Development of a Defense Technology Acquisition Portfolio Management Framework

Raney Almehmadi

orcid.org/0000-0003-1440-0032

Dissertation accepted in partial fulfilment of the requirements for the degree *Master of Engineering in Development and Management Engineering* at the North-West University

Supervisor: Prof. W Den Heijer

Graduation: 2019

Student number: 27360253

بسم الله الرحمن الرحيم

تم بحمد الله

All Praises to Allah, Lord of the Worlds

DEDICATION

I wholeheartedly dedicate this dissertation to …

To my Paradise path, who blessed me with their prayers all the time and continually provide moral, emotional, and spiritual support … my Parents.

To the one who made my life fabulous and gave me all the love, strength, endless support and encouragement … my wife♥ Reem who sacrifice two years of her educational life just to be with me and support me.

To the Falcons who drew my ambitious sky … my brothers.

All my love, appreciation and gratitude to them can never be quantified.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to the following people:

I wish to thank my supervisors Prof. Harry Wichers and Prof. Willem Den Heijer for their support and guidance throughout this project. I truly admire their passion for the subject field, their enthusiasm is a true inspiration. I would like to thank them for their patience and hard work towards the end of this dissertation. Their professionalism in the working environment and dedication to ensure that work of a high standard is delivered are admired.

I wish to thank my friends and collegues at Rheinmetall Denel Munition for their support and cooperation during the period that I stayed in South Africa.

I wish to thank my colleagues from Saudi Arabia for your support and assistance.

ABSTRACT

Defense acquisition system (DAS) is one of the most important aspects of defense systems and requires an efficient and effective strategy for implementation. DAS has been reformed in the defense industry in an evolutionary way. The critical assessment processes are required to have the ability to develop a variety of defense acquisition strategies. The best practices approach for the DAS strategies are those that have the ability to identify and recommend various solutions for gaps and shortfalls in operational military capabilities. The current defense industrial situation in Saudi Arabia requires a formal defense acquisition system which is not yet available. Meanwhile, the officials in the newly established General Authority for Military Industries (GAMI), are busy developing a formal DAS to acquire the needed capabilities that satisfy the national objectives.

Therefore, this research proposed a new integrated framework for decision-making purposes in selecting proper projects to fill the technological gaps in the local defense industry in Saudi Arabia. This research combines models, elements and metrics used for technology acquisition in the defense sector. The researcher has named his deliverable, the Defense Technology Acquisition Portfolio Management (DTAPM) framework.

Relavant literature was identified and analysed by using elements in the DTAPM. The approach to developing this framework was based on the “adapt to adopt” concept. The researcher adopted valid user models then adapted them for the usage to the benefit of Saudia-Arabian needs. An approach guarantees that efficient defense acquisition management decisions can be made, by virtue of connecting the strategic decision-makers to the technical managers, in order to facilitate the technological portfolio management.

The resulting framework was exposed to and verified by experts. The usability and validation will be tested by implementing the DTAPM in the future.

Keywords: technology acquisition, portfolio management framework, defense acquisition system, technology space map, technology management, strategic planning

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LIST OF ABBREVIATIONS AND ACRONYMS

AFED	Armed Forces Exhibition for Diversity of Requirements & Capabilities
AoA	Analysis of Alternatives
APAs	Additional Performance Attributes
CAGR	Compound Annual Growth Rate
CBA	Capabilities-Based Assessment
CGA	Capabilities Gap Assessment
DAB	Defense Acquisition Board
DAS	Defense Acquisition System
DIS	Defense Industrial Strategy
DOD	Department of Defense
DTAPM	Defense Technology Acquisition Portfolio Management
EMD	Engineering and Manufacturing Development
FAA	Functional Area Analysis
FNA	Functional Need Analysis
FSA	Functional Solution Analysis
GAMI	General Authority of Military Industries
ICD	Initial Capabilities Document
IP	Intellectual Property
IRL	Integrated Readiness Level
ITT	International Technology Transfer
JOC	Joint Operating Capabilities
KPPs	Key Performance Parameters
KSA	Kingdom of Saudi Arabia
KSAs	Key System Attributes
MIC	Military Industries Corporations
MOD	Ministry of Defense
MRL	Manufacturing Readiness Level
MSA	Materiel Solution Analysis
NASA	The National Aeronautics and Space Administration
NDS	National Defense Strategy
NMS	National Military Strategy
NSS	National Security Strategy

