, specifically the electronics that are highly used by both the military and civilians (Paret, 1989).

3.1.4.8. Science and Technology

The importance of science and technology cannot be ignored in today's world and how it has transformed the world (Saab, 2014). Science and technology investment in the military ensures a huge growth in the potential of the country's armed forces. There are several other benefits of science and technology - as it aids in countering special threats from terrorism or any other hostile elements.

The UAE should strategize its core priorities related to the industrialization of its armed forces, and how research and development will help the country in increasing the

strength of its complex military systems. Science and technological involvement need to be developed from the institutional and college level to ensure that the young educated people are aware of the elements involved in science and technology and how they can be used for the betterment of the country's armed forces (Saab, 2014).

3.1.4.9. Offset Programs

The UAE should integrate its offset programs with its national strategies in order to get an overall industrial development (Saab, 2014). Prioritizing these offset programs helps the country to reduce their dependency on other developed nations regarding the advancement in the defense sector. With the country self-capable of developing offset programs, it will not have to depend on external suppliers of technologies.

3.1.4.10. Bilateral Military Cooperation

One of the best things that the country can adopt from bilateral military cooperation with other countries is the experiences and skills of the other participating country (Saab, 2014). There are various benefits of getting into joint military operations. It helps in understanding the techniques used by other nations to tackle challenges and new technologies that the former is not using (Saab, 2014). Bilateral military operations would be highly beneficial in terms of the economy of the country, as it would offer a high chance of skills and experience exchange in addition to access to a qualified workforce.

3.2. Influence of Military Industrialization

The UAE has made several efforts in the past decade to upgrade the performance and strength of its national defense (Saab, 2014). The primary methods in these upgrades are the purchasing of the arms from other arms exporter countries such as the USA, and opening up its military for industrialization. The UAE has the required potential to develop its own weapons and equipment manufacturing programs to reduce its dependency on other nations. This will also help the country to eventually expand its reach as a global supplier of weapons and equipment.

Nevertheless, if the partnership goes well, both the host and the participating country will benefit from it, and in case the deal goes wrong, it will increase the differences

between the countries in terms of military activities. Various factors can contribute towards the creation of challenges such as policy differences, different issues and objectives, and others. A military partnership is usually beneficial for both parties involved as both get an exposure to the technologies and methods used by other countries, which can be adapted by improvising and incorporating into the existing strength of the armed forces.

The core reason and motivation for the UAE to pursue the industrialization of its military is to reduce the country's dependence, politically and economically, on these nations. The lack of self-dependency means that the UAE has to depend on its allies for several activities such as help in extreme cases. It usually happens that allies of the United States, even though have benefited from this unilateralism, sometimes also experiences problems, including undermining their security interests. The UAE needs to make it a priority to take assistance from its neighbors rather than other foreign nations. The involvement of a third country that is not in the region of the conflict, according to some experts, is not a good sign (Paret, 1989). Instead, the countries of the same region need to intervene in the regional conflicts such as the threat of terrorism faced by Middle Eastern nations, should be solved by the countries involved in the region.

The increased military strength of the UAE will also benefit its neighbors, and the country should involve itself with its neighbors by offering them military assistance. Doing this not only ensures that the region has a powerful military nation which can tackle terrorism, but it also helps the military by offering them a chance to engage in a war-like situations, which increases their efficiency and experience in fighting the terrorists. The UAE has the chance to set up their own defense bases and resources within regional areas to defuse any major crisis occurring in the future more effectively, without much preparation in less time.

The industrialization of the military may project the fact that the UAE wants to open its market for all global companies who want to trade in the market, but a majority of its upgrading of its armed forces capability can be completed with the help of partner countries such as the USA. The integration of the national defense systems such as reconnaissance, surveillance, intelligence, and missile and air defense systems for security purposes is a priority for the country, and thus it looks towards Western allies for these

upgrades. The most significant requirement of an R&D center is to avoid the need for assistance from other allied nations in extreme situations. At present the scenario is different, and the government of the UAE tends to look for its partner nations for help at the time of military crisis and for upgrading their weapons and equipment for military use.

The research and development in the country's military are on an increasing trend. However, this is highly complex as it involves dealing with complex projects that, if successful, may produce outcomes that are already present in the allied nations with the use of existing resources. On the other hand, if the complex projects fail, it means the use of necessary resources without getting anything good in return for the country (Alessandri et al., 2004). Thus, the Research and Development Center of the United Arab Emirates Armed Forces requires guidance from trusted personnel who are from the country themselves and understand the actual requirement of the country at present.

Another reason for the country to pursue the development of the research and development center of the armed forces is that at times when the country demands highly advanced items related to military, the restrictions on the export of those items restrict their availability. For this reason only the country's focus on research and development center is valid. This research and development center may not be able to produce any fruitful results initially, but eventually, with the increasing experience, it will offer enough necessary items for the military that would be enough for the country.

Forming a research and development center for armed forces will reduce the country's dependence on its allies for these items as well. The partnership with allies is a double-edged sword which offers several benefits but can also reduce the country's freedom in several military matters if its military strength is not equal to its allies. It usually happens that at the time of purchasing equipment for the military, the country's first choice is usually its allies. However, it takes a lot of time as the response is not often so fast, and in the case where the equipment or items are required immediately, this lack of response can create trouble as the circumstances are changed at the time the response is received.

It is for these primary reasons that the country is eager to set up a research and development center for its armed forces so that at the time of need, they are ready with equipment required. There is ample opportunity for every global dealer who either deals

in military equipment or research and development of military equipment to increase their business from the industrialization of the military of the UAE. It will be beneficial for the country as well because it will help in improving its workforce, manufacturing, and an increase in skilled expertise.

Unless the UAE takes an effective decision on how to move forward in the research and development center for the armed forces, and remains dependent partly or fully on the allied forces, the country will never meet the full potential. This dependency will also restrict the country's involvement with other nations offering military expertise and knowledge required for advancement in military technologies.

3.3. Motivation for R&D Center of the UAE's Armed Forces

The UAE can achieve various benefits through a research and development center for its armed forces not only on a national scale but also on a global scale. Research and development in the country can help in modernizing of the military where it is capable of competing on a global level. Also, the research and development center within the country will attract defense market investors to take part in the market (Blumenson, 1980). Various foreign and domestic policy interests are involved in the creation of a defense research and development center such offering economic diversification for example the opening R&D facilities in other areas such as the health sector and education sector with the help of investments. It can also offer political freedom where decisions are based on the betterment of the public by the political leaders. Another is nation's security and status, where the priority during the completion of project is focused on how can the result offer more security to the nation and increase its status in the global security platform. Further, it will also take into account the fact that diplomatic influence on the global scale will increase as well as an increase in military standing among other global military powerhouse nations such as USA, Russia, China, and India (Bath, 2005).

3.3.1. Motivation Factors

3.3.1.1. Political Freedom

Increasing research and development in the country will make it self-sufficient. Self-sufficiency regarding the security and defense is a significant mode, which will aid the

UAE in reducing their political dependence on other nations such as the USA and various other countries with military power, and who dominates the defense market globally. Almost every country wants to produce arms and ammunition for their military locally within national boundaries. However, it is not as easy as it seems to produce weapons locally and, hence, requires lots of research and development in this direction.

Establishment of an R&D center may seem easy, but it requires a tremendous amount of investments and thus require workforce which should be capable of offering a quality return on investment (Alessandri et al., 2004). The country as of now is in a joint venture with other nations in its research and development center, and taking help via knowledge from other developed nations to move forward by investing in equipment that is capable of meeting the requirement of the country in future.

The production of arms and technology locally means that the production costs are reduced and there is a reduction in export and supply constraints from the importing nations. It also means the country will have the ability to increase its capability in the defense sector and pursue their needs and objectives. Various equipment and weapons used by the armed forces such as combat fighter radars, electronic warfare systems, and missiles are all supplied by other nations, which the country considers for usage and thus they must be produced locally, initially with a partnership and eventually on its own.

3.3.1.2. Nation's Security

The UAE has its own share of national security threats that challenge the country and require active attention. The UAE seeks to manufacture and acquire modern weapons and technology to address these threats to national security. The country is within the region that has consistent security threats with its nearby neighbours being in a state of war with terrorism. With their neighbors fighting terrorism, the chances of the country being involved in this war are greater, and thus it requires the establishment of research and development center in the country (ALVAH, 2012).

As the situation is at present, there is no need for the country to pursue its own costly research and development program when it can quickly seek and accept help from its allies in case of any terrorist emergency or situation. The establishment of an R&D center is

costly, risky, might produce a low return on investment and includes various other drawbacks, which can easily be reduced by receiving help from its allies.

However, while such a partnership is great, a country should not rely on any foreign nation for its security because, in this modern world, the only flourishing countries are those who have the potential to tackle every challenge they face (Kaufman, 1987). On the contrary, smaller and non-developed nations are struggling to move forward as they lack both the finance and skill required to take the country ahead through global competition (Scott, 1996; Snow, 1991). Owning a research and development center may not offer a profitable return in the initial years due to the lack of various factors but will eventually help the country in growing and succeeding on a global scale.

3.3.1.3. Status

Developing technology within country means the increase in the status of a country. The country can use the defense R&D center for various other purpose innovations in other sectors apart from the innovation and introduction of new technologies for the armed forces. A country with own developed weapons and technologies is highly respected in the global platform such as France, USA, and various other nations. With a strong military power base, political relations also strengthen.

Research and development will aid the UAE in increasing its power, not only in the region but also globally, as it will increase the country's decision-making power as well. Increasing its status will mean the UAE can play a vital role in the region in mediating disputes, such as those between India and Pakistan, South Korea and North Korea. The research and development center can not only be used for military innovations and improvements in military technologies but can be used for other fields as well such as space, common public use technologies and innovation and more.

Increased status in the region means that the investors from other parts of the world would like to invest in the modernization of the country's defense, which will offer a market for international investors. The research and development center with its innovations can help the country not only in the defense field but will lead the country in the international community. It can do so by offering advanced science and technology, thereby increasing the national prestige of the country on a global level. The UAE can

display its accomplishments regarding the defense industry, which in turn will increase the military profile of the country and its international status.

3.3.1.4. Diplomatic Influence

Establishing strong military ties between nations requires diplomatic influence by leaders. The strength of the industrial sector in the country contributes towards its increasing diplomatic status. Usually, a country with a strong military power has political leverage in almost any part of the world (McEnaney, 2008; Smith and O'Connor, 1972). The research and development center of the UAE for armed forces will help the UAE to increase its military power globally, which in turn will increase the diplomatic influence of the country.

The use of science and technology to gain an advantage in the public sector is common, and thus military industrialization increases the use of science and technology and this, in turn, will provide the country with higher levels of diplomatic power. Increased diplomatic power means that the country can put influence on decision making in global affairs. It will also offer a chance for the armed forces to test their efficiencies against those of their rivals. Increased diplomatic influence means increased power in the region and thus others will look to the country to take the lead on significant decisions.

An example of this is the increasing military power of China, which makes it the significant player in the China Sea and thus the country keeps on doing things, which other small neighbors like Japan and other nations do not like (Bath, 2005). However, due to the massive military power of the country, others fear the repercussions of directly criticizing China. In global fora, including the United Nations Security Council, China has increased its military power in recent years and is among very few countries who have a Veto Power. Research and development in defense industries may not offer any direct initial returns, but over the long-term, it can offer a great advantage to the country in terms of its own defense, in fighting terrorism, regional leadership and security, and creating an impact through global security platforms.

3.3.1.5. Increase in Military Standing

If a country is a heavyweight in terms of its military capabilities, the country is inclined to display its power to neighboring countries. This posturing is not only directed towards neighboring countries but also towards its allies, which indicates that the country is capable of developing and producing equipment for its military locally within the country. It also shows that the country can rely on itself to address some security challenges is signaling that it does not require help or assistance from its allies every time its security is threatened.

The partnerships the UAE has with its allies are beneficial to its security as taking joint military exercises with its allies plays a vital role in strengthening the partnership between both the countries (Saab, 2014). With a very modest military, there is always a chance for the armed forces of UAE to learn from its partners. Joint military exercises help the armed forces to get ready for the times when defensive actions are actually required during either terrorism incursions, infiltration, or any other threats to national security.

While the establishment of a research and development center for the armed forces can guide strategic thinking and planning, the procedures and the regulations regarding the military also influence the progress of the projects involved in the research and development. Another important consideration is human resources, and these decisions determine who actually uses the munitions and technology. The core reason for having research and development in the defense sector is to develop and acquire advanced equipment for the armed forces so that at a time when they have to tackle any issue, they are capable of achieving their objectives with minimum effort, cost and loss of life (Alessandri et al., 2004).

The operation of equipment that is produced domestically is easier to understand and optimize because of the involvement of local people in the research and development process and the development of that know-how to understand the essential requirements of the people who will be using the equipment. On the other hand, importing the equipment from other nations means that the seller does not know the capability of the purchaser or their skill level, or which systems the new equipment will be integrating with, and therefore the new equipment may not meet the buyer's requirements.

It is easy to train the country's people about the equipment made inside the country as people with common thinking and understanding of the environment make the equipment. On the contrary, equipment imported from other nations requires more capital for purchasing, training related to the equipment, and the provision of a trainer who is aware of the equipment and how it functions. The learning process takes time and capital, which for domestically produced equipment can be saved and used in further research and development processes (Hoon Kwak and Dixon, 2008).

The involvement of complex R&D projects in the defense sector means the investment of huge amounts of capital. With the aid of proper project management and risk management, the majority of the projects are completed successfully, however, in some cases, these complex projects end in failure. An example of this is the biggest misstep was budgeting for the development of a combat vehicle that was capable of working both in on land and in the air – this was once seen as being the future of combat by the military.

Even after Boeing, the prime contractor of the project, kept everything on track from budget to resources, the Secretary of Defense decided that the project will not be able to get completed on time, and hence the project was scrapped after a whole $19 Billion was already spent on that project (McEnaney, 2008). This shows how the resources was wasted by investing it in a non-completed project.

A similar condition is faced by the armed forces of the UAE where complex projects are handled by the R&D center of the armed forces. The researchers are finding various challenges such as cost, innovation, speed in work, and various others. Therefore, it is always necessary to develop a risk management process, which is capable of measuring, identifying, and controlling the uncertainties and risks to apply them to the actual risk management processes involved in the armed forces' R&D projects.

3.3.2. Defense R&D in UAE

Defense research and development in the UAE has already picked the pace required by the country, and recently, research and development in the public sector has also increased apace. This increase in the research and development is not only because of the need to meet the requirement for fighting terrorism, control sovereign borders and secure

national defense but also to reduce the imports of military needed equipment from other nations. Various Arab nations including the UAE rely on other countries for meeting their military needs, and this is usually at a high cost.

The global ranking of arms importers lists the UAE at third place, accounting for approximately 4.8 percent of its military equipment being imported (Revolvy, 2018). In addition to this, the market is still showing potential growth, where the increase in the import of military equipment can be seen as being due to terrorism activities in the Middle Eastern region. The imports of military equipment have shown an increase of 113% by UAE, which makes the region a market for other equipment manufacturers to sell their equipment rather than being considered as a developer and seller (McEnaney, 2008).

The setting up of an R&D center for the armed forces may not generate any useful results for the country. However, any organization, public or private, understands the fact that R&D projects are complex and that R&D investments are unlikely to generate profits in the short-term (Graetz and Franks, 2015). Instead, R&D activities produce outputs in the long-run, which is more uncertain.

Nevertheless, the research and development center of the country for its armed forces need to be capable enough to carry out substantial activities apart from just small innovations and improvements. “Substantial activities” this context might include significant innovations for the military to reduce the country’s dependency on others for equipment imports (Mousavi et al., 2011). Another thing that the research and development center needs is a skilled workforce that is capable of competing with R&D facilities of other nations. It may not have such a staff complement initially, but eventually, it should be capable of achieving this accomplishment and be able to produce innovative equipment and systems for the armed forces of the UAE.

Another thing to consider while setting up the research and development industry for the armed forces, where the complex projects will be completed, is the need for the development of complementary industries that are necessary for effective functioning of core R&D facilities. These industries include manufacturing in metal products, non-ferrous metals, iron and steel, transportation equipment, electrical machinery, and non-electrical machinery (Saab, 2014). Even though the R&D center is not capable of

competing on a global scale or unable to produce products for the UAE's armed forces yet, it will be, eventually.

As of now, the UAE has started working on this direction, but various attempts have shown a little growth. Apart from this, there are several technical aspects that the R&D center needs to take into consideration. For instance, the technology is continuously changing and the times when the military once had the newest and latest technology has changed (Saab, 2014). Now, new technologies are equally enjoyed by both military and civilians. It is, therefore, more important to understand the basic need of the R&D center as it will not only innovate or generate suitable results for the armed forces but civilians as well.

3.3.3. Performance in Recent Years

The UAE government is highly focused on its defense sector. This indicates that the country is aiming to become a more powerful military actor by improving utilization of equipment and exporting arms internationally. The UAE military has developed significantly over the period. In the present time, the UAE military is equipped with several advanced technologies and latest design weapons and systems. However, the major segment of the weapons and defense equipment are imported from other nations.

In the last couple of years, UAE has invested significant amount of time, money, and resources in producing equipment for its military. The UAE government is focused on bolstering its armed industrial base. The UAE has established its strong military presence in several parts of the world such as in the Persian Gulf region. With the strategic aspirations, UAE has exhibited signs of utilizing its defense sector to strategic ends. Presently, the UAE military is equipped with the best weapons and defense vehicles, with most of them being imported (Revolvy, 2018).

Despite the fact that the UAE military is heavily dependent on the import of weapons and equipment, the UAE government is highly focused on the research and development of the military. The government is striving to provide the military with advanced technological weapons and equipment. Countries across the world are investing significantly in the research and development function of their military (Mousavi et al., 2011). In the present time, armies across the world are striving for producing unique and

innovative weapons and vehicles in order to show their strong presence in the defense sector. Like other countries, the UAE is also focusing on research and development in order to produce a greater number of unique and new weapons and equipment.

Every country is required to develop a strong industrial base for the benefit of the economic condition of the country (Revolvy, 2018). Industrial assets play a critical role in enhancing the economic conditions of the country as these assets are used in the production, repair, and maintenance of the equipment. Every country is required to have extensive and skilled research and development function. Like any other industry, the defense industry also requires R&D facilities – the need for this is of equal importance for the role of R&D in other industries. Furthermore, the individuals including scientists, technicians, and engineers play a very critical role in the research and development function in any sector.

Initially, the UAE had a smaller number of scientists, engineers, and technicians in the research and development functions of its military. In the context of efforts under the research and development system, the country has set some military industrial levels (Revolvy, 2018). These levels indicate a process from level 1 to level 8, which clarifies the working of the people involved with military services. These levels show that the R&D center for the armed forces of UAE needs to ensure proper and effective working from all the involved staff members. In addition, these show that the country has the capability in terms of the R&D to compete with other global military R&D facilities in the upcoming future (Revolvy, 2018). The levels are described thus:

- *Level 1:* The research and development function are supposed to maintain and repair the imported weapons and systems.
- *Level 2:* The team is supposed to do overhauling and refurbishing of imported materials and weapons.
- *Level 3:* The team sitting at the research and development function is required to assemble the imported assemblies.
- *Level 4:* The team is required to ensure the limited licensed manufacturing of locally made parts and re-export of these components to the licenser.
- *Level 5:* The team is required to ensure the licensed production and assembly of less sophisticated parts.

- *Level 6:* The team is required to ensure the limited modification to the produced (licensed) arms through independent or domestic research and development.
- *Level 7:* The team ensures the production of the sophisticated arms from local, independent research and development along with the foreign components.
- *Level 8:* There is complete independence in research and development and production.

Like other countries across the world, in the early years of development, the UAE has faced several challenges in initiating projects in the research and development facility of the military. Lack of funding was the main issue that the country faced in enhancing research and development. However, the situation is now very different from what it was several years ago. UAE has seen rapid growth and development in the last couple of years. It, to a very great extent, has reduced the problem of funding. Globalization has enabled the country to grab the opportunities available in the global marketplace. Development and growth in the economy have significantly benefited the defense industry. The government, now, has enough inventory of resources to be invested in the defense industry's research and development.

There have been several deals and initiatives that the government has made towards the research and development of the UAE military. One of the very good examples of government initiatives towards enhancing military conditions is the launching of strategy to start several projects like the joint production of ammunition, vehicles, light weapons, and electronic shooting systems (Bath, 2005).

In addition to the starting of various projects, the government of UAE focuses on coordination and cooperation with foreign militaries, coordination in military system maintenance, and most importantly, standardization of military systems through enhanced research and development functions (Bath, 2005). Such initiatives are very helpful for people engaged in boosting the research and development function of the military. With these kinds of initiatives; scientists, engineers, and technicians working in RDC get motivated to make extra efforts in order to provide the country's military with latest featured weapons, vehicles, and systems.

The country has also started to produce a significant amount of defense equipment in order to reduce the high dependency on the import of military items from the foreign marketplace. In addition, the country has realized that dependency on imports can only be reduced by investing more in research and development in the country. The government has also realized that there is a need for providing individuals (scientists, technicians, and engineers) who are working in the research and development facilities with the latest tools and instruments, so that they can advance their knowledge in order to make the country able to produce military weapons and vehicles locally.

The RDC in the UAE military has made joint deals with several foreign companies. These companies have helped the country's research and development facilities in several projects. For example, Tawazun LLC and Rheinmetall Munitions Systems joined together and helped research and development function of the country to produce military weapons (McEnaney, 2008).

The country is growing year by year. The country has strived to show its presence in every sector and around the world. The country is fully focused on its defense industry, and is consistently making efforts toward enhancing its industry. The higher authorities, even the private entities, have forced the country towards making larger and larger investments into its research and development facilities which is very critical to maintaining the robustness of the military (McEnaney, 2008).

No matter how enthusiastically the UAE starts its research and development center for its armed forces, unless there is motivation to move forward for researchers, it will not be a success. There is a need for motivation for a researcher from not only the country but from other parts of the world to get involved in the research and development programs (Scandizzo, 2001). For instance, to attract more researchers from the world and encourage them for R&D projects, the Department of Energy in the USA launched budget and reward incentives for those types of projects (Ulku, 2004).

In the case of the UAE, the customers are the member of the armed forces who at the end are the ones using the most innovative products of their research and development center. The involvement of these members of armed forces, who are well experienced and who understand the requirement of the armed forces is to develop projects that can be helpful later.

3.4. Strategic Partnership in Projects

Project management is also about going into strategic partnerships. When the scope of the project is substantially huge, then in these cases, more than one country can also be involved. One such case is the strategic partnership between the UAE and Saudi Arabia. The two countries went into a partnership that involves improvements in economic, military, and development integration. To develop a strategic plan, more than 300 government officials prepared *The Strategy of Resolve*, which is always a crucial part of the project management (Wam, 2018). The impact of this research and development project on the UAE was substantially high because it was aimed at improving three major axes of the country, - namely the knowledge and human axis, the economic axis, and, most importantly, the military, security, and political axis.

The UAE decided to achieve the pre-defined targets of the project within the next 60 months, with the aim of providing the UAE with a model that would support the Gulf Cooperation Council's work. This strategy is also aimed at protecting the interests of the UAE and offering new opportunities to the country. The overall project would be consisting of several joint projects. Some of them are related to supply security systems, medical stocks plan, and investment in petrochemicals and oil among other things.

The scope of this R&D project is substantially huge, and UAE cannot afford any discrepancies in their project management techniques. The scope can be understood by stating that this project also involves the establishment of an agricultural investment company, which would require around 1.5 billion USD. The banking sector and foreign investments will also be working under the scope of this project. The military industry sector will also be integrated, coordinated, and standardized.

When the scope of a project is huge, the management of the project will ensure that it is articulated clearly, and proper responsibility allocation becomes necessary at that time. The accountability will be reflected when the project is managed properly (Leong, 1991, pp. 240-249). Thus, UAE should establish a plan and a schedule to release the predefined goals of their projects. The establishment of a schedule should help to avoid any cost overruns and delays, which have the potential to push the project towards failure. UAE should also be able to maximize its resources if it carries out project management in

the proper way. There are many disciplines in project management, such as risk management, that will help the R&D activities in UAE to utilize the resources economically and efficiently.

With this project partnership, the UAE has the opportunity to develop a model that would facilitate cooperation activities. Such projects require unity and solidarity, and if provided, they will help in protecting the interests of the UAE and will strengthen their economy by building a better future (Zhang, Warner and Homsy, 2017, pp. 196-209). The combined military complexes of the UAE and Saudi Arabia form one of the most highly equipped modern armed forces and together, their GDP equals $1 trillion (McEnaney, 2008). The framework for facilitating bilateral cooperation can also be achieved by investing in similar infrastructure projects (Packer and Kugler, 2013). However, this would require the integration of business systems, processes, and organizations.

3.4.1. The Three Axes

3.4.1.1. The Economic Axis

The integration of the economic system is one of the major goals of the economic axis. Few of the key areas that the economic axis is planning on improving is a financial market, infrastructure and logistics, security of the supply chain, industry and production, water and agriculture, foreign partnerships, tourism, customs union, government development, and petrochemical and gas (Bruzda, 2017).

It is evident that the focus of the economic axis is substantially wide. To achieve success under the context of the economic axis, proper project management would include:

- Establishing policies that would strengthen the banking sector so that different branches of banks can improve their business operations and can enjoy benefits that are provided by the growth opportunities (Devereux and Love, 1995, p. 232). This would also help in facilitating the work procedures for the UAE and its research and development sector.
- The UAE can also ask for the sharing of experiences that are available in modern financial technology. Insurance sector from both countries can also share their experiences so that insurance markets can excel in terms of a

regulatory mechanism, pricing, and products (Sheremet and Lucas, 2009, pp. 415-425). Experiences can also be shared in the field of infrastructure development, and this would especially help the research and development sector of the UAE.

- A joint investment fund can be established for strengthening both medium as well as small-sized enterprises (Pézier, 2012, pp. 3-65). This would especially help the developing industrial sectors. In addition to this, manufacturing industries that hold the potential to add the most value can also be activated. This would particularly enhance the manufacturing sector in the fields of petrochemicals, aluminum, and iron.
- The industrial database should be built that would reflect precision and standardization. For industrial services and goods, coding systems can also be standardized (Devereux and Love, 1995). These systems will automate the majority of the process. UAE can also carry out a joint exercise that would improve the supply security system.
- UAE should consider investment opportunities in order to boost economic activities. This can be done by establishing a dedicated office and a unified electronic portal that would link both the countries to keep track of complaints and suggestions regarding common markets and customs (Pézier, 2012).

3.4.1.2. The Knowledge and Human Axis

The knowledge and human axis is aimed at creating an integrated and effective educational system. Project management in this context can include (Pézier, 2012):

- Cooperation in the fields of technical education, public education, research cooperation, and higher education (Blank, 1993, pp. 65-80). This should also include cooperation among different institutions that provide higher education. This can be achieved with the help of a joint plan that would aid in promoting common programs between both countries.
- Early childhood policies can also be established that would help in building standards from the early years of childhood and these standards should be consistent with the international standards.

3.4.1.3. The Military, Security, and Political Axis

The military, security, and political axis is focused on improving the integration and cooperation between both the countries in the fields of military, security and political fields. Project management in this context should include (Pézier, 2012):

- Initiatives that would facilitate joint manufacturing of electronic shooting systems, vehicles, light weapons, and ammunition.
- They should also establish the criteria wherein foreign military assistance should be coordinated, and military systems should be improved.

3.5. Summary

The United Arab Emirates has faced challenges in the past when its defense industry was weaker than ever. Now, several initiatives and projects related to the research and development function of the military have shown that the country is fully prepared to make higher investments of time, money, energy, and other resources in the research and development sector. The country is filled with highly skilled scientists, technicians, engineers, and managers who have shown their skills before and can take the research and development function of the country to the next level.

The country has at present a small research and development facility, where the companies are taking help from allied countries to overcome the challenges faced in the research and development of equipment for the armed forces. Setting up a research and development center in the UAE for the armed forces may help the country to understand the existing equipment exported from the allies. However, unless a clear strategy and appropriate organization of R&D is followed, the country will remain dependent on other developed nations for military equipment.

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4. METHODOLOGY

After setting up the research aims and objectives, reviewing the related literature on risk management in complex projects, in addition to the R&D environment in the defense sector and UAE, the next step was to design how to conduct the research. What was the best methodology to answer the research question? What type of data collection method was used? Who were the study's population? How was the sample drawn from this population? What ethical considerations were taken into account when designing and conducting the information collections? How was the data analyzed? What measures were taken to ensure the reliability and validity of the information gathered? All these queries were discussed in this chapter.

Thus, this chapter contains the research philosophy, methodology, research design, population, sample, data collection, data analysis, reliability and validity of the research, ethical considerations, and the conclusion.

4.1. Research Philosophy

The researcher's quest to understand the drivers or the risk factors that impact project management in R&D environment was placed at the core of the research. This understanding is based on the researcher's belief that every stakeholder is entitled to their own truth or version of the truth. The researcher kept an open mind and adapted the participants' views to build a model of the factors.

This quest and the researcher's belief have shaped the research philosophy and methodology. The researcher has kept pragmatism philosophy under consideration, which asserts that the reality is as important as the inner world of an individual's experience (Hore, 1984). Pragmatic philosophy is observed to seek a middle ground between the philosophical dualism. Thus, to understand the research problem in a better manner, this research was conducted using an exploratory qualitative method.

4.2. Research Methodology

Research methodology refers to the process through which the researcher conducts the research (Bryman and Bell, 2015). Research methodology is the key to a research

study. Every research study requires the researcher to choose an appropriate research method in order to ensure that the research study ends with the appropriate results and findings. Selection of the research methodology highly affects the effectiveness of the research study (Bryman and Bell, 2015). Choosing an appropriate research method is one of the critical tasks for the researcher. There are several options of the research methods that the researcher can choose from (Bryman and Bell, 2015). There are two main kinds of research methods; qualitative and quantitative research methods, which are the most widely used research methods and are used in almost every kind of research study (Bryman and Bell, 2015). In addition, a mixed method is also commonly used which involves integrating quantitative and qualitative approaches to generating new knowledge and can involve either concurrent or sequential use of these two classes of methods to follow a line of inquiry (Bryman and Bell, 2015).

4.2.1. Qualitative Research Method

The qualitative research method is one of the most frequently used research methodologies. Qualitative research is the scientific method which gives non-statistical data (Bowen, 2009). The qualitative research method is implemented across several academic disciplines, majorly focusing specifically on the natural sciences, social sciences, market research, journalism, and business (Bowen, 2009). The qualitative data involves the open-ended questions where the information have been gained through interviews (Lambert, Colin and Economopoulos, 1987; Kelly, 1986).

The aims and objectives of the qualitative research vary with the background of the research study. The qualitative research method is the best for the research study containing research questions about how and why questions (Bowen, 2009). Common approaches to conducting a qualitative research study are grounded theory, theoretical perspective, ethnography, personal interviews, and discourse analysis (Bowen, 2009). The qualitative method is effective in determining intangible factors such as social norms, gender roles, socioeconomic status, religion, and ethnicity (Bowen, 2009).

4.2.1.1. Advantages and Disadvantages

There are several advantages and disadvantages of using a qualitative research study. The qualitative research method provides the researcher with detailed data can be in too much detail (Bowen, 2009). By using the qualitative research method, the subject materials can easily be evaluated in more detail. The qualitative research method provides the researcher with data based on human experiences and observations (Creswell, 1994). The qualitative research method is an open-ended method (Creswell, 1994). Nevertheless, there are some cons to adopting a qualitative research methodology. For instance, the data obtained from the qualitative research method is not easy to demonstrate and assess. It is a time-consuming research method. The acceptability of the data captured has been considered to be the main problem in using the qualitative research method (Creswell, 1994).

4.2.1.2. Rationale for Using Qualitative Research

The qualitative research has been conducted in this research in order to gain a better understanding of the research issues affecting theoretical challenges as well as to attain first-hand knowledge. The researcher was aiming to gain better knowledge of what and how social issues affect the theoretical achievement. Also, by doing this, the researcher was aiming to obtain first-hand data and information. The researcher merged the data and analyzed results, from which the factors emerged from the themes.

4.3. Research Design

Research design is defined as the set of processes and methods used in collecting and assessing measures of the factors specified in a study (Creswell, 1994). The research design of a study describes the kind of study; correlation, descriptive, experimental, review, semi-experimental, and meta-analytic (Creswell, 1994). The research design links the research problem, the purpose and strategy of the research study. It is a responsibility of every individual to ensure that the research design clearly describes all the details related to the method, approaches, and strategies used in the research study (Bryman, 2008). The research design is the framework which has been developed to determine the answers to the research questions.

4.3.1. Important Consideration in Research Design

The research design is a road map or a blueprint for what a study will accomplish and has two main functions: formulating a plan of work, and making certain that the plan will yield the desired results (Kumar, 2014). The research design is referred to as the strategy that the researcher selects to integrate the various parts of the research study logically and coherently (Bryman, 2008). Therefore, it ensures that the researcher will effectively describe the research problem. The research design comprises the whole structure of research from research method to data analysis (Bryman, 2008). The selection of the research design is completely dependent on the type of research topic or study (Bryman, 2008). Researchers are required to choose an appropriate research design so that they can conduct research in a cost and time effective manner. The outcome of a thesis or research paper is highly dependent on the selected research design. Furthermore, the effectiveness of a research study is significantly influenced by the approach of designing the research (Bryman, 2008).

The research design is one of the most critical elements of a research study. It encompasses the decisions on how the research would be conducted, how the data would be collected and how the data would be analyzed (Bowen, 2009). Moreover, the research design addresses the ethical issues that a researcher should take into consideration while conducting the research. The research design also requires the researcher to address the limitation of the research study, which has always been appreciated in order to allow for future research to tackle such limitations (Bowen, 2009).

The design of the methodology is led by the questions involved in the research (Greene et al. 1989). This research aims to understand the risks involved in the research and development in the UAE armed forces regarding the complex projects. The objectives also involve the development of a framework related to the factors. The study is performed based on the guidelines and the involved elements and variables that aid in understating the risks and the factors involved.

4.3.2. Types of Research Design

The type of research design is categorized into various categories exploratory research, explanatory research, descriptive research, and evaluation research (Lambert, Colin and Economopoulos, 1987). Exploratory research is used where the research study requires the research team to explore the answer to the questions developed in 'how' or 'what' manner. In the descriptive research design, the researcher goes into more details than that in the exploratory research. This research design is also executed to answer the questions made in 'how' or 'what' manner but in more depth. Descriptive research design is mainly used where the researcher develops the abstract type of research questions, or the researcher study revolves around the abstract type of research question (Lambert, Colin and Economopoulos, 1987).

Explanatory research design is majorly used when the research questions are made in how, why, and what manner, and in which it focuses mainly on the why questions (Bowen, 2009). In this kind of research design, the researcher becomes the subject matter expert of a particular subject or topic on which the research study is being performed. In the evaluation research design, the researcher is intended to evaluate the effectiveness of the research topic or study (Lambert, Colin and Economopoulos, 1987).

The way the researcher develops the research design is affected by the type of research questions developed in the research. This research study was a quest for understanding the opinions of the project managers into what they consider a risk factor in their environment. The researcher set the priority to know the participants' points of view, their experiences, and eventually echo their voices in the results presentations. This quest to understand the different opinions, the underlying causes and the root issues when it comes to complex research environment will yield an aligned finding that forms the building block of the UAE Risk framework in such environment. The researcher was determined to understand the current procedures in place to deal with some of these risks and the procedures that the participants suggest to improve the current environment. The voices of the participants are present in the interviews, results, and the discussion, and conclusion of the research.

The exploratory research type was selected to be used for this research. The primary rationale of using this particular type of research design is that this research study

comprises several research questions and most of the research questions are developed in 'what' manner which calls for a thorough understanding into the phenomena at hand, the special social environment surrounding the research and development in a UAE context.

4.4. Research Ethics

Every research study requires the researcher to take ethical arguments or issues into consideration while conducting any kind of research. In every kind of research study, the researcher is required to ensure that the models, structures, approaches, and methods used in the research study do not harm the value or standards of any individual or social group (Piperca and Floricel, 2012).

Research ethics guide and dictate how the researcher should research the participants. It includes guiding the researcher regarding participants' rights. Research ethics require the researcher to ensure that no individual is being affected by the research (Piperca and Floricel, 2012). This research study was majorly relied on the primary research method due to which the involvement of humans was very high. Because of this, this particular research study required the researcher to be extra cautious about research ethics. Therefore, all participants of the research have been informed through a consent form on the purpose of their participation, that they will not be harmed or identified in any way throughout the study, and that they can opt out at any instance they want. These informed consent forms, **Appendix K**, must be read and signed prior to participation.

The researcher has been required to follow the university ethical code. Also, as the research study has included people from armed forces and RDCUAEAF, the researcher was required to follow the ethics and procedures of armed forces & RDCUAEAF. In addition, this particular research study has been following the approach of utilitarianism towards ethical problems in which the main emphasis is on the overall benefits of the research. Moreover, this research study has required the researcher to take the confidentiality of the armed forces data and information into consideration, and developed techniques have been used to ensure the security and safety of these data and information.

4.5. Research Validity and Reliability

Validity refers to the degree to which the data and concept are accurately evaluated in a research study (Bowen, 2009). On the other hand, reliability refers to the quality of measurement or the accuracy of the tool or instrument (Bowen, 2009). It is necessary for the researcher to ensure the validity and reliability of the research study. This research ensures that no outcome, in any manner, is biased as it can impact upon the overall research.

As researchers strive to be objective in their studies, qualitative phase involved steps undertaken to maintain the reliability of the data collection and analysis methods. The first step was recognizing the researcher's own bias and maintaining objectivity through this phase. Even though the researcher comes from the RDCUAEAF, the researcher has moved to a position in other department and thus have no interest in selecting certain themes or views over others. The researcher is aware of his own bias and has used a reflective analysis to address any bias involved in the interviews. The second step was to ensure that the sample was homogenous. In selecting participant-samples for the interviews, the researcher has maintained the homogeneity of the sample through project managers to avoid selection invalidity (Tuckman & Harper, 2012). The core focus was the identification of risks associated with the complex R&D Projects that the sample of the study was well aware of and shared similar opinion on the importance of this factor. Lastly, using the feedback of the participants ensured interpretive validity and using the direct quotation of the participants ensured achieving low-inference descriptors (Johnson & Christensen, 2012).

4.6. Population

The research population is defined as a group of individuals or a set of objects that possess similar characteristics (Bryman and Bell, 2015). Objects and individuals within a particular population, in general, have the same kind of characteristics. The population is the group or set from which the researcher selects participants to participate in the research study.

In designing research, it is important to define who will constitute the research population (Kumar, 2014). Since the research study focus is risk management in

RDCUAEAF, the population of the study, by definition, were the military personnel that took a role in the development of complex projects as project engineers. This population had two types of such managers; the ones who have been promoted to other positions in the research center or transferred outside the center but were involved in the past as project managers, and those who are still within the facility and are still managing current projects.

4.6.1. Population Characteristics

Another design question criteria for the population was defining the way in which the population was identified (Kumar, 2014). This design consideration was carefully looked into, and the researcher had defined the differentiating characteristics of the population of the study as follows:

- The first characteristic is that the person has to have played a role as a project manager in the past or in the present.
- The second characteristic was that a person had to be a UAE citizen, to gauge the impact of social aspects of the local culture, and to be able to select a homogenous sample of the population.
- The third characteristic was that the person had to have an experience of at least three years in managing complex projects within the UAE Army. This was necessary so that the drawn sample to participate would have the experience and the deep insight and recollection of events that shaped their opinions on the risk involved in such projects.

As the researcher comes from the same environment, it was an easy task to locate personnel who resemble the characteristics mentioned above. The population have been identified to be 10 people fit the profile and characteristics of the study. All the identified members of the population were males. This was not surprising as more UAE males join the military than females, and the fact that working in these projects required lots of field tests and long hours that extended beyond working hours. There were two female managers in the past, however, both of them have opted to transfer to other units, and both

of them did not fit the third characteristic of having held project manager positions for three years.

4.7. Sample

The sample is defined as the group of individuals or objects selected from the targeted population of the research study to conduct the survey or the interview (Denscombe, 2007). There is a specific process through which the research extracts samples from the target population of the research. The process starts by identifying the goal of the study and ends with selecting the sample (Denscombe, 2007). In this research, the researcher has made use of judgmental research design. In the judgmental sampling, the researcher chooses the sample from the population based on professional judgment and knowledge (Denscombe, 2007).