NTT	National Technology Transfer
NWU	North West University
OEM	Original Equipment Manufacturer
OS	Operations and Support
OSAs	Other System Attributes
PD	Production and Deployment
PfM	Portfolio Management
PIF	Public Investment Fund
PrM	Programme Management
QA	Quality Assurance
R&D	Research and Development
R&D3	Degree of Difficulties to proceed to the next level of TRL
RDT&E	Research and Development / Test and Evaluation
SAMI	Saudi Military Industries Company
SPA	Saudi Press Agency
SRL	System Readiness Level
TA	Technology Acquisition
TCE	Technology Critical Elements
TD	Technology Development
TDm	Technology Demonstration
TI	Technology Integration
TM	Technology Management
TMRR	Technology Maturation and Risk Reduction
TRA	Technology Readiness Assessment
TRADOC	The U.S. Army Training and Doctrine Command
TRL	Technology Readiness Level
TSM	Technology Space Map
TT	Technology Transfer
TTO	Technology Transfer Office
US	United States
WBS	Work Breakdown Structure
WS	Weapon System

CHAPTER 1: INTRODUCTION

1.1 Background

1.1.1 Importance of technology

At the end of the eighteenth century, the Industrial Revolution marked a major difference between nations. This difference lasted for generations and was a transition from hand-production to machine production. Moreover, it linked theoretical science to the human lifestyle by bringing all the innovative technological ideas into useful products which made life better for humans. Technology is "the use of science in industry, engineering, etc., to invent useful things or to solve problems" ("Merriam-Webster," 2018). Technologies that have been cultivated in countries deliver strong nations' structure to their organisations in the form of rising their economy and power basis.

Additionally, it had a very positive impact on people's daily lives. Technology has an important effect on business operations. No matter the size of the enterprise, technology has both tangible and intangible benefits that will help the business grow economically and produce the results that customers demand. Technological infrastructure affects the culture, efficiency and relationships of businesses. It also affects the security of confidential information and trade advantages ("SBDC," 2018).

Technology has made a significant development in various fields of armaments. The amazing and successive technological developments have led to the emergence of new generations of weapons, or to the increased capacity and effectiveness of others. This has led to differences in the power balance between nations. Cultivating the technological capabilities through a Technology Acquisition process is a massive project and very risky and takes years to accomplish its goals. However, it can effectively succeed if it is well managed.

1.2 Technology in the Defense Industry

1.2.1 Pre-industrial world Defense

More than a thousand years ago, the sword, arrow and spear were the main elements of the military equipment. The invention of cannons has influenced the form and methods of wars and even societies in general in ways that almost no other weapon has done. During the 7th century, the Chinese invented gunpowder. Armies quickly learned about this powder, which today can be used in bombs, mines and other weapons. The gunpowder was transported to Europe in the 13th century, probably via the Silk Road and Central Asia (Andrade, 2016).

1.2.2 A sea change in Defense

In recent decades, the world has witnessed the development of defense technologies into powerful techniques that led to the transfer of armies from one era to another. Countries are competing for the best technologies in order to become dominant and to protect their citizens and resources. This started with the industrial revolution when the first warship was powered with steam in 1860. And still, the flow of new inventions has not stopped. As science evolved, the engineering disciplines improved. In the defense industrial history, the engineering branch grew from mechanical engineering (steam power), civil engineering (canals), to electrical engineering up until aeronautical engineering. In the twentieth century, the defense industry has seen the development of more complex weapon systems. This complexity necessitates the defense project managers used a discipline that integrates all the engineering branches in a single architecture “System Engineering”. (Edgar, 2016)

1.2.3 Defense Technology Management

Technology management (TM) is crucial to today’s organisations. It includes knowledge management and innovation, and the utilisation of the available technological capabilities. Organizations, in order to manage their technology development portfolio, should employ an integrated framework to ensure timely technological investment decisions and capability development (Foden & Berends, 2010).

Managing technology in defense is about acquiring and developing the required technology for the needed development in capabilities. This may be achieved through the following:

- Technology development (TD);
- Technology demonstration (TDm); and/or
- Technology Integration (TI).

All of the above are considered Technology Transfer (TT). Many authors have defined TT from different aspects – some consider it a technology adoption, meaning the scientific technology moves from the academic sector to the marketplace. While other authors define it from the business aspect and consider it a technology acquisition, which is buying the right to use the technology from the developer/owner of the technology.

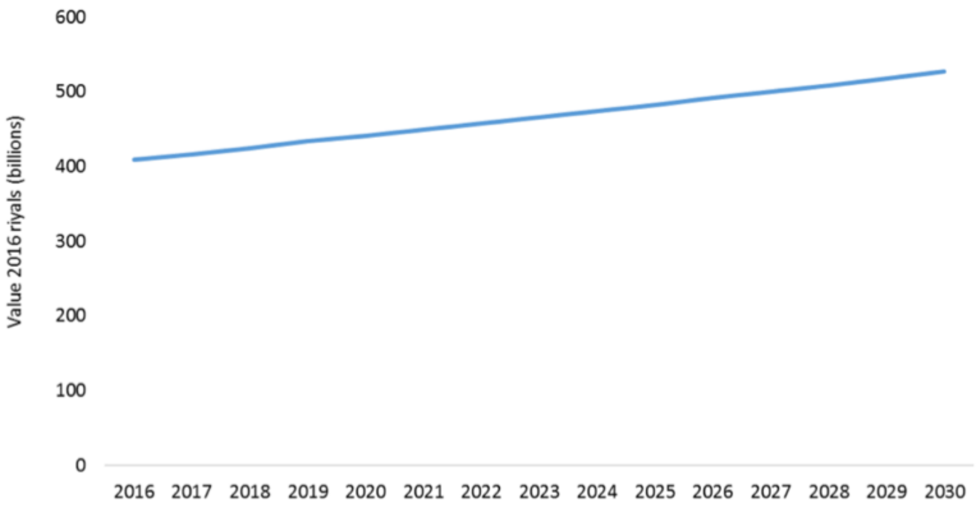
These obscure definitions for TT, confuse the researchers in this field. Before going further, this paper will redefine some definitions for clarity purposes. In order to obtain a clear picture of the two confusing definitions, we need to recognize the maturity of the aimed technology. This recognition will be obtained through a metric called Technology Readiness Levels (TRL), which will be discussed in Chapter 2.

In the defense industry, the industrial situation is very complicated due to the complexity of the systems. Technology management and its tools such as; technology maturation assessment, technology watch, technology roadmapping, technology make-buy, technology risk management and technology acquisition have been used widely in the defense sector as well as other sectors. This research aims to develop a framework to manage large technology programs in the Saudi Arabian Ministry of Defense (MOD).

1.3 Saudi Ministry of Defense (MOD)

In the Kingdom of Saudi Arabia (KSA), thriving long-term economic investments is one of the first goals of the new Saudi Vision 2030 (“Saudi MOD,” 2018). Although oil and gas are the fundamental pillars of Saudi Arabia’s economy, diversifying the investments is vital for sustainability. This approach can be achieved by implementing massive transforming projects to acquire needed technologies to stimulate the Kingdom’s economy during prospering in the post-oil era.

In 2016 Saudi Arabia was placed third in the world in terms of military spending. The 2019 fiscal budget allocated approximately $56 billion for the military sector. Notwithstanding this massive expenditure, the share of localised military spending does not exceed 2% of the Kingdom's current total spending on armament, maintenance and related spare parts.



Source: USSABC, REMI

Figure 1: Saudi Defense Sector Demand

There is a strong outlook for the security and defense sector as Saudi Arabia continues to invest, sign contracts with international firms, and increase Joint Ventures for the design, assembly, manufacturing and maintenance of military equipment. The Saudi Arabian defense sector has a 1.8 per cent forecasted compound annual growth rate (CAGR). Local employment in this sector related to government expenditure is expected to grow steadily at a 1.3 per cent CAGR (Figure 1). Continued growth of the sector reflects the region's geopolitical situation. The announced aim for the Ministry of Defense (MOD) that aligns with the new vision is to increase this percentage from two to fifty per cent by 2030. This technological leap in such a short timeframe is not easy to reach, but it can be accomplished with effective strategies that are enhanced in many ways (USSABC, 2017).

Behind just being one of the most significant importers of military materiel, the KSA also wants to become to one of the world's largest weapons manufacturers and is now investing in its capabilities.

In response to this urgent need, the MOD has launched the "MOD development program" and has set the following strategic objectives ("Saudi MOD," 2018):

1. develop and achieve joint operating capabilities (JOC);
2. improve MOD performance;
3. modernize weaponry and armament;
4. optimize spending efficiency and nationalize industrialization; and
5. nurture morale of MOD staff and improve individual performance.

From these objectives, we can recognise that the first objective is the most critical one that influences the remaining objectives. Evolving and achieving the joint operations capabilities will result in the performance improvements and modernisation of the weapon systems and support the national industry. Consequentially, also improving MOD performance.

These objectives necessitated taking massive steps toward the stated goals; to be among the 25 largest arms producers in the world. The MOD already initiated these steps and launched the Armed Forces Exhibition for Diversity of Requirements & Capabilities (AFED), the Saudi Arabian Military Industries (SAMI) and the General Authority for Military Industries (GAMI) to support this drive.