A judgmental sampling design, as in **Appendix L**, is useful for describing an existing reality during the qualitative phase where only a little information is known (Kumar 2014). Thus, the primary rationale for selecting this particular type of sample design is that this research study involves qualitative research method and data in which the researcher has selected managers of RDC. Another rationale for this selection is that the managers are closely associated with the risk and challenges related to the projects. It is noteworthy to mention that in this type of sample design, the sample is considered achievable when reaching the saturation point where no new or insignificant information is started to be gathered during the data collection phase (Kumar 2014).

The researcher had to decide to either include the whole population as participants or draw a sample, **Appendix M**, from the population (Kumar, 2014). This principle is affected by the number of the population and the chosen data collection method. As the total population is 10 people and the method of collecting information was chosen to be interviews, it was not required to have more than 6 participants to the study. However, the researcher took into consideration that not all invited managers will take part in the research, and decided to send invitation letters to all the population.

The anticipated rate of participation was 70% to 80% of the population. This yielded 7 to 8 participants. This also allows the researcher to exclude research bias when selecting a sample. The researcher had worked in the past with some of these managers and would

have had a working relationship with them to be favored over others he did not work with. Eight participants agreed to take part in the research, confirming the 80% participation rate of the population. The two who declined were the two managers that the researcher has worked with before, one declined because of his busy schedule and the other was pursuing his PhD outside the UAE. The advantages of that are that all participating eight members who constitute the sample of the study are managers who did not work with the researcher and thus could express their views discreetly about their working relationships with their project teams or other managerial risks they would normally decline to mention if the researcher was part of their team.

4.8. Data Collection

Qualitative research study does not provide research with any kind of numerical data (Bowen, 2009). The researcher gets the data and information in the form of concepts, theories, and real facts (Bowen, 2009). Therefore, the chosen data collection method for the research was through conducting interviews. These interviews with participants helped to gain insights on their opinions and perspectives related to the complex R&D projects and the various aspects of the R&D process.

The aim was to collect data regarding risks and difficulties exists within RDCUAEAF projects. The researcher collected the data related to completed and on-going projects. The interviews were used to get general information about the perceptions of employees of RDC about the risk management of the projects.

A set of questions were used for the interview sessions, as shown in **Appendix N**. The protocol consisted of five questions. The first question was a warm-up followed by a convergent question and then main topic questions followed by a wrap-up and conclusion question. In addition, probe questions were used, and they were extracted from the responses of each interviewee to extract more detailed data and evidence on certain subjects or opinions. It is noteworthy that the protocol was developed with the help of the main supervisor. Then a test interview was conducted with the UAE-based advisor to check the clarity and clear any misconceptions the questions might provoke. This step resulted in more robust questions using simpler terms.

4.8.1. Language

The used language for the interview was English. The choice of language was for several reasons:

- The whole population of the study were educated in the United States, the United Kingdom, and Australia with at least a master's degree. This translates to 4-6 years of fluent in English.
- The technical terms, as well as managerial terms used in project management, were more easily understood in English than in Arabic.
- The nature of work, work procedures, team management, and the daily used language of communication in the RDC environment is mainly English.
- The use of English has the advantage of being easily transcribed without losing the meaning of the word, as compared to having to translate Arabic interviews to English.

4.9. Conducting the Interviews

This section describes the actual settings and conduction of the interviews with the research participants. In this section, a discussion of the permission requests, informed consent explanation, settings of the interviews, and reflections after each interview are discussed.

4.9.1. Communicating with Participants

It is not enough to have known the population, but also to have a proper, ethical-based communication channel to invite them to participate (Kumar 2014). The first contact was an official letter sent to the UAE Department of Defense (UAE DOD) by the researcher's university. In this letter, the research study, objectives, aim, and sample questions were explained. The contacts of the researcher, his advisors, and the ethical section of the university were also mentioned in case the researcher breaches the ethical code of conduct of the research. Also, the informed consent paper was part of the letter, explaining to the participants their rights and their freedom to participate or decline and that taking part in the research will not harm them in any manner.

The UAE DOD sent the letter to the RDCUAEAF for their response. During this time, the researcher did not get involved with either entities' HR to know the status of the invitation letter. This was in line with the ethical code to not interfere with the free will of the invited sample to participate. The response came after 4 months with the approval. The researcher was then interviewed by the head of the RDCUAEAF and the introductory session set the stage for the research study to be conducted.

In this session, the researcher explained further the benefit of the research to the military and the project management practice and showed interest in taking part in sending the invitation letters to the participants. This co-management of the research sample ensures that the proper sample, the one that fits the research characteristics, is being contacted and chosen.

4.9.2. Interviews Venue

When the eight participants responded with their agreement a month later, two other factors were then to be determined; the type of interview and the time and place of it. Four participants showed interest in being present for the interview while the other four requested to send them the interview questions and that they will fill it up and send it back to the researcher because they didn't have enough time for a meeting. The researcher sent the informed consent to those participants who were not available for a face to face meeting and they sent back to him signed. After that, the interviews questions were sent to them. It took another month and had a weekly reminder email to get the interview feedback from the four participants.

With the four participants who accepted a face-to-face meeting, the researcher had to set a time and a place for the interviews. The main principle was that the interview must take place outside the work environment, in a quiet area. There was a military library close to the RDCUAEAF with a discussion room for group work. The researcher contacted the library and they agreed to lend them the room for the interviews. This ensured that the participants will have the privacy and the comfort to talk without the feeling of being surrounded by the work environment. When the dates and times were confirmed back and forth between the researcher and the remaining four participants, the interview schedules were followed and the remaining interviews were conducted within a span of three weeks.

4.9.3. Recording the Interviews

The researcher asked permission of the participants to record the interviews. These permissions were granted in the informed consent. Prior to the start of each interview, the researcher explained the information on the informed consent again and assured the participants of the face-to-face interviews that they can leave the interview at any time without giving a reason and without further obligation or consequences. They were also briefed about their personal safety and anonymity in that the information obtained cannot be traced back to them and will not reveal their identity during the processing, analyzing, presentation, discussion, and publication of any part of the study.

4.9.4. Reflection and Addressing Bias

After each interview, the researcher had time to listen to the audio of the session and did reflect on the quality of the questions and answers. Reflection is a powerful tool that helps to identify the researcher's bias. The researcher, with the help of the UAE-based advisor, discussed this issue. The UAE-based advisor has coached the researcher on avoiding leading the participants towards issues or risks that the researcher had prior knowledge of, and have also explained that some questions needed more probe to enrich the content with personal experiences. The researcher also reflected on his own bias, voice pitch, hints, probe questions, and had refined both some questions and the style of administrating the interview to make his voice less apparent and the participant's voice the dominating voice.

The reflection also has led the researcher to think about the interviewee interpretations and invokes his own experience into explaining some details. The principle is that the interviewee talked about certain conditions but did not take into consideration the social elements because the participant thinks as he is speaking to a UAE citizen thus sharing the same social apprehension. The researcher took into account that these social elements, factors, and environmental settings have to be made clear in some instances for the intended readers of the research. These explanations, when necessary, were made in separate paragraphs labelled researcher's observation. The separation is intended to make the distinction between a participant's viewpoints and the researcher's insight.

4.10. Data Analysis

Every research study requires the researcher to invest a significant amount of time, money, and resources in analyzing the data. There are several tools and techniques that the researcher can use to analyze the collected data. The widely used tool for qualitative data analyzes is NVIVO. After collecting the data through interviews, NVIVO software was used to organize the results. This software is a qualitative data analysis tool (software application) for organizing, storing and analyzing unstructured or non-numeric data obtained from the qualitative research study (Arkkelin, 2014). NVIVO has been used for importing, coding, querying, taking memos, visualizing, reflecting, and exploring interviews data. The researcher used transcribed text in order to create nodes, test theories, key points, ideas, and display connections.

4.10.1. Transcription

Four of the interviews had to be transcribed. Manual transcription is recommended for a beginner researcher. It helps reinforce the information and understanding. This effort took two weeks of work as the researcher typed all the responses and then arranged the files for the thematic analysis.

Once the transcription was complete, the researcher chose to listen to the recordings of the interviews again and follow the transcribed data for comparison. This was a necessary task to make sure that no data has been missed.

4.10.2. Long Table Approach

The researcher used long table approach guidelines to help the thematic analysis of the results. The long table approach is advised for researchers in their first qualitative research, as is the case here because it is "…systematic. It breaks the job down into doable chunks. It helps make analysis a visual process" (Krueger and Casey, 2000, p. 137).

In the long table approach, the interviews data were sectioned and grouped into meaningful blocks. Each block of information was labelled in a group. When a new block of information is analyzed, it is compared to the current groups and if it doesn't match, a new group is created. When the researcher came across information that is not related to

the question it was set aside. Once all of the answers for each question were treated in the same manner, the information that lifted aside was then revisited. If the information fitted into any of the answer groups to any question, it was then added. If it still did not fit, it was then gathered on the side as a side finding of the research.

For each group of answers to each question, a table was produced. In this table, the name of the group and the eight participant's quotes were displayed for each answer. The participants were not labelled in the order of the interview but rather a random sequencing has been applied and they were given a number such as Participant 1, Participant 2, and so on. These tables helped organize the writing of the results chapter.

4.11. Challenges and Limitations

Every research study consists of some constraints and challenges as conducting research requires the researcher to make use of knowledge relevant to the topic, and methods which sometimes correct partially. The limitations and challenges may occur in any stage of the research methodology including research design, approach, purpose, data collection, or data analysis. The main challenge of the study is that the research study has been discussing most of the armed forces and RDC information and data which is considered secure and cannot be published publicly. However, the military often produces certain information in their journals that may not require much confidentiality and is available to all the researchers and those who would like to consume it. Another major point in the context of limitation of this research is that the majority of the RDC projects were divided among the RDC staff, where each team was not allowed to discuss the details with the other team of their project.

4.12. Summary

This chapter detailed the plan for collecting and analyzing the data needed to answer the research questions. Starting with the main research question and then its subsections, the main direction of the study was exploratory. This quest dictated that the qualitative methodology be the main overarching choice of conducting the field information gathering. The data collection method of choice was interviews and its advantages and disadvantages were discussed. The chapter also covered the aspects of population

characteristics and careful sample considerations. The researcher's efforts to design the data collection questions, then communicating with participants and then conducting the interviews were discussed in detail. Transcribing and analyzing data with the long table approach was then executed to extract the thematic groups and preparing these themes for the next chapter, the results chapter, which presents the results in thematic groups.

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5. RESULTS

Following the methodology proposed for this study, as discussed previously, this chapter includes the data collected as presented by the interviewees of this research, in order to answer the research questions, thus, get the shade for the risk factors and the practices used to mitigate these risks, along with the recommended methodologies for similar R&D projects and environments.

In order to collect general background information about perceptions of RDC employees regarding risk management of the project, the researcher has analyzed the transcribed interviews with the help of NVIVO software. From the data collected, the researcher was able to determine the themes with the help of the software.

Figure 5-1: Word Cloud

Figure 5-1 shows the word cloud, as generated by the NVIVO, for the data collected by conducting interviews with the RDC's managers, project managers, and system engineers. From the above figure, it can be seen that 'risk' is one of the brightest and

largest words, which shows that the frequency of risk or risk related stemmed words, is very high.

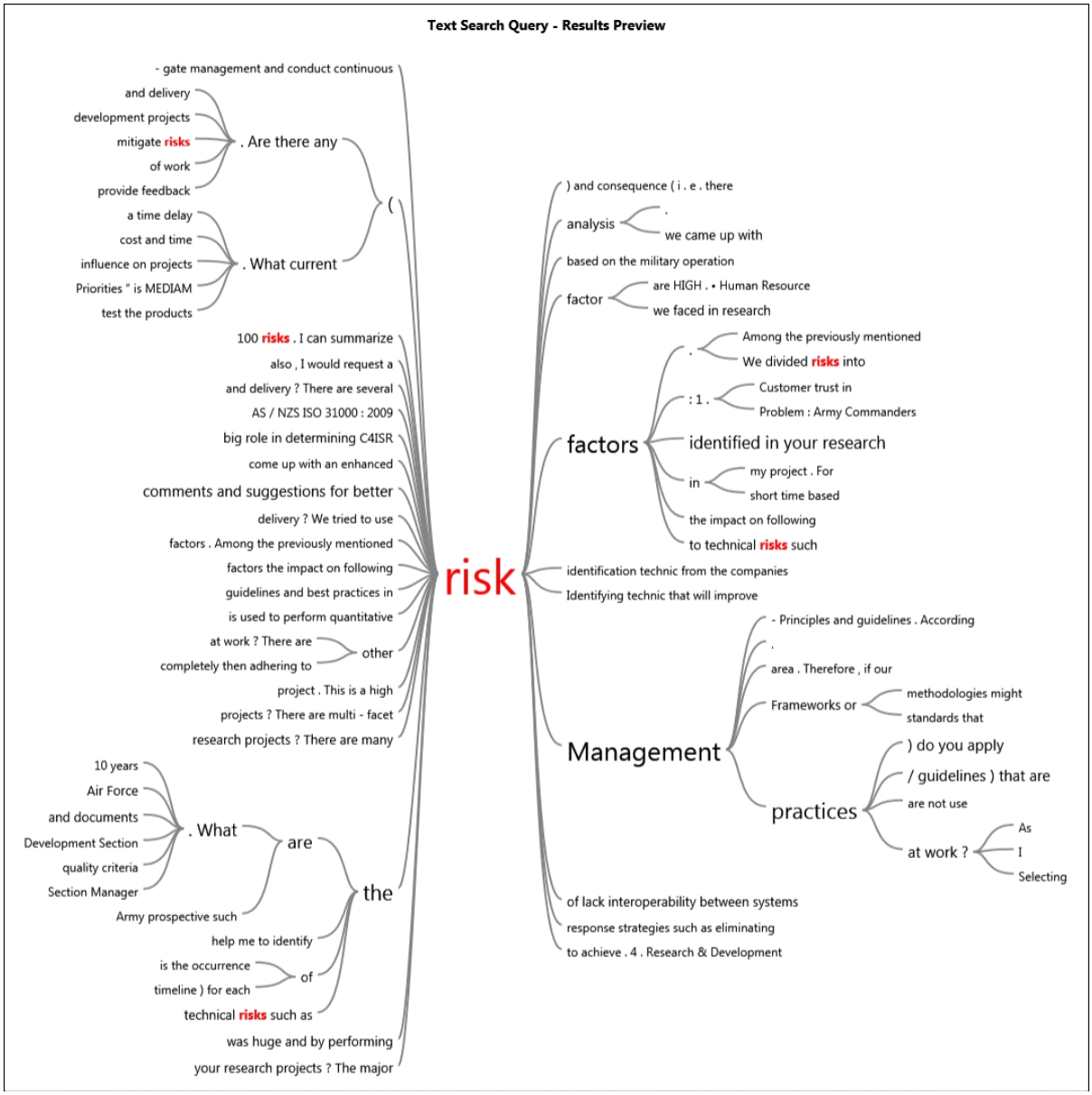

Figure 5-2: Word Tree

Figure 5-2 shows the Word Tree, as produced by the NVIVO, for the responses collected from the interviews. From this figure, it can be seen that risk management and risk factors are the most common words used by the respondents. Therefore, the researcher has considered these two words 'risk management and risk factors' for the data analysis. Moreover, the researcher has also used 'impact of risks' as another element because most

of the respondents have talked about the impact of risks on projects. Also, practices have been considered as another element of risk management because practices play a vital role in managing the risks, which were mentioned by the respondents.

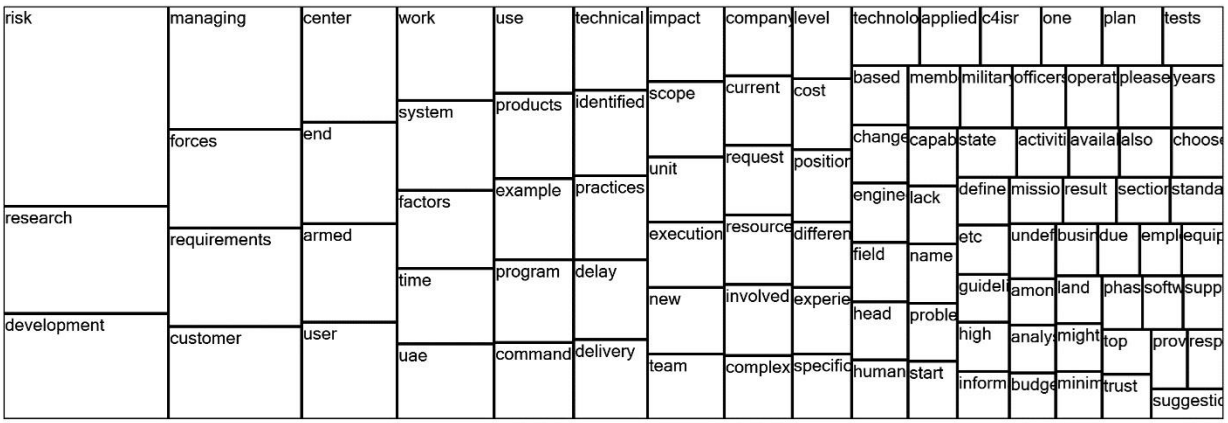

Figure 5-3: Word Frequency Query

Figure 5-3 shows the Word Frequency Query, as produced by the NVIVO, for the collected data where risk, research, and development are in higher frequency. This figure shows the words used by the interviewees as per their frequencies. In this case; risk, research, and development have the highest number of frequency; and then managing, forces, requirements, customer, and so on. These above figures helped in obtaining themes in order to analyze the data.

5.1. Participants Background Data

The interviewed participants are all well-established technical managers at the RDCUAEAF. The participants had diverse educational backgrounds ranging from electrical engineering, electronics, mechatronics, and computer engineering. All participants played different roles in the different projects carried in the RDCUAEAF different departments and sections. These roles included project engineers, system analysis, system engineers, test engineers, and, certainly, project managers. It is also noteworthy to mention that they have been involved in different complex projects over the years, from communications systems to software engineering, to integrating two or

more military systems, and numerous projects on software and hardware upgrades for the different operations systems in the military. Some managers explicitly mentioned what projects they worked in, such as Enterprise Architecture, Business Process design, system compatibility tests, and governance policies and procedures, while others did not mention specifics.

Participants to this research have each had more than ten years of experience working in the complex military projects and have evolved from team members, to project managers with some promoted as department managers over these years. They have all worked with technical teams, different hardware and software technologies, and manage stakeholders' requirements and solution delivery and field tests.

Although most participants worked as project managers for a long time, only a few of them had formal training in project management skills. For those who did not take the certification in project management, they learned how to manage by experience, trial and error, and using different project management guidelines and frameworks. For those who have had the official training, all of them underwent a PMBOK project management training program. Nevertheless their training, there were common issues amongst projects and teams due to the common environment and sometimes similar working guidelines and customer affiliation.

5.2. RDCUAEAF Project Risk Factor Themes

This section is an attempt to answer the following research questions:

- **Research RQ1:** What are the main risk factors, from the point of view of impact and likelihood of occurrence, in the undertaking and delivery of current RDCUAEAF complex projects?
- **Research RQ2:** What is the effectiveness of these risk factors with respect to the completeness, accuracy, validity and correctness of the execution, testing and delivery of complex projects undertaken by RDCUAEAF?

There were many project-management-risks identified in the current RDCUAEAF environment. These risks were then re-arranged into three main groups:

- Client related risks;

- Project related risks; and
- RDC related risks.

This distinction of the client in a separate group will help shed light on the discussion on the importance of client involvement, and disengagement sometimes, and their level of awareness of the complexities of such projects. The project-related risks are a combined list of all risks encountered during the initiation, implementation and execution, and closure phases of the projects, except for client related issues as mentioned before. RDC unit related risks describe challenges that hinder projects indirectly, affecting the human resources, either in a positive or negative way, and their implications on the retention of employees in such high demanding environment.

It is noteworthy to mention that participants spoke more about the risks than speaking about the impact of those risks. Therefore, some risks did not include the impact section and some did. Also, in some instances, participants spoke about the cumulative impact of the risks they identified without specifying the impact of each individual risk.

The researcher added observations where necessary for some mentioned risks. This was done to show a complete picture of the surrounding environment that will help clarify the relative importance or the causal relationship between risks and their sources. Each risk was identified as a potential threat to successful project implementation and completion. Each group are presented hereafter in the following subsections.

5.2.1. Client Related Risks

Data analysis from the qualitative interviews identified several risks posed by their clients' behavior either in the requirement specification, communication delay, and project closure. The following sections present these clients' associated risks.

5.2.1.1. Unclear Operational Requirements

Some units ask for equipment with the latest technology without defining their operational requirement. As one participant mentioned that their client requested a thermal camera and when he tried to understand "the operational mission for such camera the answer was undefined" (Participant 1). another participant mentioned that this loose

criterion of operational requirement lead to price increase as "some equipment might be filled with options that the end user will pay and not use at all, in which it increases the cost effectively" (Participant 2).

Unclear operational requirements can also be caused by multiple, sometimes with opposing views, operational requirements by the same unit or client. This is caused when a new commandant is appointed to the unit, for instance. New commanders usually have slightly, or totally, different views of how the unit should operate and thus this causes fluctuation in the project specification. One participant has talked about this issue and mentioned that "the hardest part where military end users are moved/changed from their original unit to others" and that "every new commander will have new ideas that will change the scope of the project" (Participant 4).

- **Impact:**

These unclear operational requirements impact both project scope, causing scope creep, and project completion cycle. One participant was particularly specific on the issue of the vague specification and that the "customer will have more requirements, will change project scope, and the project will have longer execution time and never end" (Participant 7). Another participant agrees and added that "changing the scope is not preferred as it causes increase in cost and time delays" (Participant 4).

- **Researcher Observation:**

Military units, in general, are defining operational use for their missions that involves whole systems, but not a specific operational definition for each subsystem. This plays a role in the difficulty of defining a specific operational mission for a subsystem. In addition, some units are reluctant to talk about their operational missions, which also plays a role in the ambiguity of these specifications.

5.2.1.2. Unclear Technical Specification

In addition to the unclear operational requirements, sometimes the client does not have clear technical requirements. One participant has mentioned that a unit requested a subsystem without operational requirement but when the project manager asked the client about the technical specification the reply was "please provide us with the best subsystem in the market" (Participant 1). In other instances, the client asks for technical options that

they don't need. One such case involved a client asking for a subsystem with too many specifications. The problem was that space was limited but the client wanted "too many sensors. It was difficult to satisfy the mission requirements and adding more technical specifications that the end user might or might not use" (Participant 3)

- **Researcher observation:**

Many operational units do not have engineers but operators in their departments, and thus this might lead to vague technical specification if not present at all. In other instances, there is a cultural belief that the latest equipment with lots of technical options are better for system upgrade and might come in handy in the future. This is due to the lack of awareness of the importance of alignment between subsystems technical specifications for the task and their price and integration issues with other subsystems in the product.

5.2.1.3. Information Sensitivity

The sensitivity of information is an added factor of risk when dealing with military clients. In one instance, a unit had a remote system which needed solar panels to produce its power. The project manager recalled that "when we asked the technical specification for that equipment it was classified" (Participant 8). In other projects which required piece of sensitive information that cannot be found in the research and development center meant that project managers had to look around the company or government sector to provide such information. In this case, a lot of paper works need to be signed and to agree among all the parties and then share the sensitive information. These Memoranda of Understanding can take time to discuss and be signed which lead to project delay. As an example:

> "There was a project involve military vehicles, and the end user wanted to test some of the capabilities of this vehicle. In order to do so, they needed a sensitive information that cannot be reached by the manufacture. Therefore, a third party was involved to supply the information" (Participant 1).

5.2.1.4. Customer Delays

Delays can take many forms and can lead to scope creep and shifting delivery dates. These delays can be communication delays, approval delays, payment delays, and so on.

One such delay is customer approval delay. One participant recalled the issue they had with a unit that kept postponing the approval on the start of the next phase of the system update project. In this regard, he mentioned:

> "This program follows regular system engineering V Model methodology. The project's execution was based on sequential tasks. Customer delay to give approval on current task delayed the kick-off of the next one" (Participant 2)

Another type of delay is customer payment delay. The RDC use client payments to settle project debt and does not have enough cash flow to sustain payments for the project while waiting for the customer to pay. One participant gave details on this dilemma and said:

> "This program is funded solely on the customer. The program budget is used to pay all type of resources such as hiring new employees, training cost, hardware cost, software cost, and production facilities. The payment delay did affect acquiring new item that were essential to start a new activity" (Participant 3)

- **Impact:**

Customer delays had a clear link on the duration of the projects. Both approval and payment delays had a negative impact on the deliverables of the projects. As one participant mentioned that "the program suffered a delay and was behind the schedule due to late customer response. Due to payments delay, we could not expedite some activities" (Participant 6).

5.2.1.5. Customer expectations

To some participants, most customers from military units seemed to judge the final RDC products by comparing them to international products. The RDC is relatively a young organization and its final products are prototypes that when approved are

outsourced for military partners for productions. Unit commanders will judge the prototypes as if it was the end product and hold it against international standards.

One participant has commented on this by saying that "Unit Commanders will always compare the final product to the HIGHEST standards available in the market" (Participant 5). This sometimes leads to undesired results where the customer opts for a commercial product because of trust issues and "will most likely try to choose a fully developed system that is well proven by other forces rather than choosing to have a research project" (Participant 5).

- **Impact:**

As a result of high customer expectation sometimes, some customers do not come back for other projects to the center and they prefer to scan the market for a ready solution. In some instances, they would cancel a project during execution. One participant recalled this happening to him in the past as he claimed that "a customer, unit commander, will not request a project, or, will cancel an ongoing project" (Participant 2). In other instances, the customer would simply decline to receive the end product, as the participant continues recalling that "products will not be accepted by customers unit commanders" (Participant 2).

5.2.2. Project Related Risks

5.2.2.1. Software Issues

In many projects, software plays an integral part in subsystem compatibility and the overall system function. Participants have identified some issues while working on software development or software compatibility for the complex systems being developed or upgraded.

One participant mentioned planning software issues as an example of software issues that lead to incompatibility between two systems that were supposed to be integrated. The first system was based on preselected planning software, a commercial off the shelf (COTS) product which is sold with predefined specifications. On the other hand, the planning tool of the second system was to be developed from scratch by the project team. The participant recalled the difficulties in making the two systems compatible and referred it to the fact that "both products have to exchange information, but difficulties

were experienced due to different technical specifications and architecture between each product" (Participant 3).

Legacy systems also pose another challenge in software compatibility between subsystems. In one project, the project team could not access the old database in a legacy system and so the integration between the old and the new system was abandon in favor of buying a completely new system which proved to be a very expensive alternative. The participant recalled this incident saying "the intended system has to call users information from client's database, however, this database is managed by old technology that cannot be integrated into the new system" (Participant 2).

Not only that but also lack of software is also an issue that poses risks on RDC projects. One participant mentioned that there were "limited number of material resources (e.g. required software not present)" (Participant 7) in the projects.

Furthermore, software development was a challenge in terms of the time it takes to understand, program and debug the code. Teams would work extra time to comprehend the issues and come up with the right software design to solve those issues. One participant describes this experience as follows:

> "Understanding of how the software is done, how the software is programmed it takes time and if the software is not commented right, it would be difficult for you to find out what this procedure does and what that procedure does, so it takes more time" (Participant 5).

- **Impact:**

Software issues had an impact on many aspects of the projects. As one participant mentioned that "software risks affected the project triple constraints time, cost, and scope and we suffered two years of delay, scope creep, and higher costs" (Participant 8). In addition, software issues led some project managers to outsource some of their work to other units in the military or even sometimes halt the project until such software is purchased.

5.2.2.2. Hardware Issues

Technology obsolescence is an added challenge to hardware risks in the RDC environment. Usually, it is not the software that will be the issue, but the hardware itself might reach the end of its lifecycle. One participant mentioned his encounter with such dilemma and said: "It is five years' project, so acquired products and technology in early stage will become obsolete by the time of system delivery" (Participant 6). Another issue is the lack of required hardware. One participant identified several examples of lack of hardware equipment citing shortages in "lack of servers and computer terminals" and "required equipment not present" (Participant 3) as a major risk in the success of his projects.

- **Impact:**

Time, scope, and cost were the main impact of technology obsoleteness of some hardware parts in the projects. In one instance, a participant claimed that "incompatibility across system architecture resulted in requesting extra time to analyze technologies specifications" (Participant 4). Another participant talked about rising cost as they "spent extra cash to acquire a suitable solution to integrate customer legacy systems" (Participant 5). Yet another participant was dealing with deviation from the original plan as he "suffered scope creep as the customer always requested to change products to assure acquiring latest product and latest technology" (Participant 1).

5.2.2.3. Human Resource Issues

Human capital plays an important role in every project's success. Lack of human capital or lack of expert human capital can lead to many issues in the project lifecycle. One participant mentioned, "risks arising from human resources (e.g. lack of specialists working in my area, lack of skilled resources, unable to get required people" (Participant 3) as a serious obstacle hindering the execution of successful projects.

Lack of expertise was more evident in a software development project. One participant mentioned that one of the risks of the project he kept encountering was the lack of "highly skilled engineers, scientists, and supporting technical staff" (Participant 6). Other participant mentioned the difficulty in getting approval for training courses to bring their expertise on par for the requirements of software development projects. Instead, the

team worked extra time to try understanding and solve software related issues. As one participant recalled:

> "The problem itself is complex, and our expertise fall short of solving the problem or comprehending the full scale of the problem, so it would take us time to read and bring ourselves to the level of expertise of the risk issues. That time also was a risk for us because the military commanders do not see intangible things which is the time that you need to read and to do a trial and error cases" (Participant 5).

- **Impact:**

As seen above, increasing project time was the major impact of the lack of proper human resources to accomplish the tasks in the project. A participant confirmed this impact when he said that "not finding the available skills to execute the required tasks, lead to delays in execution and project schedule" (Participant 1). Another participant went a step further on the negative impact when he mentioned that "projects gets delayed or stopped due to lack of expertise" (Participant 2).

5.2.2.4. Budget Issues

Budget is important for resources procurement, whether their resources are hardware or software or even sometimes enlisting human resources and experts to join the project team. One issue related to budget is the lack of invested money that goes into projects. One participant commented that the "right amount of money not being allocated for the project" (Participant 8) which diminished his ability to procure the required testing equipment for the project.

5.2.3. RDC Related Risks

Some participants have talked about the RDC environment and the managerial practices in this environment. Although these risks were not linked directly to the projects, it affected the human capital, project managers, and engineers specifically.

5.2.3.1. Lack of Expert Managers

The lack of expert RDC managers stems from creating a relatively new division in the military, the Research and Development Center that oversees all research and development efforts in the army. As one participant puts it, the new division is "a relatively new organization and currently undergoing a set up phase, at this moment in time there are lot of complexities" (Participant 3). Most managers come from an engineering background but do not possess managerial skills. One such issue as a result of this is the lack of a clear career path. As one participant mentioned:

> "When the RDC hired a graduated people, the career path in which title and positions that they will be is unclear. This is due to the lack of expertise in managing such center and people" (Participant 2).

Loosely defined responsibilities are also another impact of the lack of expertise in management positions. One participant noticed that there are "no clear guidance on roles and responsibilities" (Participant 7) in the current department. In addition to that, project managers are always juggling on priorities dues the reason that "the department is dealing with several projects concurrently. There is always issues on prioritizing my projects with department activities" (Participant 8).

- **Impact:**

The impact of the lack of expert managers in the RDC extended to the relationship with customers. One participant talked about the long time it takes to get clearance for field tests, or customer reply or payment, and hinted that these issues could be resolved if "R&D center top management had influence on customers and other related military units" (Participant 4).

5.2.3.2. Cultural Differences

In addition, cultural differences amongst RDC staff impact project planning and execution. There are many nationalities who come from different countries and have different expertise, training, and education perspectives on how to carry on projects, or how to develop certain criteria for system upgrades, and so on. One participant recalled this diversity issue and its impact on the process of work by stating:

> ”This is multi-culture program that is consisted of more than 25 nationalities and team members can debate among each other in term of agreeing on concepts and standards” (Participant 6).

- **Impact:**

Thus, these cultural differences impacted on the project’s time. For example, a participant mentioned that “culture issues resulted in miscommunication among team members in which effected quality and caused a time delay” (Participant 5).

5.2.3.3. Lack of Clear Direction

Another issue is the vague strategic directions of such centers. In many instances, the vision and mission do not align well to the strategic direction of R&D center, which leads to unclear future direction. A participant has mentioned that:

> “The strategic plan for the future vision and mission is not decided, in which it causes the center not to focus in one field of technology and undefined the capabilities that the center would be involved. Example, in unmanned system, or in defense technology or in solar power” (Participant 1).

Another participant agrees on this issue of unclear strategic direction as he commented that the R&D center “should have clear path for all its employees and where they will be in the next years” (Participant 4).

- **Impact:**

As a result, some employees end up leaving the R&D center for other departments or even operational units where the vision and career path are defined more clearly. One participant mentioned that “loosing current people” (Participant 3) posed a human resource risk for the projects he is involved in.

Another impact of the unclear direction was the sudden removal or shift of project team members which causes disruptions to projects. One participant talked about this when he argued that “employees taken out of projects to be transferred to other unit forced me to change the deliverable deadline because I spent a month to find a replacement” (Participant 2).

5.3. RDCUAEAF Risk Management Practices

This section presents the current risk management practices that the participants of this research used, as well as the recommended practices that might be suitable for managing risks of complex projects in such R&D organizations. Although the participants talked about some specific risk factors that have been challenged within their R&D projects, their dialog about the risk management frameworks was in general and they did not link each treatment to specific risk encountered. This section is an attempt to answer the following research questions:

- **Research RQ3:** Are current RDCUAEAF procedures and practices adequate for managing the risks in complex projects in a significant military research organization?
- **Research RQ4:** What innovative risk management approaches can the management of RDCUAEAF use to effectively manage and control the risks associated with the undertaking of complex projects in a military research organization?

5.3.1. Current RDCUAEAF Risk Management Practices

As per the participants, there are various risk management frameworks or standards that are currently used or followed during the execution of the R&D complex projects. For instance, one of the participants mentioned that his team refers to many risk management frameworks when executing his projects, as he states:

> "we use Risk Identification, Risk evaluation and prioritization, Risk analysis (applying tools like FMEA, Risk Priority Number, SWOT analysis and Root-cause analysis...etc., Assigning risk owners, Risk response planning, Risk monitoring and controlling, and Risk reporting" (Participant 5).

Another participant stated that by identifying risks early and trying to solve them can be one of the best risk management practices resulting in minimizing the risks and their impacts on the project. He claimed that the general practice is to "identify risks early and try to solve them, define and plan tasks a head of time, and communicate updates among the project team and provide feedback" (Participant 4). Another participant

mentioned that he started thinking about risks early enough through brainstorming with his team. In his words, he mentioned that he uses

> "The brainstorming technique as it help me to identify the risk factors in short time based on the experience of the other team members. But also, I would request a risk identification techniques from the companies who are involved in the development projects" (Participant 1).

Apparently, other participants use similar procedures. Another participant also mentioned that "we tried to estimate the time and cost based on previous projects. We also introduced some risks and contingencies to avoid overshooting the time and the budget" (Participant 6). Another one added in this same manner

> "We assigned a team to manage the suppliers and make sure that will deliver on time. We obtain a signed requirement list from the end user to make sure we stick to the same scope of work" (Participant 8).

Additionally, while some participants use pre-risk management practices, others use responsive techniques. One of the participants pointed out the use of these strategies to mitigate threats. As an example, he mentioned, "we negotiated with the customer to reduce the scope by scraping requirements that are difficult to meet" (Participant 2). Another participant pointed out, "I assured to use Project Management Institute (PMI) standards to minimise and mitigate risks" (Participant 7).

5.3.2. Recommended RDCUAEAF Risk Management Practices

Furthermore, the results obtained from the interviews show that there are various risk management frameworks or methods that are suitable for complex research projects. As per one of the respondents,

> "An effective one might be AS/NZS ISO 31000:2009 Risk management - Principles and guidelines. This standard provides one of the most comprehensive guidelines and best practices in risk management area. According to this standard, risks are identified first, then analyzed, evaluated and finally treated.

> Application of AS/NZS ISO 31000 can effectively minimize the impact of risks on research project execution and delivery. Therefore, if our organization embraces completely then adhering to other risk management frameworks or methodologies might not be required" (Participant 3).

Another participant talked about that:

> "Using a tool and simulation techniques such as Monte Carlo Analysis will be very beneficial. Also, I have seen practitioners for expected monetary value analysis. Unfortunately, we did not use it" (Participant 2).

Another one commented, "I will add Decision Tree as a good technique that is used to perform quantitative risk analysis" (Participant 8). Consequently, another participant added that: "Project Risk Management Software to manage Enterprise Risk Management" (Participant 5), and: "once risks are identified, always assign risk owners early in the process to give them time to work on a risk mitigation plan" (Participant 5).

In addition, one participant pointed out that: "using lean techniques, selecting team members for a long-duration project, use stage-gate management, and conduct continuous risk management" (Participant 6) are good examples of tools and techniques which can be used within the RDCUAEAF to manage their R&D complex research projects.

Furthermore, one participant said "there are other risk management practices which are not used such as Root Cause Analysis, Cause-Effect Diagramming, and Influence Diagramming" (Participant 1). Another one commented for managing risks that are related to the army perspective that:

> "as the UAE armed forces is establishing such development programs, a suggestion to come up with an enhanced Risk Identifying technique that will improve the project from army prospective such as the risk based on the military operations or training" (Participant 7).

Moreover, in the aspect of the military issues, one participant expanded the importance of the customer awareness regarding the R&D and mentioned, "educate the

customers (unit commanders) about the importance of Research and Development Center in the Armed Forces, and educate customers on the project lifecycle" (Participant 4).

5.4. Summary

This chapter presented the data collected from the targeted population and sample, and their response to the research questions. Thus, it included the participants' views and observations for the risk factors identified during the execution of their projects within the RDCUAEAF. It also included the practices and methodologies that those participants used to mitigate the identified risks together with the recommended and the appropriated methods, which might be useful in managing the risks of the complex R&D projects of the United Arab Emirates Armed Forces.

The next chapter will present the discussions in details of the collected data and compare it to the literature of the R&D risk management.

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6. DISCUSSIONS

This section covers in detail the discussion about the results and findings of the study, which have an impact on the complex research and development projects that are carried out by the UAE Armed Forces. It includes the discussions of risk factors and impacts, and risk management practices according to the participants of the research along with discussions of findings from other related studies and researches.

6.1. Discussions of RDCUAEAF Projects Risk Factors' Themes

As per the results obtained from the responses of the participants, it has been observed that there are several risks involved in the RDC projects. These risks were arranged into three main groups, which will be discussed hereafter.

6.1.1. Client Related Risks

As per the findings, some of the risks related to the customers are: unclear operational requirements, unclear technical specification, information sensitivity, customer delays, and customer expectations. The following sections will present a brief description of the client related risks, their causes, types and impacts, followed by a discussion section of the risks.

6.1.1.1. Synopsis of the Client Related Risks

In the results' chapter, there were five risks within the customer related risks group that are summarized in **Table 6-1** hereafter.

Client Related Risks				
#	**Risk**	**Types / Causes**	**Impact**	**# Participants Mentioned the Issue**
1	Unclear Operational Requirements	▪ Undefined mission requirements ▪ Opposing views ▪ Loose definition of operational requirements	▪ Options that no one use ▪ Extra cost ▪ Scope creep ▪ Time creep	3
2	Unclear Technical Specifications	▪ Lack of technical knowledge ▪ Lack of engineers in some operational units ▪ The allure of acquiring the latest technology	▪ Integration with other subsystems	2
3	Lack of Information	▪ Sensitive information	▪ Time creep	1
4	Customer Delays	▪ Approval delays ▪ Payment delays	▪ Time creep	3
5	High Customer Expectations	▪ Trust issues	▪ Project cancellation ▪ No new project requests	2

Table 6-1: Client Related Risks

The table shows a synopsis of the customer related issues that participants have talked about in the interviews. Some issues were talked about more than the others, like customer delays and unclear operational requirements, and some issues were only mentioned once like the lack of information. In some issues, participants mentioned causes of the challenges, like the lack of engineers from the customer side, or trust problems, while in other instances participants mentioned the types of the issues like approval delays and payment delays that were related to customer delays.