1.3.1 The AFED Conference and Exhibition

In February 2018, The Ministry of Defense had organised (for the fourth year), the Armed Forces Exhibition for Diversity of Requirements and Capabilities (AFED), in order to display the requirements of the shareholders, as well as capabilities of local and international industries and research centres. This initiative is part of the means to accomplish the aims of Vision 2030 and the application of the Kingdom's movement towards a strong and effective strategy to localise primary and supplementary industries, which covers equipment, spare parts and materials.

The first exhibition was held in Riyadh in 2010 with the participation of branches of the Ministry of Defense only. The second exhibition was held in Dhahran in 2012 with the participation of branches of the Ministry of Defense, and the participation of Aramco, SABIC and Saline Water Conversion Corporation as strategic partners to provide investment opportunities to the private sector in the manufacturing of materials and spare parts.

In 2016, the third exhibition was held in Riyadh with the participation of the branches of the Ministry of Defense, General Directorate of Civil Defense, Military Industries Corporation (MIC), Saudi Oil companies, Saudi Arabian Basic Industries Company, Saline Water Conversion Corporation and Saudi Electricity Company to provide investment opportunities for the sector.

The AFED (2018) covered all military sectors (Ministry of Defense, Ministry of the National Guard, Ministry of Interior, State Security Presidency, Royal Guard Presidency, MIC) (80,000) investment opportunities to manufacture the materials and spare parts needed by the beneficiaries in front of businessmen, companies, institutions and national factories. Also participating in the exhibition were the Saudi Company for Military Industries and many government agencies, national factories, economic balance companies, state-owned investment funds and agencies and universities and research centres, as well as King Abdulaziz City for Science and Technology and many international companies that have contracts with the Ministry of Defense.

The importance of the exhibition is the meeting of both beneficiaries and participating companies to proffer their requirements, as well as the local and international companies to showcase their manufacturing capabilities in the Kingdom of Saudi Arabia. Thus, it will contribute to encourage the development of investment encouragements and develops the industrial atmosphere in general, and raise the stature of the Kingdom of Saudi Arabia on a global scale and be esteemed among developed countries.

Maj. Gen. Eng. Attiya al-Malki, the General Director of the General Directorate of Local Manufacturing Support at the Saudi Ministry of Defense; pointed out that the total number of the locally manufactured parts did not exceed 182 items in 2010, but through the direction and support of the government, the number of products manufactured locally reached about 5,427 items in 2017, more than 65 million pieces of these items were made with the help of more than 12 local projects in Saudi Arabia (“Al Arabiya,” 2018).

1.3.2 The Saudi Arabian Military Industries (SAMI)

On 17 May 2017, Saudi Arabia's Public Investment Fund (PIF) announced the launch of a state-owned military-industrial company aimed at contributing more than 14 billion riyals ($3.7 billion) to the Kingdom's gross domestic product by 2030. The Saudi Arabian Military Industries (SAMI) is part of the kingdom's 2030 Vision. SAMI aims to become one of the world's top 25 defense companies by 2030 ("Arab News," 2018).

The company will seek to localize 50 per cent of total government military spending in the Kingdom by the year 2030, up from just 2 per cent now and will seek to provide over 40,000 employment opportunities by 2030, the PIF - the Kingdom's top sovereign wealth fund - said in a statement ("Reuters," n.d.). By partnering with universities, SAMI will provide students with apprenticeships and careers in cutting edge technologies, which were previously unavailable in the Kingdom ("Arab News," 2018).

1.3.3 The General Authority for Military Industries (GAMI)

In August 2017, the Council of Ministers chaired by Saudi Crown Prince Mohammed bin Salman in Jeddah directed the establishment of the General Authority for Military Industries (GAMI). Prince Mohammed bin Salman directs its board of directors with members including the Minister of Energy, Industry and Mineral Resources; the Minister of Finance; the Minister of Commerce and Industry; the Chairman of the Board of the Saudi Company for Military Industries; representatives from the Ministries of Defense, Interior and National guard; and three experts in the field of military industries. The formulation of the new authority arose after Saudi's Public Investment Fund (PIF) announced the launch of a state-owned military-industrial company in May 2017 ("Gulf Business," 2018).

The official Saudi Press Agency (SPA) mentioned that; the new General Authority for Military Industries has been handed eleven tasks ("Gulf Business," 2018):

1. Proposing policies, strategies and regulations relevant to the military industries' sector and complementary industries.
2. Managing the military procurement operations of arms, ammunition, equipment, supplies, military uniforms, maintenance and operation contracts for arming the security and military authorities in the kingdom and participating in the examination

and acceptance of products and services to ensure compliance with the required specifications.