6.1.1.2. Discussion of the Client Related Risks

The client-related risks are well recognized in risk management research literature. Many researchers observed that the fundamental risks occurred in R&D projects are related to customers (Mazareanu, 2010; Lehar, 2003).

- **Unclear Operational Requirements + Unclear Technical Specification + Lack of Information**

The risks of unclear operational requirements, unclear technical specification, and Lack of information are acknowledged within the risk management professions including R&D sector. For instance, Luppino, Hosseini, and Rameezdeen (2014) performed quantitative research using RFEMA model to determine risks that occur in R&D projects.

In their study, they selected South Australian organizations that undertake R&D projects as part of their core business, and a review process was undertaken to identify potential projects that could be used as case studies within these organizations. Therefore, they approached a company with a specialization in system integration and industrial automation for private and public customers, and two projects were selected for the purpose of their research (Luppino, Hosseini, and Rameezdeen, 2014).

Their research categorized the identified risks into key result area. The RFMEA technique was applied to the existing risk registers of the two projects to determine if the method can be more effective in identifying and managing critical project risks. This had been followed by interviews with project managers from three different R&D organizations, including the selected company, who have extensive experience in managing R&D / NPD projects in order to determine if the interviewees agreed that improved risk management methods on R&D projects are required (Luppino, Hosseini, and Rameezdeen, 2014). Their findings highlighted:

> "The need for effective risk management methods in the South Australian context, emphasizing the role of risk management in the success of R&D projects. In addition, the interviewees expressed concerns with the traditional risk management methods and the high rate of failure of risk management practices in R&D projects" (Luppino, Hosseini, and Rameezdeen, 2014, pp. 81).

According to Mar (2016), the risks of unclear operational requirements and unclear technical specification fall within the area of 'Scope risks' in which had been identified in Luppino, Hosseini, and Rameezdeen (2014) findings and scored 'High' risk impact in the two analyzed projects.

Similarly, Antinyan, et al. (2018) in Sweden did research in the main technical risks identified at software development companies. The aim of their research was to explore the essence of technical risk and define it in a manner that supports risk assessment and management. They identified a list of technical risks based on input from four large software development companies; Ericsson, Volvo Car Corporation, Volvo Group Truck Technology, and Saab. They concluded that

> "The consequences of technical risks can include overall increase of development time and cost, and decrease of pre-delivery product quality. Despite the importance of technical risk assessment, the existing definitions of risks appear not supporting risk assessment due to inadequate design solutions of processes and product artifacts, but these solutions cannot be regarded as explicit adverse events" (Antinyan, et al. 2018, pp. 6).

One of the main technical risks identified of their findings was that "unfeasible, unclear or untestable requirements have high likelihood impact causing difficulty to understand and implement these requirements because of unclear syntactic description" (Antinyan, et al. 2018, pp. 4).

- **Customers Delays**

Customers' delays risks take many forms from the payment approval to milestones tasks approval as have been recognized from this research's results, which cause delays on execution and delivery schedule. The customers' delays have been addressed on many occasions in the risk management literature. For instance, Mar (2016) has categorized this type of risk under the 'Approval' risk category. Also, Dillerup, Kappler, and Oster (2018) performed a study in the risk of shortages of skilled workers at the German Machinery and Plant Engineering Industry, as these shortages are the main risks associated with innovation, impacting on project timings, output, and performance amongst others. According to their research, many companies are medium-sized and are using standard

static risk management methods, which means that critical situations are detected late and they do not help in the understanding of problem characteristics and their interdependencies, thus, lead to erroneous results.

The research concluded that the development of specific System Dynamic models can help to overcome certain problems and incorporate multi-causal interconnections and multidimensional views on risk. Among their research findings were that "milestones starting after order placement cause time delay" (Dillerup, Kappler, and Oster, 2018, pp. 36).

- **High Customer Expectations**

The risk of high customer expectations has been recognized by other researchers as well, confirming the finding of this study. Mar (2016, pp. 2) has listed this risk under 'Stakeholders' risk category as "stakeholders develop inaccurate expectations" and 'Communication' risk category as "users have inaccurate expectations". Also, Luppino, Hosseini, and Rameezdeen (2014, pp. 75, 79) results encompassed that "customer satisfaction and expectation" scored 'Extremely' impact in the two analyzed projects of the research.

In addition, Shin, Lee, and Yoon (2018) conducted quantitative research using FMEA and Decision Making Trial and Evaluation (DEMATEL) methods. The purpose of their study was to propose a systemic approach to R&D failures and risk management in the R&D process. They selected a representative R&D project that develops a new patent analysis system in a software industry developed by a Korean company. The project was performed by various experts, namely software engineers, research consultants, and data miners, and aims to implement a full-fledged system that applies a neural network method to visualize patents and to explore patent vacuums, providing new opportunities for disruptive innovation. Their study findings included that failure mode could occur in R&D process due to "wrong idea", and "customer analysis error" and therefore can affect the success of R&D projects (Shin, Lee, and Yoon, 2018, pp. 8).

6.1.2. Project Related Risks

As per the findings, there were four main risks related to the projects which are software issues, hardware issues, human resource issues, and budget issues. The following

sections will present a brief description of the project related risks, their causes and impacts, followed by a discussion section of the risks.

6.1.2.1. Synopsis of the Project Related Risks

In the results chapter, there were four risks within the project related risks group, which are summarized in **Table 6-2** hereafter.

Project Related Risks				
#	**Risk**	**Types / Causes**	**Impact**	**# Participants Mentioned the Issue**
1	Software Issues	▪ Incompatibility issues ▪ Integration issues ▪ Legacy system ▪ Lack of required software	▪ Extra cost ▪ Scope creep ▪ Time creep ▪ Outsource	3
2	Hardware Issues	▪ Technology obsoleteness ▪ Lack of required hardware	▪ Extra cost ▪ Scope creep ▪ Time creep	4
3	Human Resource Issues	▪ Difficulty in the execution ▪ Lack of experts	▪ Time creep ▪ Project cancellation ▪ Extra cost	5
4	Budget Issues	▪ Misallocation of budget ▪ Difficulty to acquire the required	▪ Time creep	1

Table 6-2: Project-Related Risks

The table outlines the project-related issues that participants have talked about in the interviews. Some issues were spoken about more than the others, like human resource issues, and software and hardware issues, and some issues were only mentioned once like the budget issues.

6.1.2.2. Discussion of the Project Related Risks

- **Software + Hardware**

Through browsing the literature of the risk management, software and hardware issues are among the well identified technical risks of projects (Mar, 2016). Also, Dandage, Mantha, and Rane (2017) did a study to review the risk categories which are predominant in international projects and to rank them according to their effect on project success. Their data collection method was that they performed a literature survey for the period from 1995 to 2017 of peer-reviewed journal articles, survey reports and books on project management. The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method was applied mainly then to rank these risks according to their importance of projects failure, where the data were collected for TOPSIS through questionnaires. Their findings led to the identification of eight different types of risk categories associated with international projects, hoping it might provide new opportunities for rigorous and relevant researches that would contribute to an in-depth knowledge of risk management methodologies.

Furthermore, the study revealed that technical risks' issues such as technological developments, variation in codes and standards, have been ranked as the second important cause of projects failure. In addition, the design risks have also been recognized in their study, and ranked the third important cause of projects failure, as they can lead to operational or technical risks (Dandage, Mantha, and Rane, 2017). Other studies too have concluded the same outcome. In the study of Luppino, Hosseini and Rameezdeen (2014), the technical results scored 'High' in the two analyzed projects of the research.

Moreover, as each phase of the Software Development Life Cycle (SDLC) is vulnerable to different types of risk factors, Hijazi, et al. (2014) presented a comprehensive theoretical study of the major risk factors threaten each of SDLC phases. An exhaustive list of 100 risk factors that threaten each SDLC activity was produced. In the list, these factors reflect the most frequently occurring risk factors that are common to most software development projects. The list could serve as a checklist that guides the project team in identifying probable risk factors and help them in designing strategies to mitigate them. Their study recognized technology change as a software risk factor in which "the project may involve the use of new technologies that has not been used before, which developers may find it difficult to deal with these technologies" (Hijazi, et al., 2014, pp. 224). In addition, other researchers' corroborated the result of this study that legacy

systems pose issues in software development projects. In her article, Mar (2016, pp. 4) has revealed that "integration with undocumented legacy components and integration with legacy components that are no longer in support" are among the high risk factors of 'Technical' risk category.

- **Human Resource**

Another finding of the project related risks was the human resource issue. Human resources play a vital role in all life aspects. In the context of R&D practice, the lack of expert human resource can lead to many issues in the R&D lifecycle and cause projects failure. Mar (2016) has listed the inability to secure sufficient resources for the project as a project risk factor confirming to this research results regarding the hazards of the lack of experienced human capital in R&D projects. Moreover, Shin, Lee, and Yoon (2018) have also recognized insufficient R&D resources as one of the failure causes of R&D projects. Trained or expert human resources was also a risk factor for the software developments projects which was addressed by the research of Dillerup, Kappler, and Oster (2018, pp. 32), as they have mentioned that a "lack of technical qualification will lead to technology incompetence".

Additionally, those insufficient trained human resources could pose a major risk impact on the projects such as installing new systems or equipment. This has been addressed in the Luppino, Hosseini, and Rameezdeen (2014) study, in which, due to a lack of human resources, 'installation risk' scored 'High' impact in one of the two analyzed projects of the research. Furthermore, Dandage, et al. (2018) performed an exploratory study through literature survey and feedback from project professionals, for the period between the years 1995 to 2015, regarding various risk categories and barriers to risk management in domestic and international projects.

The primary focus of their study was on risk management in projects in various sectors such as construction engineering, piping engineering, power generation plants, mining, automotive industries, steel industries, and other heavy industries. Interpretive Structural Modelling (ISM) and MICMAC analysis have been applied then to analyze interactions among the barriers and prioritize them. The study included the general seventeen risk categories and ten barriers associated with effective project risk management. The analysis indicated that lack of top management support, lack of formal

training, and lack of addressing cultural differences are the high priority barriers, among many others. Their study concluded also that lack of resources would cause delay to the project (Dandage, et al., 2018).

- **Budget**

Budget is an important aspect of any project. A survey conducted by Standish Group International Inc. shows that only 25–30% projects are completed successfully and that most of the projects fail due to cost overrun or schedule overrun (Dandage, et al. 2018). In addition, the financial and economic risks such as shortage of funds have been ranked in the Dandage, Mantha, and Rane (2017) study as the sixth important cause of projects' failure. Furthermore, the Hijazi, et al. (2014) study identified 'Unrealistic Budget' as a risk factor in which has been defined as:

> "The estimated cost for the project may exceed the available budget, if this was not mitigated successfully, the project may be out of fund early in the software development lifecycle, and thus fails" (Hijazi, et al., 2014, pp. 216).

Moreover, In the Luppino, Hosseini, and Rameezdeen (2014) study, project cost scored an 'Extreme' impact in one of the two analyzed projects of the research. Similarly, unrealistic time and cost estimates were of the main risk factors identified at the software development projects of the four analyzed companies of Antinyan, et al. (2018) study. Likewise, the Shin, Lee, and Yoon (2018, pp. 8) study findings included that "Financial assessment error" is one of the failure causes which occur in the R&D process.

6.1.3. RDC Related Risks

As per the findings, some of the risks related to the projects are lack of expert managers, cultural differences, and lack of clear direction. The following sections will present a brief description of the project related risks, their causes and impacts, followed by a discussion section of the risks.

6.1.3.1. Synopsis of the RDC Related Risks

In the results chapter, there were three main risks within the project-related risks group that are summarized in **Table 6-3** hereafter.

RDC Related Risks				
#	**Risk**	**Types / Causes**	**Impact**	**# Participants Mentioned the Issue**
1	Lack of Expert Managers	▪ No clear guidance on roles and responsibilities ▪ Lack of top management support ▪ Juggling on priorities ▪ Difficulty in the execution	▪ Scope creep ▪ Time creep	3
2	Cultural Differences	▪ Integration Issues ▪ Miscommunication	▪ Scope creep ▪ Time creep	2
3	Lack of Clear Direction	▪ Difficulty in the execution ▪ Unclear career path ▪ Unclear vision and mission ▪ Lack of top management support	▪ Time creep ▪ Extra cost ▪ Losing People ▪ Juggling on technology focus	4

Table 6-3: RDC Related Risks

The table outlines the organization related issues, RDC, that participants have talked about in the interviews. Some issues were spoken about more than the others, like lack of clear direction and lack of expert managers.

6.1.3.2. Discussion of the RDC Related Risks

- **Lack of Expert Managers**

One of the risks related to RDC issues was the lack of expertise in managers of RDC units. Mar's (2016) findings pointed out that lack of expert managers is among the main project risks. In addition, the lack of top management support has been addressed in many risk pieces of risk management research as the main project risk cause (Dandage, et al., 2018). Dillerup, Kappler, and Oster (2018) have recognized the lack of expert managers as a recruitment risk factor which was categorized under the internal capacity group of risks for the German Machinery and Plant Engineering Industry. Another research has recognized lack of expert managers as a type under internally generated risk category and

referred the main cause for it to the "failure of project manager" (Dandage et al, 2018, pp.155).

- **Cultural Differences**

Another risk group under the RDC unit related risks was the issue of cultural differences. Cultural differences risk has been found to be a recurrent challenge in project management risks within the risk management literature. Dandage, et al. (2018) have categorized this type under the category of cultural risk and referred the main cause for it to the "language barrier and differences in cultures" (Dandage, et al., 2018, pp. 155). Furthermore, in Dandage, Mantha, and Rane (2017) study, they have ranked the cultural risks as the fifth important cause of projects' failure.

- **Lack of Clear Direction**

According to the participants of this research, the lack of the clear direction risk has led to many issues such as unclear career path and difficulty to project execution, which cause delays in project's schedule and losing expert people in favor of gaining better job opportunities. Mar (2016) talked about the impact of such risk as "Resource turnover leads to delays and cost overrun" (Mar 2016, pp. 3). The impact found in the current study of some RDC staff leaving the unit because they do not foresee a clear direction is a staff retention issue. In this regard, Dandage, et al. (2018) revealed that retention of competent staff as key risk causes of managerial risk category. This type of risk impact has been noted within the profession of risk management, as Hijazi, et al. (2014) have ranked this risk under 'Team Turnover' as they stated

> "In most organizations, experienced team member are looking for better job vacancies and leave their work if any was found. This factor threats any project in any of its phases" (Hijazi, et al., 2014, pp. 230).

6.2. Discussions of RDCUAEAF Risk Management Practices

Risk management observation is an important part of the RDC risk management practices, aiding project managers to mitigate the impact of risks on the projects. Identifying risks at the early stage of the project, and defining and planning tasks ahead of time can be an effective risk management practices. Communicating updates among

the project team and providing feedback are considered to be risk management practices that can be highly effective in managing the impact of risks on the research project's execution and delivery.

In order to minimize the impact of risks on the execution and delivery of the projects, there is always a need for following risk management practices, which all the participants of this research had agreed on, confirming the literature review as indicated by Luppino, Hosseini, and Rameezdeen (2014, pp. 74) as well, who stated that:

> "All of the interviewees agreed that risk management is vital to the success of R&D projects. However, the various risk management methodologies currently adopted within the interviewees' organizations varied in their maturity and level of formality".

As per the results obtained from the participants of this study, it has been observed that there are several risks management methodologies and practices, which can be used and integrated into the RDC projects in order to mitigate or minimize the impact of risks. For instance, it has been mentioned that *AS/NZS ISO 31000:2009 Risk management - Principles and guidelines* can be one of the effective risk management practices in the military R&D projects since it offers comprehensive guidelines and best practices in the risk management area. This is confirmed in the risk management literature via a study accomplished in 2016 by researchers from three different countries; Olechowski, and Seering from Massachusetts Institute of Technology in USA, Oehmen from Technical University of Denmark in Denmark, and Daya from the American University of Sharjah in UAE.

These researchers have performed an empirical investigation of the effectiveness of the *ISO 31000* risk management principles in the engineering industry. They conducted a large-scale survey of engineering practitioners, which was distributed to six major industry sectors and one government risk management entity. The survey was also administered via professional association mailing lists. Out of 291 respondents who participate in the research, 215 respondents completed the final portion of the survey, where about 50 % of the respondents were from the aerospace and defense industry. The survey collected extensive information, 171 questions, from each respondent about a past

project, specifically regarding project outcomes and risk management process. The survey addressed methods and practices in the areas of risk analysis, risk evaluation, decision making, and risk monitoring. Their empirical evidence from the statistical analysis suggested that the *ISO 31000* is indeed a promising guideline for the establishment of risk management in engineering management. Also, the *ISO 31000* principles were found to be a significant factor in better reaching cost, schedule, technical, and customer targets, in addition to achieving a more stable project execution. They concluded, as well, that their findings provide evidence of the potential for the principles to form the basis of a project risk management body of knowledge and to have a strong impact on the professionalization of the risk management function (Olechowski, et al., 2016).

Moreover, various other risk management practices have been observed in the findings, which include educating customers, which offers customers better understanding regarding the research and development process in general and in the armed forces specifically, as well as making them understand the project lifecycle. This has been confirmed in the literature on many occasions, as some researchers suggested integrating customers into the innovation process to reduce the risks of unmet customer needs (Wang 2010). Also, another researcher favored the participation of customers in the innovation process to achieve the necessary objectives which are as per the customer need (Mikkelsen, 1990).

Furthermore, as per the literature review and the findings, there are a lot of available and developed tools, standards, methodologies, practices, and frameworks that can fit for risk management of projects and R&D projects (Luppino, Hosseini, and Rameezdeen, 2014; Shin, Lee, and Yoon, 2018), which the UAERDCAF can use and benefit from. However, a new and expert judgment can always be used also to provide the best solution to tackle the risks.

Luppino, Hosseini, and Rameezdeen's (2014) findings acknowledged that 77.8 % of the interviewed project managers believed that "their respective organizations would benefit from a new, more structured risk management methodologies for their R&D projects" (Luppino, Hosseini, and Rameezdeen, 2014, pp. 74). They expanded that the new methodologies should be flexible and can be adapted to accommodate the risks associated with the R&D projects, and must involve relatively simple processes and

procedures so that it doesn't carry out additional overhead to the project (Luppino, Hosseini, and Rameezdeen, 2014). Therefore, the management of the RDC organization should consider the recommended practices suggested by the participants of this research, along with other methodologies.

6.3. Summary

There are many risk factors that are faced by the project managers of the Research and Development Center of the United Arab Emirates Armed Forces when they execute their R&D projects. Although this R&D facility deals with projects that are related to armed forces equipment and capabilities, the risks factors existed in this environment and projects tend to be as similar as to the risks occurred in other similar environments elsewhere. The project managers of this environment try to use the existed risk management methodologies, tools, and standards which proves its efficiencies in managing similar R&D projects and mitigating the occurred risks. However, there is always a place for improvements and more and better methodologies and practices can be applied.

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7. CONCLUSIONS

7.1. RDCUAEAF Risk Factors and Management

This section presents the risk model generated for the R&D projects carried by the Research and Development Center of the United Arab Emirates Armed Forces along with recommended management and practices for these projects' risks.

7.1.1. RDCUAEAF Risk Model for R&D Projects

Results and discussion of this study led to the development of a risk model for the UAE R&D Project environment. This risk model is illustrated in **Figure 7-1** below.