3. Issuing manufacturing licences for the public and private sectors, local and external, for the establishment of military industries and complementary industries in the kingdom and establishing the relevant controls and procedures.
4. Setting specifications for military industries and complementary industries
5. Establishing monitoring mechanisms for the military-industrial sector and its complementary industries and following up their application.
6. Managing and developing the economic balance programme for the military industries and negotiating with foreign companies to transfer technology and increase local content.
7. Managing all research and development operations in the military industries, including the allocation of research and development budgets, technology transfer and management of research and development projects, utilising research centres and universities – internal and external – and establishing research centres as needed.
8. Coordinating with the relevant authorities to match the outputs of education and technical training with the needs of the military industries sector and working to attract technical expertise to the industry.
9. Developing incentives for the development of the military industry sector.
10. Supporting local manufacturers by transferring technology, considering the distribution of projects among local companies, promoting the sector internally and externally, contributing to the rehabilitation of local manufacturers, providing infrastructure and supporting the export of domestic military products.
11. Building strategic partnerships with the public and private sectors locally and internationally to achieve their objectives.

With all the previous efforts of initiating conferences and establishing new industrial entities under the newly founded general authority, researchers are still looking forward to finding means and approaches to accomplish the new national ambitious intentions. The researcher was trying to understand the root cause of the problem, while all the financial resources go towards purchasing and procurement processes to acquire foreign products. In the next point, challenges will be highlighted, the research problem will be stated, and a research question will be formulated.

1.4 Problem statement

1.4.1 Understanding the challenge

Saudi Arabia's changes in the defense sector called for a new military doctrine and strategy, considering the role played by the Kingdom regionally and internationally, and in line with the threats and rapid changes in the region. According to the new strategy, the armed forces will modernise their military capabilities with high-tech weapon systems that are granted by military superiority. The new MOD model aims to increase transparency by separating powers and responsibilities and by carrying out clear controls. Analysts believe that these changes, which focus on the modernity, will inspire the youth and developmental spirit of the Ministry of Defense, and also provide evidence of Saudi Arabia's drive towards engineering the innovation and informatics that are the heart of the modern military industry.

As mentioned before, the announced aim for MOD that aligns with the new Saudi vision is to increase the expenditure on the local contents from two to fifty per cent by 2030, which is needed to improve Saudi military planning, budgeting & fiscal management, and military operations. There is an urgent need for the transfer of newer technologies to compete and assimilate the critical technologies that will satisfy the needed requirements. However, all the previous technology transfer efforts were know-how machinery transfer. This approach did not cultivate the required technological capabilities aligned with the kingdom's strategy/vision, which need to be raised from the indigenous capabilities. Moreover, the contractual agreements in the previous technology transfer projects were agreed upon between the Department of Projects and the manufacturers and approved by financial departments without technical oversight.

1.4.2 Identifying the research problem

In order to manage and control different technological projects, there is a need for an effective acquisition system in order to achieve the strategic objective of having an indigenous self-sufficient defense industry that delivers needed capabilities demanded by warfighters. However, the problem is that the MOD still needs to have a formal Defense acquisition system (DAS), right here it would be well to point out that the purpose of this study is proposing a framework aiming to help in the management of the technology acquisition portfolio in MOD.

1.5 Research aim and objectives

This work aims to contribute to the new movement in the MOD to enhance the indigenous capabilities as described in the previous sections. In light of the stated research problem, this research aims to develop a strategic framework for decision-making purposes in selecting proper projects to fill the technological gaps in the local defense industry in Saudi Arabia. This will assist to find the appropriate approach to fill the identified gaps and develop the local contents and enhance the national economy.

1.6 Research methodology

In order to complete this study, the following method was applied.
Firstly, a critical literature study was conducted. The literature study served as a basis for:

i. understanding the available defense acquisition systems;
ii. identifying limitations within this field of study;
iii. determining the critical elements of the defense acquisition systems; and
iv. identifying useful metrics to assess the elements.

Secondly, a framework was modelled for the strategic level in the MOD, in order to evaluate the capabilities gaps, to select the best practice programs to fill the gaps, and to oversee the progression of the selected programs. Then, in order to obtain the industry's perspective applicable to the developed framework, interviews were conducted with experts in the defense industry field. This stage also served as verification to evaluate the framework. The developed framework was then adjusted according to the feedback from the interviews, and finalized.

1.7 Ethical considerations

According to the knowledge of the author, there were no ethical implications during or as a result of this study and the rules and regulations set out by NWU were carried out.