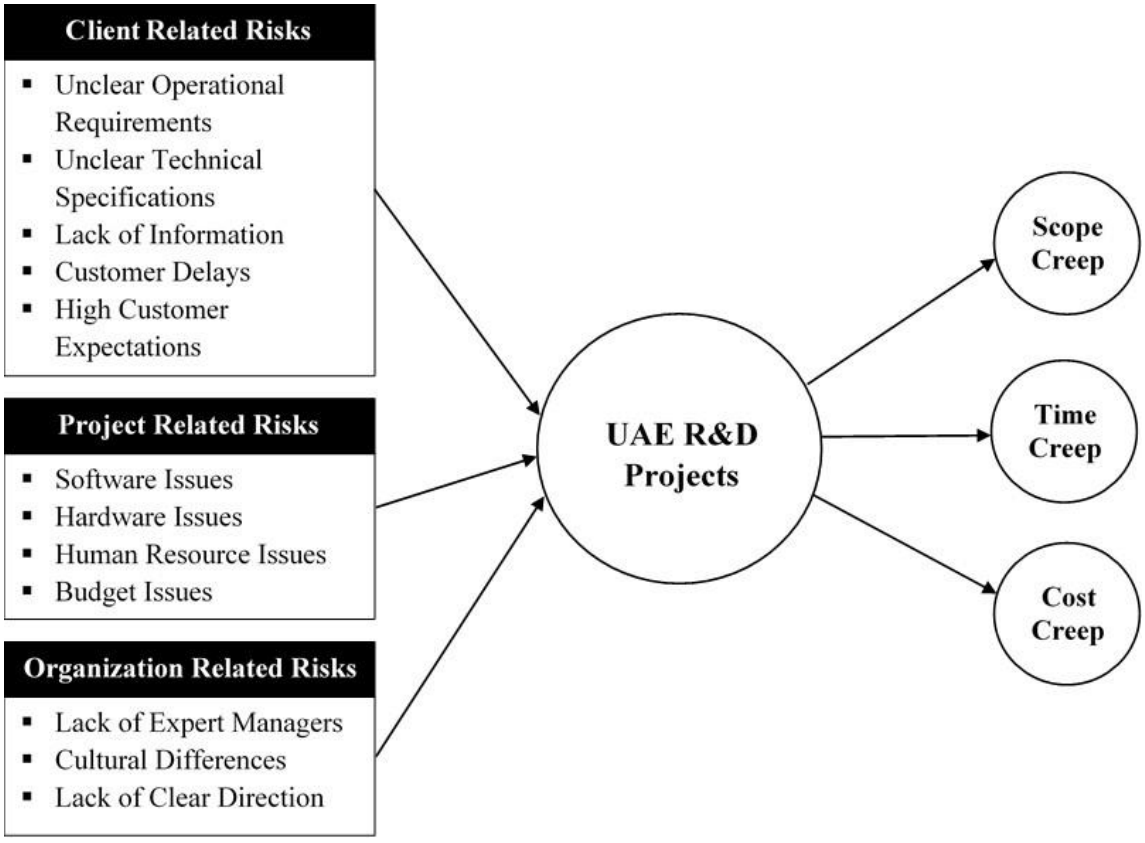

Figure 7-1: UAE R&D Risk Model

(Source: Produced by the researcher for the purpose of this study)

The three main group risks are as discussed previously: client related risks, project related risks, and organization related risks. Each risk includes variables deemed important by participants of this study. These risk groups have a direct impact on the management of the project within a research environment. The resulting impact, direct and indirect, leads to three main issues: scope creep, time creep, and cost creep. These, in turn, have an impact on employee attrition rate and project failure or cancellation. This risk model can be used by interested organizations, students and researchers in future qualitative and quantitative studies to test, update and generalize the model to the wider R&D community in the UAE.

7.1.2. UAE Risk Management practices

RDC follows various risk management standards, methodologies, and practices in order to manage or mitigate the impact of risks during the lifecycle of the projects. These frameworks include educating customers, identifying risks at the early stage of the project, defining and planning tasks beforehand, communicating updates related to the project to the other members of the project, and providing feedback at every stage of the project. In addition, *AS/NZS ISO 31000:2009* Risk management – Principles and guidelines can be one of the effective risk management practices. Furthermore, there are always a need and a place for new and updated practices and methodologies that can aid in managing risks of the complex R&D projects within the environment of the armed forces.

7.2. Recommendations

The research and development center's achievements have offered a vast difference in the power of the military. However, the objectives are to develop a research and development center that is capable of handling complex projects, which will help the armed forces to rely more on technology in-house.

Figure 7-2: Strategy for R&D

(Source: View Points, 2018)

Apart from stability in the research and development environment, various factors such as political stability, abundance or lack of capital or technology transformation can influence the research and development programs thereby creating an impact on the armed forces. However, to develop a world-class R&D center for the armed forces that is capable of undertaking complex projects would require various aspects in place and implementing these aspects can result in a huge success. The set of recommendations mentioned hereafter can aid in the success of the R&D center.

7.2.1. Science and Technology

Defense science and technology often gives an important focal impulse to industry and contributes to economic growth with a multiplier effect. Hence, funding of R&D agencies is one of the significant investments of countries. The contribution offered by the defense industry sector and technological base to employment, exports and innovation, and highly qualified jobs are well-documented (Mauro and Thoma, 2016).

Therefore, the RDC in the UAE is only able to serve at a fundamental level unlike those of countries with high military power such as the USA, Russia, or China, who spend

enormously on military R&D. R&D requires a huge investment in various elements, and one of them is science and technology, which can increase the capability of the armed forces tremendously if implemented in the R&D projects successfully and effectively. For the benefit of RDC, investment in science and technology (S&T) is necessary and foreign investors can also invest in the modernization of the armed forces thereby profiting everyone involved. The researchers working under RDC projects will get knowledge and capital to pursue desired knowledge, the armed forces will get advanced equipment to combat threats, and the investors will get a market where they can invest.

As UAE is one of the NATO partner nations, as shown in **Appendix O**, the Armed Forces, and consequently the RDCUAEAF, should involve, get training and practices, and get assistance from the different scientific organizations of NATO such as the NATO Science and Technology Organization (STO) and the NATO Science for Peace and Security Program (SPS). This will enhance cooperation and dialogue of science and innovation, and research and development projects. In addition, it will embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific methods (Science and Technology in NATO, 2019).

7.2.2. Transfer of Technology

Transfer of technology is the sharing of the required knowledge in the R&D to the young generation so that they can also become an efficient part of the country's R&D and take the technology to the next level. However, this requires knowledge related to the technology used in the R&D projects, which can be transferred through proper training about the technology and science involved in these complex projects. The UAE can also take the approach where it can invite the great minds from other nations who are willing to work in the R&D center of the country, and from them, the country's researchers can learn new things and technologies that can contribute to the complex projects.

The UAE military should also perform collaborative work with defense R&D agencies of foreign allies in the transfer of technology initiatives, by assigning different

aspects to one or another partner for instance. Taking in consideration that these engagements require a cadre of personnel skilled in putting together and managing such arrangements, in addition not to jeopardize the security issues, which may be controllable in the basic research field, but difficulties occur during the applied research and beyond (Sciarretta et al., 2008).

7.2.3. Purpose and Strategy Clarity

Strategy is a systematic approach to solving a problem. Thus, while undertaking the responsibility of any work, it is highly necessary to understand the purpose of that work and the strategy it will require to achieve the predefined objectives of the work, similar is the case of the UAE's R&D projects. The traditional project requires clarity regarding the strategy, and it becomes highly necessary to understand the strategy and purpose of the complex R&D projects related to the military as the chances of errors are almost null there.

The RDC should take into consideration the three essential purposes and requirements of a good strategy, as following (Pisano & Figgie, 2012):

- **Consistency:** A good strategy provides a framework for making consistent decisions, actions, and behaviors over time that build cumulatively toward the desired objective.
- **Coherence:** In complex organizations, many decisions are taken may shape competitive capabilities, and a good strategy provides an integrating mechanism to ensure these tactical decisions are coherent.
- **Alignment:** Organizations do well when their strategies are aligned to the realities of the operating environment. Hence, an appropriate strategy should help drive this alignment.

Furthermore, the RDC should deliberate the main elements of a successful R&D strategy, as shown in **Figure 7-3**: architecture, processes, human resource, and portfolio, which are described hereafter (Pisano & Figgie, 2012).

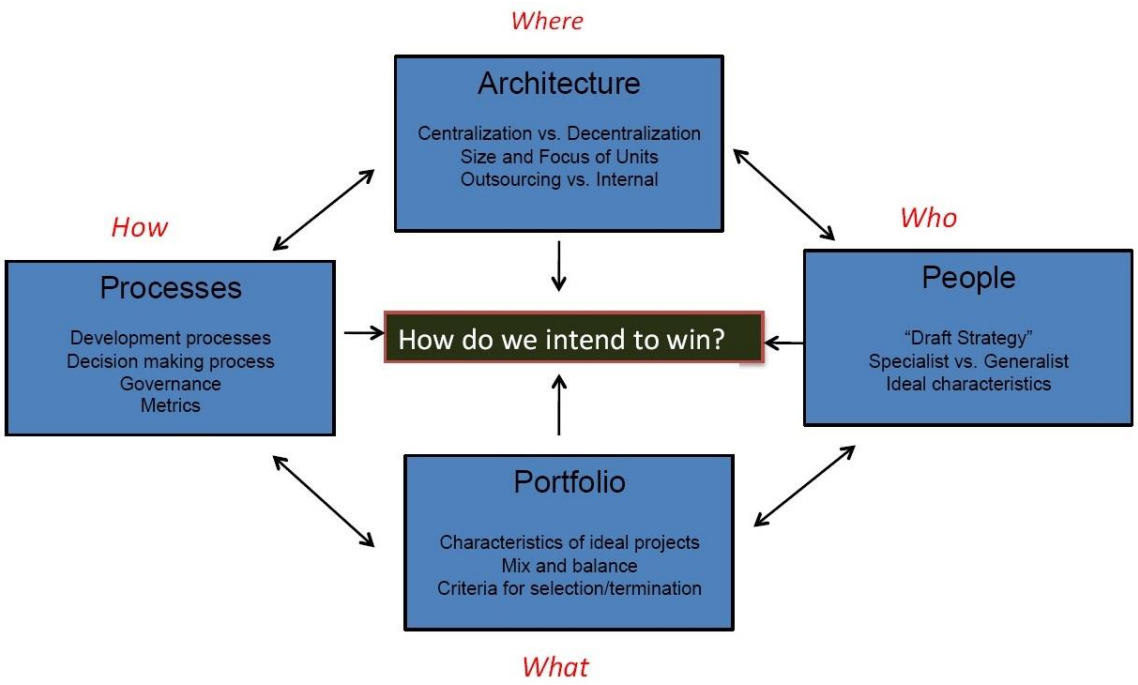

Figure 7-3: Elements of R&D Strategy

(Source: Pisano & Figgie, 2012)

- **Architecture:** Refers to the set of decisions around how R&D is structured, which includes decisions such as the focus of R&D units, whether research is organizationally separated from development and the degree to which R&D utilizes external resources and partnerships.
- **Processes:** Refers to the formal and informal ways that R&D is implemented, which includes the project management systems, the governance of projects, the lifecycle of the project tasks, and the indicators used to track projects. For instance, R&D organizations working on highly uncertain technologies may need flexible processes to have the opportunity to explore and iterate. However, specified processes may be required in R&D organizations where different functions must be aligned and organized with other functions such as in manufacturing.
- **Human Resource**: Although of the growing use of latest technology globally, R&D is still a labor-intensive process. Hence, the mixture of human resources

from all levels such as experts, engineers, technical backgrounds, managers, trainees, etc. have a significant impact on R&D performance.

- **Portfolio:** Refers to the desired resource allocation across different types of R&D projects and the criteria used to sort, prioritize, and select projects. The R&D portfolio should reflect the priorities of the R&D strategy.

7.2.4. Develop the Dispute Resolution Plan

As defense research is a race against the clock, the UAE should launch an ambitious Defense Research Action Plan consistent with and in anticipation of a full-fledged of the other national strategies of the country. The Plan should ensure that a relevant share is dedicated to testing facilities and technology activities taking into account the specificities of defense constraints. The focus should be on R&D organization's studies working at fundamental research, which could be used for defense purposes as well (Mauro and Thoma, 2016).

Dispute resolution plan can also provide an alternative solution for managing the potential and complexity, based upon the quality, technicality, financing, cost, and time of the complex research and development projects. The plan of dispute resolution is highly recommended for such complex R&D projects. These methods should be built for the partners and shareholders of the complex projects when these individuals are offered the contracts to take part in the projects.

7.2.5. Identify Critical Permit Issues

The proper identification of the critical issues can help in controlling the cost and scope of the resources, which are used in the complex projects. Proper financing on the risk management may help in lowering down the risks which are developed during complex R&D projects in the UAE.

It is therefore very important for the researchers involved in the complex R&D projects to understand the strategy they need to follow to successfully finish the project and the purpose it will fulfil after the completion. As the R&D center is not as experienced as that of countries with high military power, the researchers should move slowly in the direction where the chances of projects ending as a failure are very low and the equipment

produced may be small as well. Once the accuracy, experience, and knowledge are acquired, then they can move to the more significant and complex projects, as they will be motivated during those projects and can implement new ideas on them without any fear.

7.2.6. Risk Management

RDC management should establish risk management function that facilitates and monitors the implementation of effective risk management practices by operational management, assists risk owners in defining the target risk exposure, and reports adequate risk-related information throughout the organization (The Institute of Internal Auditors, 2013).

7.2.6.1. Risk Planning

Planning for risks that may occur is a habit that can save valuable resources and should be implemented in almost every organization with a research and development agency. The researchers at the UAE R&D center need to plan for their complex projects much prior before the commencement of the actual project. A reason for planning too ahead is that during the time the project planning is done, the researchers will get enough time to identify the uncertainties that might occur during the project lifecycle, which will help them to prepare in advance for those uncertainties, and therefore, will preserve the wastage of resources and capital to a huge extent.

7.2.6.2. Risk Analysis and Treatment

It is certain that the UAE should develop the ability to perform risk assessments. The UAE Armed Forces personnel should carry these assessments. They should involve the experienced persons to carry out such analysis which has in-depth knowledge regarding the project. The UAE Armed forces project management personnel should be trained for risk management in the complex R&D projects. This training should not only include the techniques but should also involve the managerial responsibilities which are involved in the interpretation of the risk mitigation, assessments, and management of

risks. The UAE Armed Forces need to develop certain cutting-edge abilities, which can help in managing complex R&D projects.

There should be development and adoption of specific processes, which should include identifying, evaluating, designing, and selecting alternatives to the risks. Before starting the complex R&D projects, the project managers in the UAE Armed Forces should consider the aspects of human resource, cost, and time to select the type of matrices. The UAE Armed Forces should openly include the substitutes which can provide an advantage for the uncertainties after the starting of the complex R&D projects. There should always be a backup plan during the critical situation of the complex R&D projects.

The risk analysis should openly consider the interdependence of the activities which happen during the complex R&D projects in the UAE. The UAE Armed Forces should make an internal database of the R&D projects. The internal database system should be established to capture the data regarding the current and future R&D projects of the UAE Armed Forces. The existing development of the project's reporting and analysis should be included. This could be the most important footstep in the direction of achieving the goal. The committee in the UAE Armed Forces should follow the plan to work on the complex R&D projects with interest. They should develop more improved and expertise tools for risk management. The innovative approaches should be used for the adaptability of the R&D projects and risk management.

The project manager at the UAE Armed Forces should pay more attention to the uncertain risks, which occurs in the complex projects. This is due to the fact that these factors have the potential to endanger the success of the project. However, if the risk is identified, then there can be various strategies and contingency plans for risk treatment that can be applied to the complex R&D projects. The utilization of advanced matrices are recommendable theoretically, but these cannot be applied in the risk management in delivering complex R&D projects. There should be an easy basic matrix that can be used, which is easily understandable and can be applied in the field of risk management.

7.2.7. R&D Structure

No one can work alone in today's world. As complexity involves in each aspect of the life cycle, the cooperation among all sectors is required. Thus, the RDCUAEAF should

involve and cooperate with the related sectors in the development and implementation of the R&D projects, taking in concern a close control of highly classified research and without jeopardizing the safety of the Armed Forces information and security. This ensures the breakdown of work with the related sectors, the professionalism of the work performed, and the economic benefits and the learning experience gained of the involved sectors, in addition to the assurance of the dual usage of technologies which are developed for military purposes but also have great impact on civilian applications or vice versa.

As **Appendix P**, the R&D environment has multiple stakeholders and can involve multi sectors in the country. Thus, the UAE government, including the Armed Forces, can cooperate with the academic sector as well as the industrial sector to execute the R&D projects, as each sector has set of capabilities and requirements that can benefit and exchange with the other sector. Hence, forming the Knowledge Triangle as shown in **Figure 7-4**. **Appendix Q** demonstrates a rigorous approach on innovation developed by the European Institute for Innovation and Technology (EIT), which links the knowledge triangle components of education, research, and businesses into an innovation system.

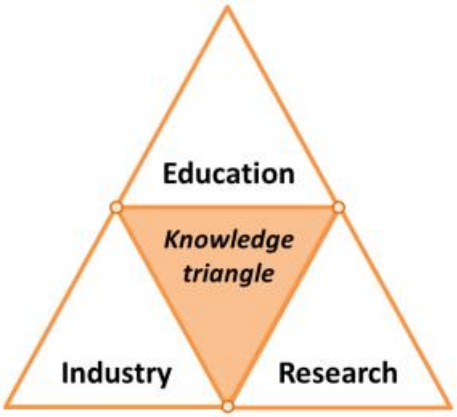

Figure 7-4: Knowledge Triangle

- The government seeks a diversified economy and capable, modern, well-equipped armed forces, and self-dependent. The government has the finance, the strategy to develop the country, and the requirements for the R&D.
- The Academic sector has the theoretical information, the fundamental and basic research, the innovation environment, concentrate on the pursuit of

knowledge, and has the responsibility of qualifying and preparing the young generation.

- The industrial sector has the practical knowledge, the production capabilities, and the workforce. Its primary focus on product development, new technologies, understanding of technologies in existing products, technologies in manufacturing, and application of knowledge for commercial purposes.

The R&D management can also implement the USA NASA / DOD Technology Readiness Level (TRL), **Appendix R**, which describes the level of maturity of R&D technologies, to determine the life cycle of R&D and NPD in each sector. Consequently, the United Arab Emirates Armed Forces structure for the R&D can include the following departments:

- **Strategic Technology Management Department:** The functions of this department can include:
  - Preparing analysis to identify strategic R&D topics and initiatives.
  - Identification and monitoring of opportunity procurement programs for R&D.
  - Advise on funds allocation for programs.
  - Develop and execute a technology management strategy in alignment with national strategies.
  - Consolidate national defense and security requirements to define programs.
  - Define and manage defense and security R&D specialization clusters.
  - Maintain a database of developed technologies.
  - Monitor and advise on emerging technologies.
  - Provide technical advice for government's Buy decisions.
  - Select R&D programs based on prioritized areas.
  - Select and introduce R&D elements in Offset programs.
  - Direct / Link R&D programs to corresponding Lab / R&D facility.
  - Avoid duplicate payments in contracts that include technology development elements.

- **R&D Programs / Operation Department:** The functions of this department. can include:
  - Execute, manage, coordinate, and monitor the successful delivery of R&D programs with clear goals, timelines and budget to meet the national defense R&D strategy.
  - Prepare and manage documents and tenders for R&D contracts.
  - Adopt a set of best practices, standards, and methods for the technical management of R&D programs.
  - Work internally with R&D functions to ensure R&D programs outcome are aligned with strategic goals.
  - Build upon results from other R&D programs.
- **Stakeholders Management Department:** The functions of this department can include:
  - Coordinate with academic institutes, companies, and OEMs.
  - Align R&D management with other ministries.
  - Contribute toward the required national capabilities.
  - Conduct R&D gap analysis.
  - Maintain international relations for R&D.
  - Develop government's relations and position R&D entity as an "intelligent customer".
  - Support R&D specialization clusters concept for academic institutions and R&D centers.

7.2.8. Miscellaneous Strategies

Another possible successful strategy is stimulated by Jordan (2019) who mentioned that organizations should encourage project managers which show potential characteristics such as the following:

- **Broad and deep experience leading projects:** Project managers get experience through managing more projects and are involved in different business areas, and thus they rely on their own abilities rather than relying on defined processes.

- **A questioning attitude:** Ambitious project managers who are always looking for other methods to accomplish activities and do not teach themselves by existing approaches have the best chance of encountering innovative approaches. These project managers are often seen as the 'troublemakers' who repeatedly ignore to follow processes they don't believe in.
- **Exceptional self-belief and self-control:** Project managers who attempt to take innovative and difficult decisions in situations where lack of experience with the approaches being used exist.

Moreover, Dandage, et al. (2018) have suggested some project risk management strategies, which have been concluded in consultation with more than 20 project practitioners. These strategies include the following:

- The project should have a clear scope, realistic cost and time estimates, and clear communication with all stakeholders.
- Risk management must be an integral part of the organizational culture.
- Risk management structure must be established within the organization.
- Top management should support to risk management efforts.
- Risk management cost should be seen as an investment to prevent the forthcoming losses of the risk occurring in the project.

7.3. Epilogue

Several projects finish successfully, while others end as a failure. The reason for the failure of projects can be enormous and thus to ensure that the project can achieve the predefined objectives, it is necessary to properly manage every aspect of the project. Projects are unique, and thus a slight change in the surroundings may result in deviations from the predefined objectives including costs, resources, and time.