1.8 Scope and limitations of the study

- This paper represents the view of the author and does not indicate any official position.
- This study proposes a strategic tool to identify the technological gaps, and it does not discuss the cost or the human factors or any non-materiel solutions.
- I assume that there are no restrictions (political/financial/manpower) for the Saudi government to acquire defense technologies.
- The validation process of the framework of the study is not in the scope of this research.
- The implementation of the work will not be discussed due to the lack of input data.

1.9 Major contributions

The major contributions of this study are:

- the support of the MOD development program;
- the proposal of an effective tool for the decision-makers in the MOD;
- the minimization of the localization gap through the application of strategic planning methods; and
- the contribution to the new national vision in Saudi Arabia.

1.10 Summary

This study endeavoured to review models and tools used in the defense industry and proved its validation. Previous efforts conceptualized how to manage and control major project portfolios. In the next chapter, literature is reviewed to explore some effective practices in the defense sector.

CHAPTER 2: LITERATURE SURVEY

2.1 Introduction

This chapter seeks to discuss and review the literature relevant to the used models and tools to develop the deliverable of this study. Reviewing similar previous work was not possible because of the military sensitivity, and it was very hard to obtain literature with frameworks developed for the defense industry, as they are not available and classified as confidential.

The discussion will review the theoretical and practical sides of the framework that this research intends to develop. The theoretical part will conclude; management framework, portfolio management, and technology management. The practical part will discuss the two models used in technology management such as the Technology (Pull-Push) model and Technology Space Map (TSM). The practical discussion will also focus on the defense acquisition system and its related documentation and some needed analysis like Capabilities-Based Assessment (CBA), Capabilities Gap Assessment (CGA), Analysis of Alternatives (AoA) and Make-Buy Trade-off analysis. Also, this chapter will review some useful well-known metrics in the maturity assessment like; Technology Readiness Level (TRL), Manufacturing Readiness Level (MRL), Integration Readiness Level (IRL), and System Readiness Level (SRL).

This study aims to analyse specific models and tools and establish relationships between them so as to develop a strategic framework that hopefully will help the decision-makers to identify the technological gap in the local defense capabilities. The framework will be representing the first brick for establishing a new tailored DAS for any Ministry of Defense in any country. It aims to provide a broad view of the current situation. A framework should be flexible and allow for creative adaptation. This is in contrast to the procedures or methodology that has to be more prescriptive and rigid to phases and tasks. Confusion exists between the framework and the methodology, and the role of every approach and how to demonstrate them. This chapter will first review the question: what is a management framework?

2.2 Management framework

A conceptual framework is an interconnected set of elements or ideas (theories) about how a particular phenomenon functions or is related to its parts. The framework serves as the basis for understanding the causal or correlational patterns of interconnections across events, ideas, observations, concepts, knowledge, interpretations and other components of experience (Svinicki, 2010). The management framework which this paper aims to develop has been described by Zoughaib (2017) as follows:

> Frameworks exist to provide structure and direction on a preferred way to do something without being too detailed or rigid. They are powerful because they provide guidance while being flexible enough to adapt to changing conditions or to be customised for your company. Framework A creates a structure of what to do but rely on the doer to determine the best way to get the “what” done. A framework is a loose but incomplete structure which leaves room for other practices and tools to be included but provides much of the process required.

Zoughaib (2017) also proposes a comparison of framework versus methodology (Table 1).

Table 1: Framework vs. Methodology Comparison

Attribute	Framework	Methodology
Structure	Flexible	Prescriptive
	Allows for creative adaptation	Phases, tasks, methods, techniques and tools
Standard	What, “When” to do	What, When and How to do
Provide Phases and Steps	Yes	Yes
Consistent Outcome Predictability	Low	High
Can be Tailored	Yes	Somewhat
Level of Expertise needed to use effectively	High	Medium
Effort level to implement	Medium	High
Ease of governance and compliance	High	Low
Provides Metrics of Estimation	Yes	Yes
Provides underlying principles	Yes	Yes

2.3 Portfolio Management (PfM)

To distinguish between portfolio management (PfM) and program management (PrM). one needs to understand what they are. Steyn (2015) presents a good distinction to avoid confusion (Figure 2).