Managing a project from the time when the idea is generated to undertake a project ensures that everything is taken care of and every step is predefined. Monitoring and documenting the steps in advance make sure to allocate necessary or estimate the resources, time, and budget to those steps or phases. It helps in tracking the activities that will take place in the project in advance.

Moreover, risks are associated with each stage of a project lifecycle. Regardless of whether the project is big or small, some of the projects fail to deliver from both segments. The reasons can be many for the failure of a project. While it is easy for almost every organization to commit towards completing the project within the predefined objectives, it is hardly the case. Majority of the organizations fails to meet the deadline due to various constraints such as budget, time, resources, and various other constraints. Some industries have least projects failure reputation while others have a bit higher failure percentage or lower success rate. One of the industries with most failures is the technology industry with more than 50 % failure regarding undertaken projects (Symonds, 2011).

Nevertheless, risks that are threats to the project may be accepted if the risk is in balance with generating opportunities or reward that may be gained by taking the risk, such as R&D projects. Accordingly, organizations perceive risk as it relates to threats to project success, or to opportunities to enhance chances of project success. Therefore, the objectives of risk management are to increase the probability and impact of positive events, and decrease the probability and impact of events adverse to the project (Perera et al., 2014).

Therefore, while proper and effective project management planning is necessary to support project completion within predefined objectives and allocated resources, risk management planning is also necessary to predict the uncertainties that the project can face at the time of execution. Though risk management planning does not necessarily ensure that the project will get finished without any errors or risks, it ensures considerable management and mitigation of these uncertainties. Risk management efforts are often addressed by the project managers during the planning phase and are rigorously addressed in the following phases. As well as there are many sets of guidance, tools, methodologies, frameworks, and practices for project management and risk management, which organizations and project managers can rely on, qualitative assessments by subject matter experts, experienced project managers, and customers are also essential (Sciarretta et al., 2008).

R&D projects and activities are familiar increasingly nowadays, which can be as complex, interdependent, and highly intelligent activities. R&D projects are typically based on international cooperation, cultural differences, language and political

orientation, and its value for the sake of quality of life is highlighted in every strategic plan (Mikulskiene, 2014). While risks are introduced in every project, R&D projects by its nature are under high risk and uncertainty, usually irreversible in terms of future rewards, and, thus, require special managerial attitude. Despite R&D management specificity, the importance of project management and risk management as an instrument to make activities more effective is well acknowledged (Mikulskiene, 2014).

The military R&D is highly involved in the technical aspects of their projects, which include technical and operational performance, scope, schedule, and costs. Technical and operational performance risks are highly related to the technical maturity of the technologies and subsystems being integrated into a system (Sciarretta et al., 2008). The R&D facilities of armed forces though take immense care while initiating a project, sometimes end up with a failed project. The failure of the project does not only mean that the project was unable to produce an outcome but even if the outcome is present, its integration or the technology used is not what is required, which makes it less worthy.

These aspects demand more than a revolution in technology; it requires a revolution in thinking, and organizations that embrace and adapt to these aspects of technology and management characteristics will dominate those that do not. It is for these various reasons, extra caution is taken in the military R&D environments regarding the projects as they are not ordinary projects, and their success means an improvement that is in the nation's interest. While profit, saving cost, and market share are important objectives for the private and commercial organizations, other factors such as military capability enhancements and dependency are key to the defense environment (Sciarretta et al., 2008). Thus, this requires special methodologies and approaches to manage military R&D investments.

Building this kind of military is not only desirable; it is becoming technologically feasible. Overcoming the challenging obstacles require leadership at the highest levels of government to set clear priorities, drive change in resistant institutions, remake their incentive structures, and recast their cultures (Brose, 2019).

Defense research has made a great difference in the past and will continue to make a significant difference for the future military. Hence, even though the R&D center for the UAE armed forces has not created a significant mark of its presence on the global scale,

yet it offers a chance for the country to increase its power and position on the global market.

Thus, the UAE Armed Forces should take into consideration the feasibility of such R&D facilities within its territory, hearten its activities, and encourage its cadre. The RDC must invest in basic research in order to foster progress in niche areas, conduct focused research to develop and tailor knowledge and technologies to address military needs, and support a full spectrum warfighting force that is capable of meeting a multitude of future mission requirements (Sciarretta et al., 2008). This includes both evolutionary research that advances the state-of-the-art and revolutionary concepts that provide the basis for breakthrough capabilities. In addition to technology and management individualities and skills, RDC must retain the flexibility to take advantage of technological opportunities as they appear and to foster their application to meet military requirements (Sciarretta et al., 2008). The application process itself can take time as well.

The cooperation between all the stakeholders and sectors in UAE would result in world-class R&D that links and leverages the development of capabilities to secure technological foundation, enhance military capabilities, and stimulate economic growth. This will result of a collaborative R&D environment supporting the defense industrial sector growth in UAE, manage and guide R&D national and international cooperation programs that meet stakeholders requirements, and maximize outcome through effective R&D lifecycle and efficient spending, hence taking the UAE to the next level of prosperity.

7.4. Limitations and Follow-Up

Due to the nature of the researched organization, the RDC, which contains the Armed Forces information and secrets, the participants of this research have not disclosed confidential information or mentioned briefly requesting not to be released in this research. In addition, some identified information has not been mentioned and discussed for the sake of the safety issues of the Armed Forces. This may pose a limitation for the findings of this research, which may additional unidentified risk factors or risk management methodologies and practices have been developed and can be furthered explored benefiting the R&D risk management literature.

Moreover, the participants talked in general about the encountered risk factors they experienced and the methodologies used not mentioning specific project or the case where it has been applied or its effectiveness causing limitation for this research to assess which method fits for each case or which risk has been encountered in which R&D stage or process. These limitations may provide additional openings to perform studies and investigations in the area of risk management of the R&D projects that are associated with the research and development environments of the Armed Forces. Follow-on researches may also demonstrate the usefulness of this study and may be able to apply its components in a use case analysis involving R&D complex project in the defense sector.

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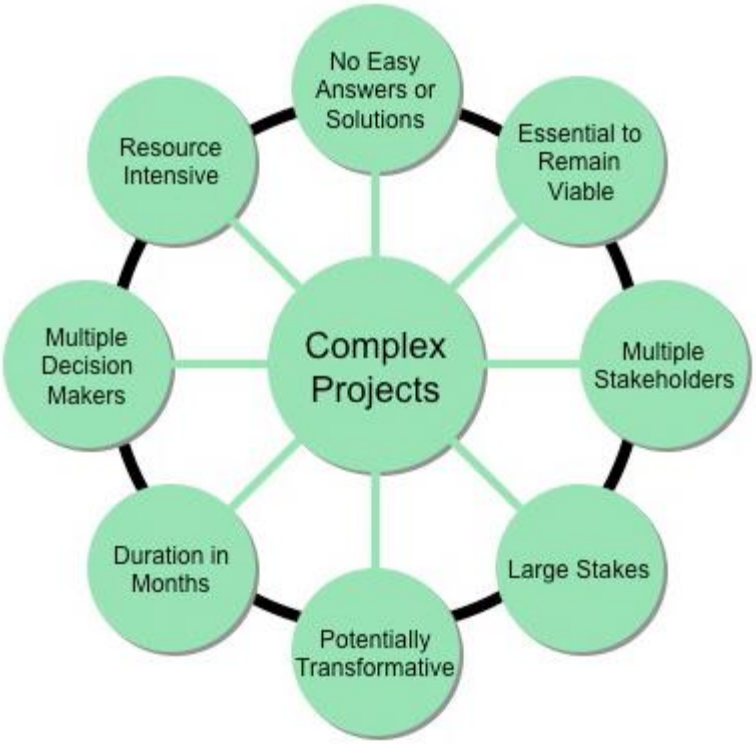
APPENDICES

Appendix A: Difference between a Project and a Program

	Project	Program
Objectives	Outputs – tangible; relatively easy to describe, define and measure; tending towards objective.	Outcomes – often intangible; difficult to quantify; benefits often based on changes to organizational culture and behaviors; introducing new capabilities into the organization; tending towards subjective.
Scope	Strictly limited; tightly defined; not likely to be subject to material change during the life of the project.	Not tightly defined or bounded; likely to change during the life cycle of the program.
Duration	Relatively short term; typically three to six months.	Relatively long term typically eighteen months to three years.
Risk profile	Project risk is relatively easy to identify and manage. The project failure would result in relatively limited impact on the organization relative to program risk.	Program risk is more complex and potentially the impact on the organization if a risk materializes will be greater relative to project risk. Programme failure could result in material financial, reputational or operational loss.
Nature of the problem	Clearly defined.	Ill-defined; often disagreement between key stakeholders on the nature and definition of the problem.
Nature of the solution	A relatively limited number of potential solutions.	A significant number of potential solutions with often with disagreement between stakeholders as to the preferred solution.
Stakeholders	A relatively limited number of stakeholders.	A significant number of diverse stakeholders; probable disagreement between them as to the definition of the problem & the preferred solution.
Relationship to environment	Environment within which the project takes place is understood and relatively stable.	Environment is dynamic; and programme objectives need to be managed in the context of the changing environment within which the organization operates.
Resources	Resources to deliver the project can be reasonably estimated in advance.	Resources are constrained and limited; there is competition for resources between projects.

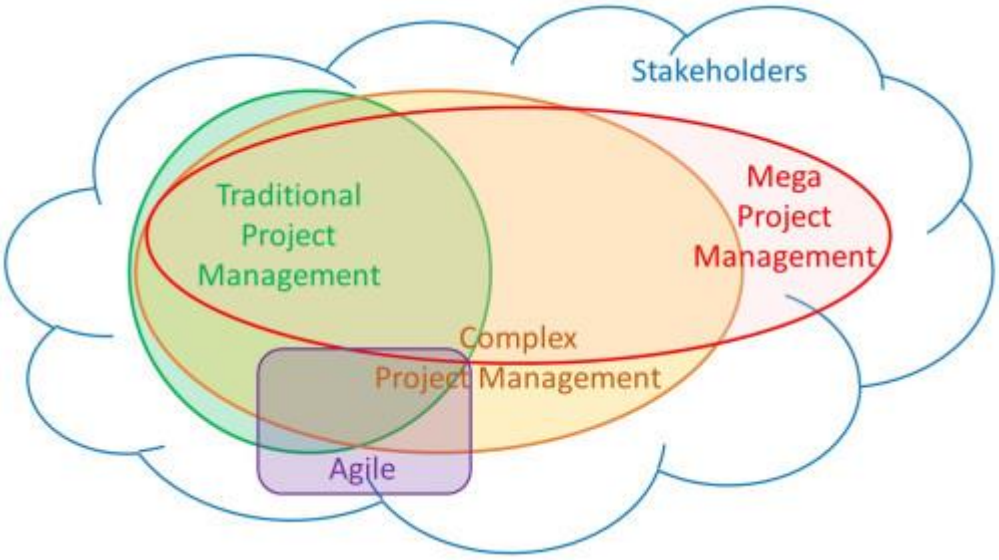
(Source: Independent Consulting Bootcamp, 2018)

Appendix B: Complex Project Overview



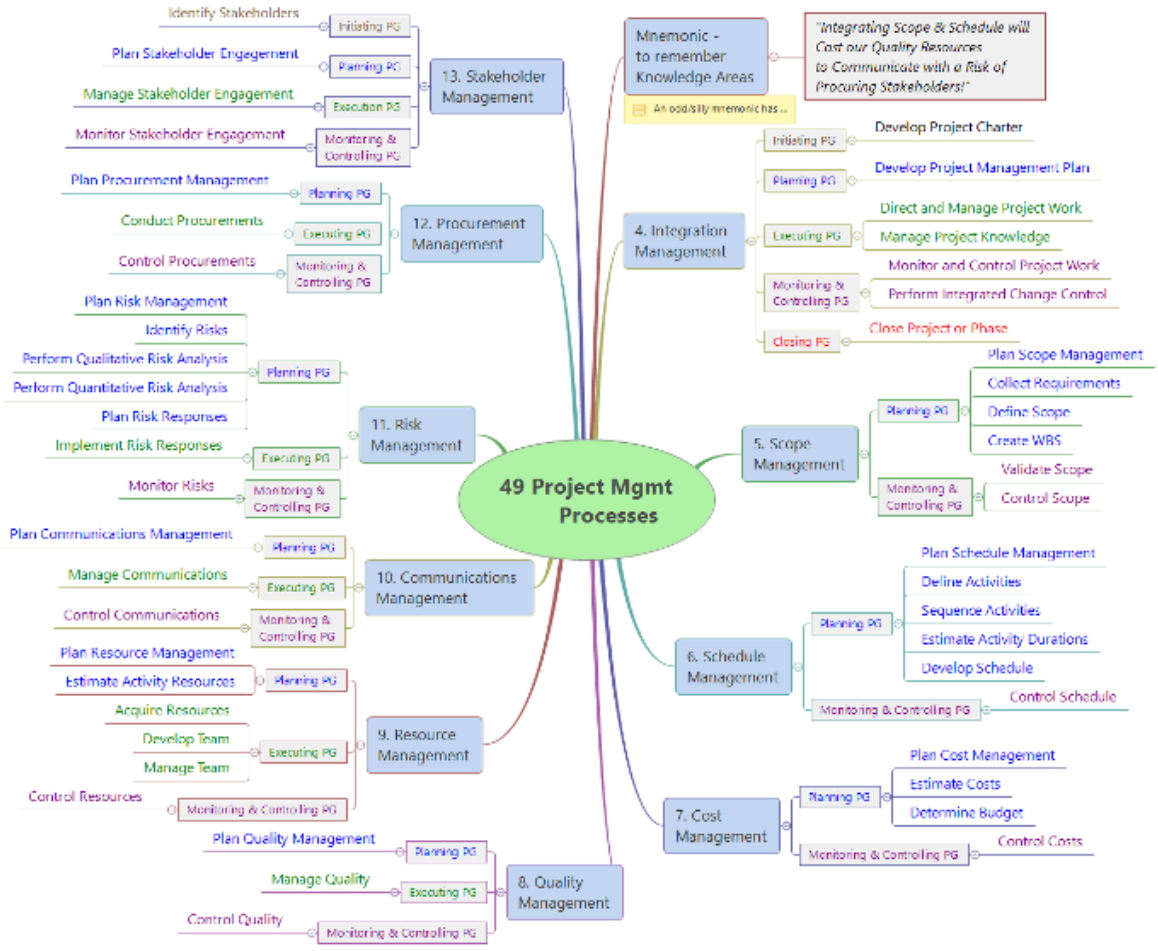
(Source: InnovationLabs, 2018)

Appendix C: Projects in the cloud



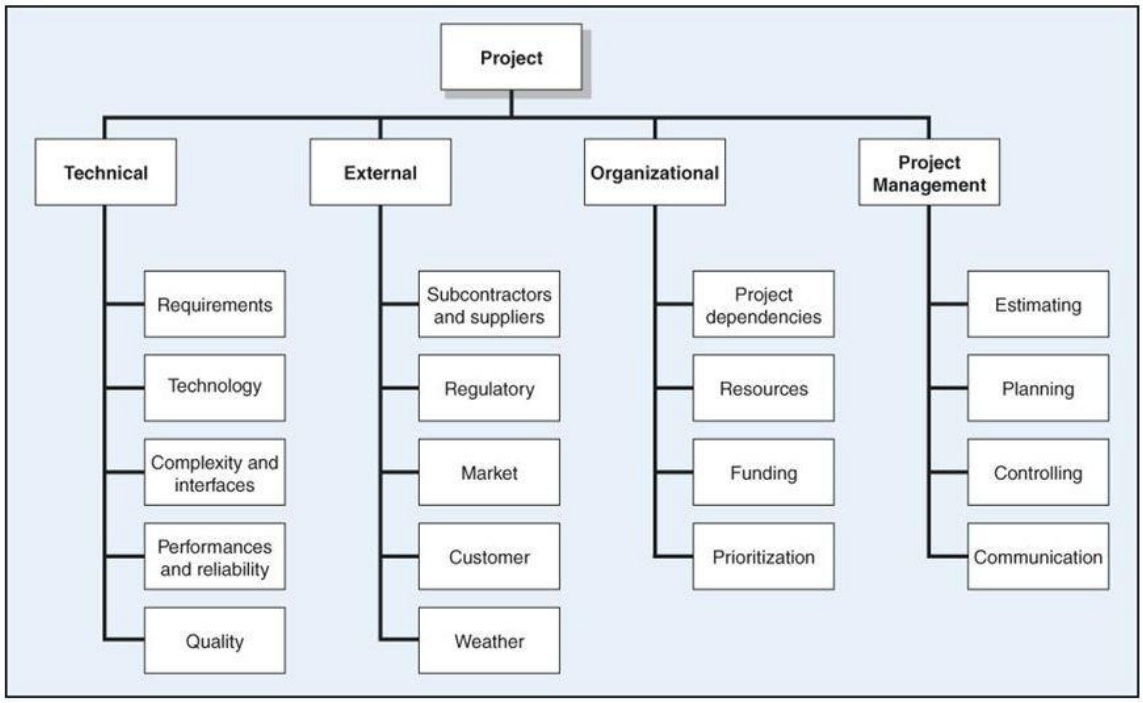
(Source: Mosaic projects, 2018, Adapted from PMBOK)

Appendix D: Project Management Knowledge Areas & Processes



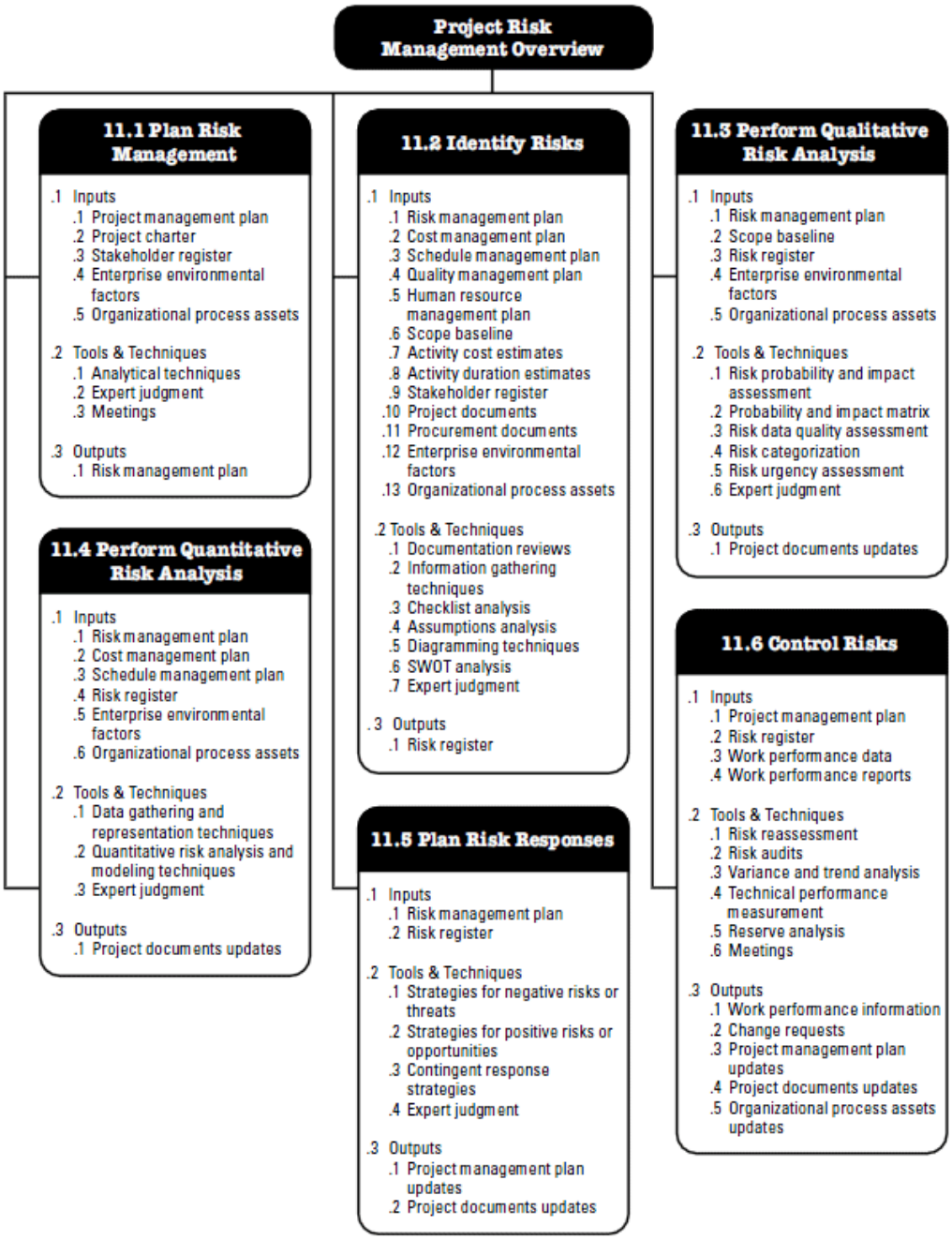
(Source: PM Exam Smartnotes, 2018, Adapted from PMBOK)