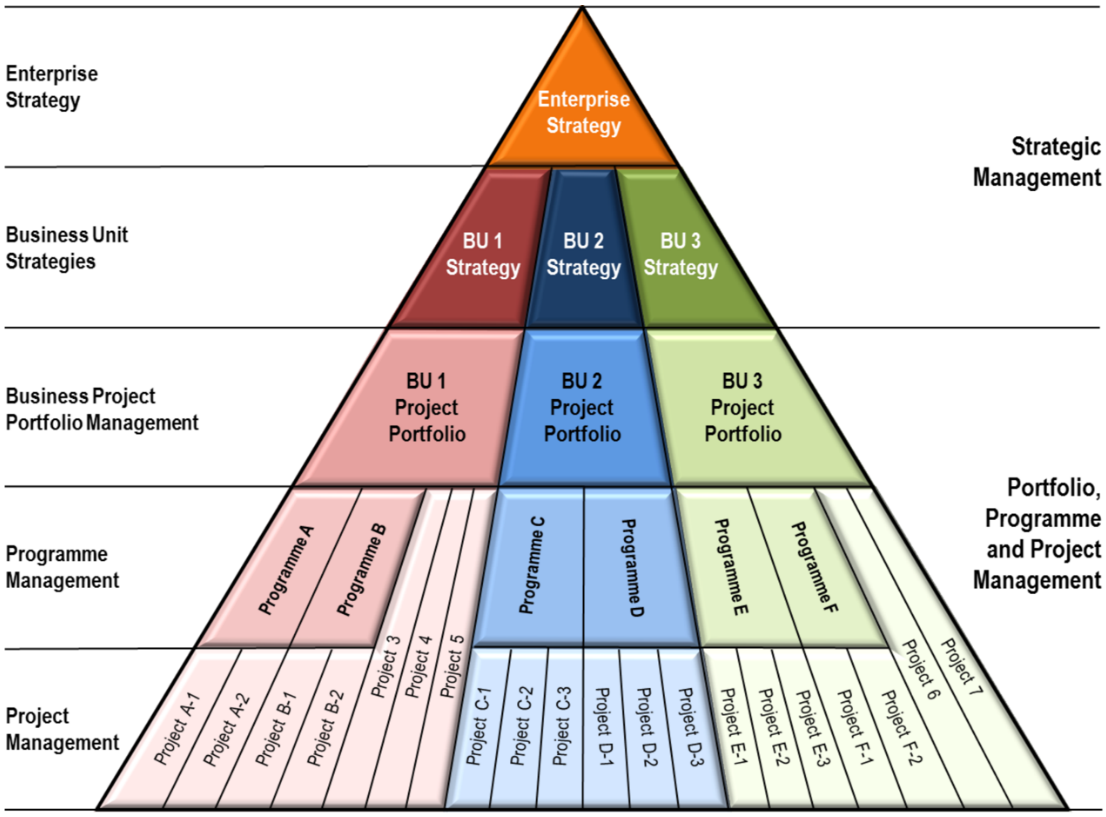


Figure 2: Putting project portfolios, programmes and projects in the context

Before focusing on project portfolios, programs and projects it is necessary to start with the strategy of an enterprise. The enterprise strategy presents a vision of where the organization wants to be in the future. Therefore, the enterprise strategy is placed at the top of the pyramid. As you go up the pyramid from the bottom (project to the programme to portfolio) then the budget, life expectancy, complexity and interdependencies all become greater. Programs can also reach across several or all the business units in the enterprise. Therefore, portfolio management means managing non-related projects/programs that contribute to the organization's strategic objectives. Program management is managing related projects that are delivering the same desired outputs and goals.

2.4 Technology Management

Technology management is a collection of management tools that assist organizations in managing their technological assets to create competitive advantages. Effective technology management requires integrating multiple activities and tools (Foden & Berends, 2010).

Foden and Berends (2010) believe that in order to manage their technology development portfolio, organizations should employ an integrated framework to ensure timely technology investment decisions and capability development. A framework modelled to manage technological projects can be structured in several stages. Table 2 illustrates the breadth of tools used in the technology framework.

Table 2: Technology Management Tools (Foden & Berends, 2010).

Framework Stage	Tool	Description
Identification and Monitoring	Technology Networking	Exploratory tool for increasing external environment awareness through participant networking.
	Technology Watch	Identification of organisation's critical established, competing and disruptive technologies.
	Make-the-Future	Inward-facing technology opportunity identification aligned with product development programs.
	Technology Maturity Assessment	The assessment of the position of a technology's maturity along its S-curve/life cycle.
	Technology Benchmarking	Internal benchmarking of technology alternatives with the organisation + benchmarking against competitors.
Selection and Approval	Make-the-Future Selection	Inward-facing technology opportunity down-selection aligned to new product drivers.
	Technology Roadmapping	Convergence of inward and outward-technology opportunities aligned to market and product drivers to enable selection of R&D programs.
	R&T Funding Approval	Technology investment decision-making for technology opportunities presented by Technology Roadmapping.
Capability Development: Development Research, Acquisition & Adaptation, and Exploitation & Review stages	Technology Make-Buy	Make or buy decision-making for development of down- selected technology program capabilities.
	Capability Acquisition	Definition, launch and management of technology programs aimed at developing technology maturity through R&D.
	Technology Readiness Scale	A gated process against which current technology maturity can be gauged and managed.