Appendix E: Project Risk Categories



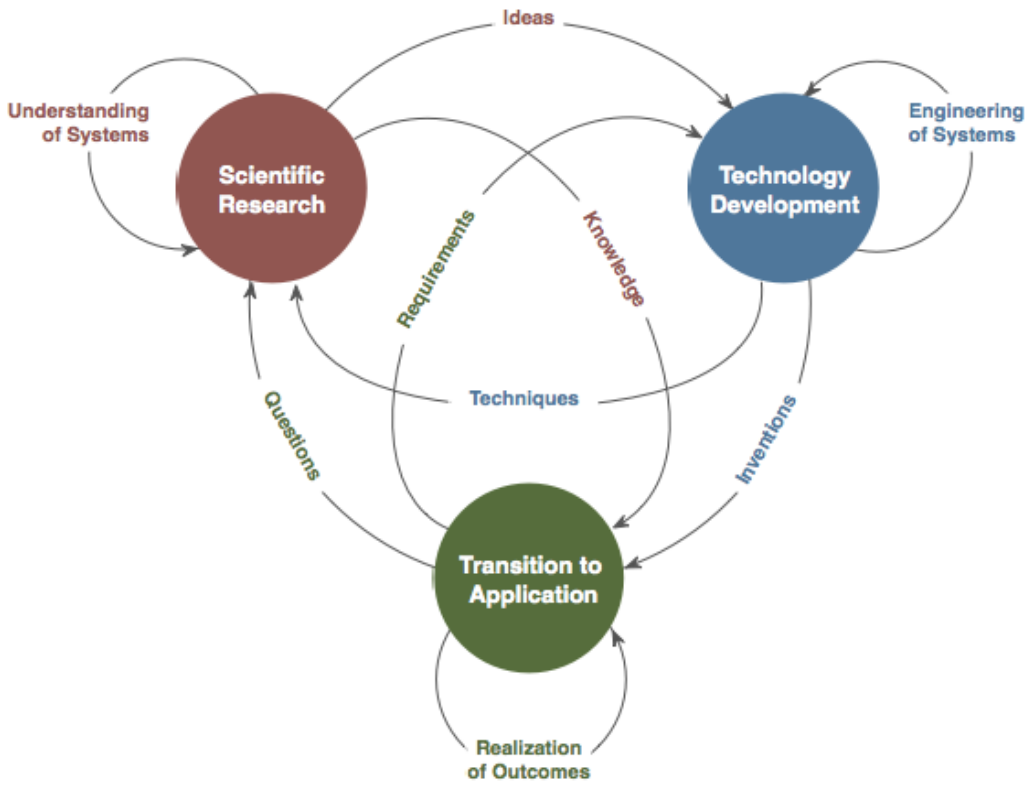
(Source: Saurabh, Bhola, Kumar, 2014)

Appendix F: Project Risk Management Plan Overview



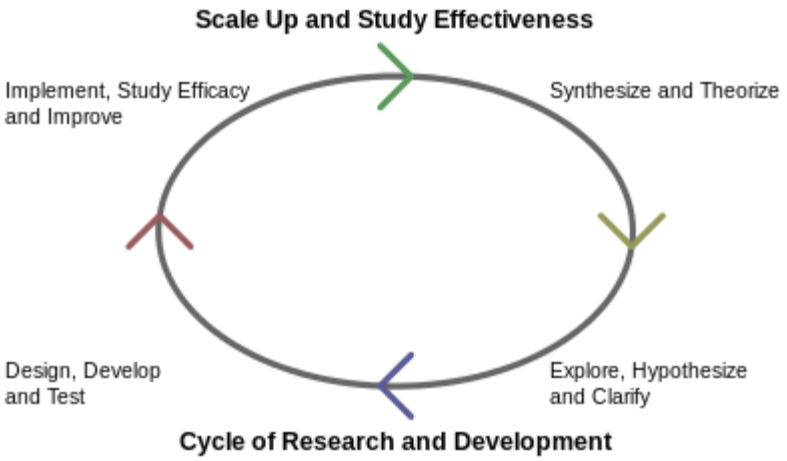
(Source: PMI PMBOK, 2017)

Appendix G: Research and Development (R&D) Concept



(Source: NOAA, 2018)

Appendix H: Cycle of R&D



(Source: Wikipedia, 2018)

Appendix I: Summary of Normative, Descriptive, and Prescriptive Decision Theories

	Normative	Descriptive	Prescriptive
Focus	How people should decide with logical consistency	How and why people decide the way they do	▪ Help people make good decisions ▪ Prepare people to decide
Criterion	Theoretical adequacy	Empirical validity	Efficacy and usefulness
Scope	All decisions	Classes of decisions tested	Specific decisions for specific problems
Theoretical Foundations	Utility theory axioms	▪ Cognitive sciences ▪ Psychology about beliefs and preferences	▪ Normative and descriptive theories ▪ Decision analysis axioms
Operational Focus	▪ Analysis of alternatives ▪ Determining preferences	Prevention of systematic human errors in inference and decisionmaking	▪ Processes and procedures ▪ End-End decision life-cycle
Judges	Theoretical sages	Experimental researchers	Applied analysts

(Source: Versluis, 2014)

Appendix J: Researchers in R&D per million people

The number of Researchers in R&D per million people in some countries per each mentioned year. Postgraduate PhD students engaged in R&D are also included. The study is conducted by the UNESCO Institute for Statistics.

Country	2013	2014	2015	2016
Australia	---	---	---	---
Bahrain	---	493	---	---
Brazil	172126	183853	---	---
Canada	163180	162090	---	---
Egypt	47652	61058.55	62208.35	65097.2744
Estonia	4407	4323	4187	4338
Jordan	---	---	2339	5660
Kuwait	---	2289	1518	---
Malaysia	---	61351	69864	---
Oman	497.244	716.5	906.969	---
Pakistan	30244	---	55611	---
Republic of Korea	321841.848	345463.427	356447.29	361291.534
Saudi Arabia	---	---	---	---
Singapore	36025.435	36665.597	---	---
United Arab Emirates	---	---	18344.97104	22308
United Kingdom	267698.5	276583.8	284483	291416
United States of America	1305862.356	1351903.194	1379977.162	---
UIS Regions	---	---	---	---
World	7959052.385	8226322.157	8496039.727	---
Arab States	166298.019	187997.6416	194884.7701	---

Source: Adapted from (UIS, 2018)

Appendix K: The Consent Forms for Research Project Interview

University of Southern Queensland

Consent Form for USQ Research Project Interview

Project Details

Title of Project: **Management of Risk in Delivering Complex Research and Development Projects: A Case of the Research & Development Center of the United Arab Emirates Armed Forces**
Human Research Ethics Approval Number: **H15REA111**

Research Team Contact Details

Principal Investigator Details

Mr Badr Ahmed Dallak Alshehhi
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Telephone: **00971 50 6663225**
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Supervisor Details

Dr David Thorpe
Email: **thorped@usq.edu.au**
Telephone: **(07) 3470 4532**
Mobile: **(07) 3470 4532**

Statement of Consent

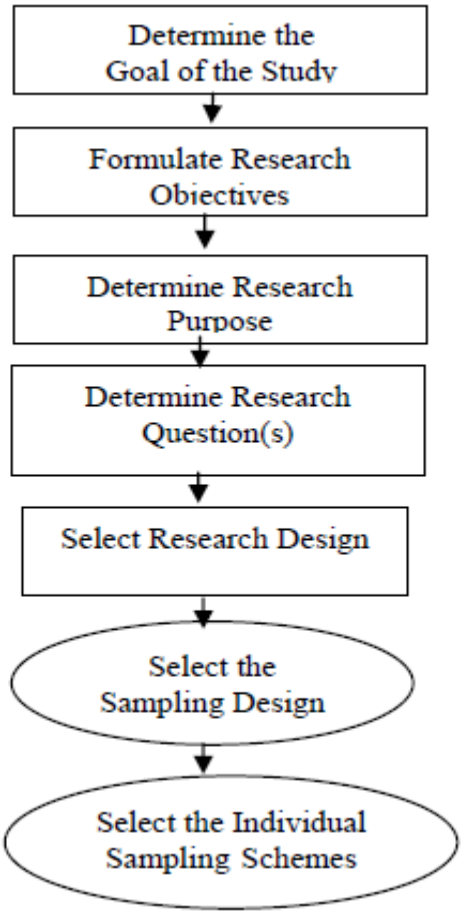
By signing below, you are indicating that you:

- Have read and understood the information document regarding this project.
- Have had any questions answered to your satisfaction.
- Understand that if you have any additional questions you can contact the research team.
- Understand that the interview will be audio recorded.
- Understand that you are free to withdraw at any time, without comment or penalty.
- Understand that you can contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au if you do have any concern or complaint about the ethical conduct of this project.
- Are over 18 years of age.
- Agree to participate in the project.

Participant Name	
Participant Signature	
Date	

Please return this sheet to a Research Team member prior to undertaking the interview.

Appendix L: Steps of the sampling process



- **To develop framework for managing risks of complex R&D Projects of UAEAF**

- **To explore risks occurred in RDCUAEAF and stakeholders' perceptions**
- **To construct a frame work of these factors**

- **To construct an R&D risk framework to manage UAEAF complex projects**

- **What is the perception of RDCUAEAF stakeholders regrading risk management of complex projects?**

- **Exploratory**

- **Judgmental**

(Source: Adapted from Onwuegbuzie & Collins, 2007)

Appendix M: Sampling of Interviews

	Sampling Consideration	Result
Population		▪ RDC Top Managers – 4 ▪ Army commanders – 4 ▪ Customers – 4
Sample	▪ A small number of cases, or subjects, may be extremely valuable and represent adequate numbers for a research project ▪ This is especially true for studying hidden or hard to access populations such as deviants or Army or elites ▪ Here, a relatively few people, such as between six and a dozen	6 – 12 people ▪ RDC Top Managers – 2 ▪ Army commanders – 2 ▪ Customers – 2

(Source: adapted from Kumar, 2014)

Appendix N: Interview Questions Sample

Research Interview Questions

Management of Risk in Delivering Complex Research and Development Projects: A Case of the Research & Development Center of the United Arab Emirates Armed Forces

1. **Startup Question:** Please state your name, and position at UAE Armed Forces?
2. **Transition Question:** What is your experience in complex UAE research projects?
3. **Main Question:** What are the risk factors identified in your research projects? (Identify at least 3 risk factors & examples)
4. **Main Question:** What is the impact of these identified risks on your project (execution & delivery)?
5. **Main Question:** What current (risk Management practices) do you apply to minimize the impact of these risks on research projects execution and delivery?
6. **Main Question:** Are there any (Risk management Practices/ guidelines) that are currently not applied at work?
7. **Review Question:** Have we missed anything? Any comments and suggestions for better risk management practices at work?

Appendix O: The NATO Nations and Partner Countries
(Source: Science and Technology in NATO, 2019)

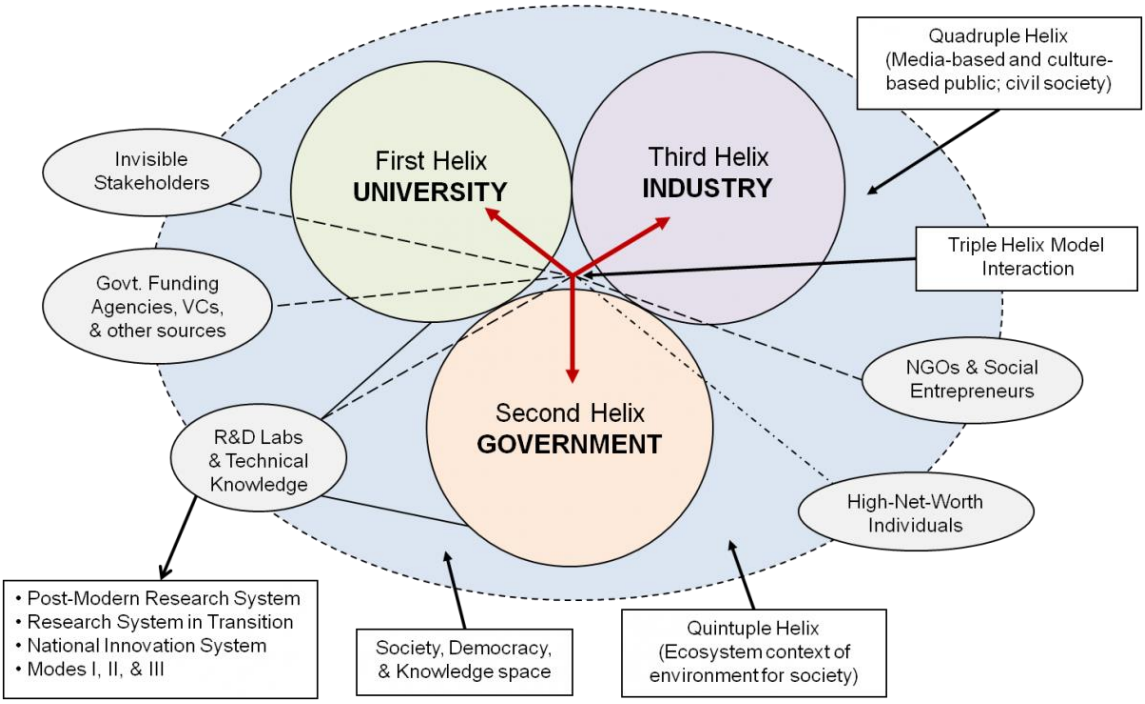
NATO Countries

Albania, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iceland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Turkey, United Kingdom, United States.

NATO Partners

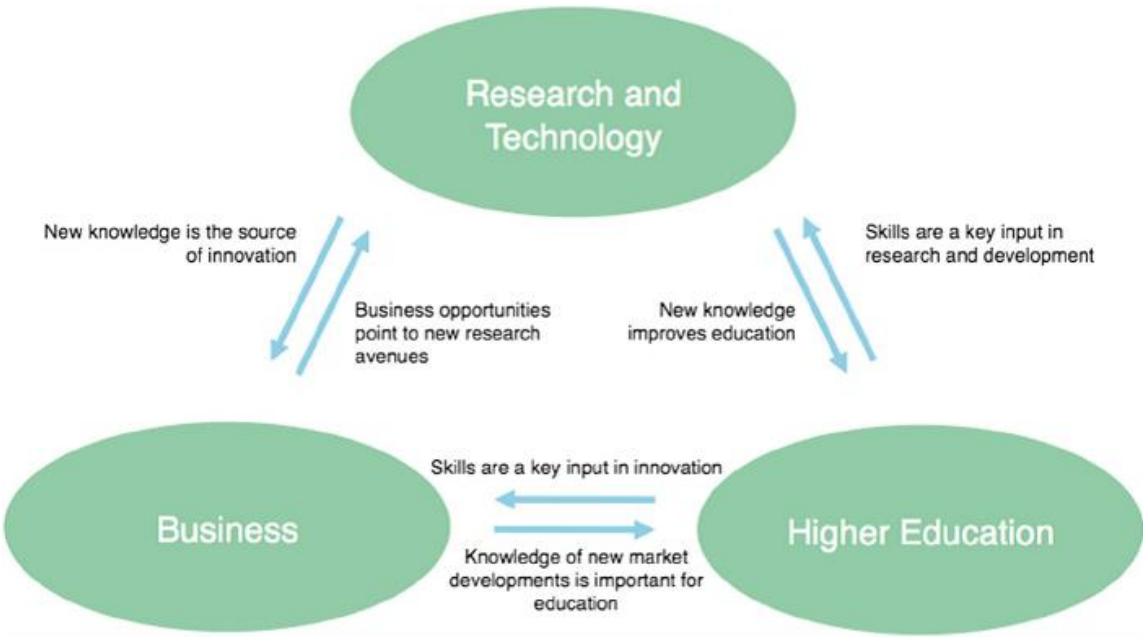
Afghanistan, Algeria, Armenia, Australia, Austria, Azerbaijan, Bahrain, Belarus, Bosnia and Herzegovina, Egypt, Finland, Georgia, Iraq, Ireland, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyz Republic, Malta, Mauritania, Moldova, Mongolia, Montenegro, Morocco, New Zealand, Pakistan, Qatar, Republic of Korea, Russian Federation, Serbia, Sweden, Switzerland, Tajikistan, the former Yugoslav Republic of Macedonia, Tunisia, Turkmenistan, Ukraine, United Arab Emirates, Uzbekistan.

Appendix P: The knowledge system landscape



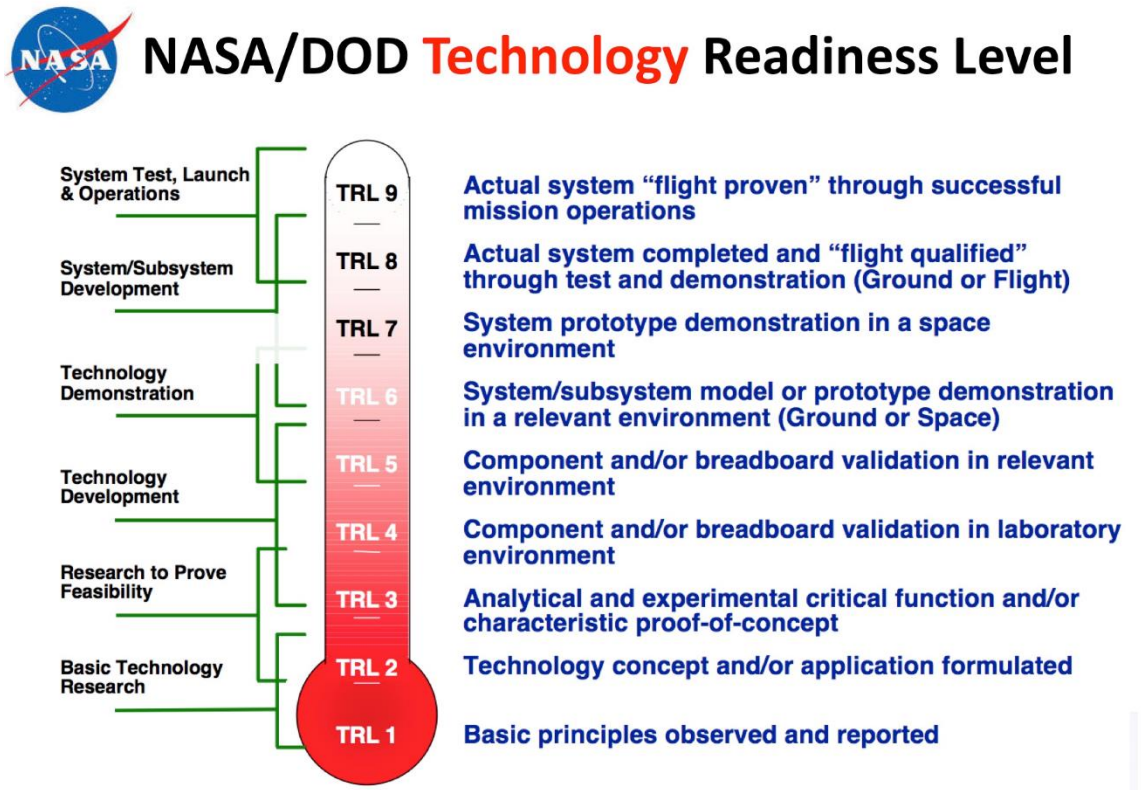
(Source: Saurabh, Bhola, Kumar, 2014)

Appendix Q: The Knowledge Triangle



(Source: EIT, 2012)

Appendix R: USA NASA / DOD Technology Readiness Level (TRL's)



(Source: Adapted from NASA, 2018)