Protection	Technology Risk Management	Management of risks arising from R&D technology programs.
	Knowledge Base Protection	Capture of valuable knowledge such that it can be re-used
	Intellectual Property (IP) Protection	Protection against unauthorised transfer of IP outside of the organisation.

This paper will generate a framework which by adapting similar tools from the above table, such as; Technology Acquisition, Push-Pull Model, Technology Space Mapping, Technology Maturity Assessment and Make vs Buy analysis.

2.4.1 Technology Acquisition

There is an African proverb that says ‘latecomers eat bones’. This is always the biggest concern for developing nations as technological latecomers; their catch-up journey makes them lag behind the developed nations. Many studies argue that the key elements for the technological catch-up are the indigenous efforts and the overseas technology transfers. Nonetheless, the firm is acquiring technology, whether it is “Technology Development” or “Technology Transfer”. The acquisition of indigenous technologies and scientific capabilities have become and will continue to become, of ever greater importance for countries attempting to successfully catch-up to critical technologies (Mazzoleni & Nelson, 2007).

Technology acquisition is a significant process that requires integrated efforts. Organizations considering implementing such practices, have found many different ways and channels to accomplish these kinds of projects (Majidpour, 2017) introduced the traditional technology acquisition channels (Figure 3) which are sorted based on internal (make) or external (buy) technology sources.

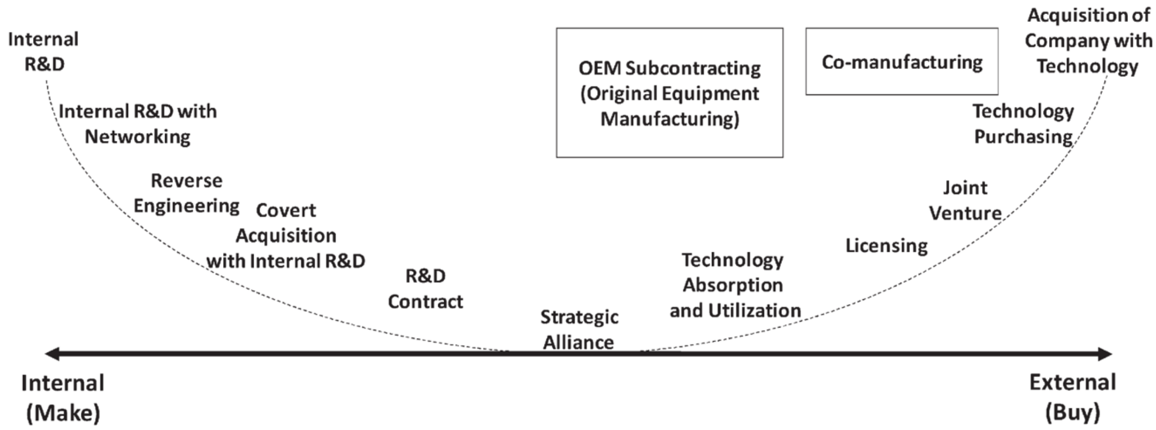


Figure 3: Technology Acquisition Channels

These wide channels illustrated by (Majidpour, 2017) almost cover all the possible means to acquire technologies. The comparison between buying or developing the technologies shows major implications on the national economy (Topcu *et al.*, 2015).

Authors have used the terms “Technology Acquisition” and “Technology Transfer” interchangeably and this may mislead researchers. This paper aims to redefine some definitions, in order to ensure that the readers and the writer are on the same page.

2.4.2 Technology (Pull-Push) model

The primary difference between a pull or push scenario is solving a problem versus accommodating a solution. In the pull scenario, the focus is on solving a problem by providing a technical answer to a market need (which can be either anticipated or existing). In the push scenario case, the focus is on identifying a market need to accommodate an existing technical solution (Oversteegen, Barneveld, Leermakers, & Lyklema, 1999).

The common description of this model is “Technology-Push and Market-Pull”. However, some authors have defined the terms from either a technology or market point of view. Oversteegen et al., (1999) have defined the terms as: “technology push has been historically defined by an innovation-cycle-driven culture focused on marketing/technology management analysis. In this context, the R&D division of a firm brings an idea from the invention stage to its fruition in the commercial markets". The not-so-typical technology pull is best described as the reaction to demand in the market. The desire for more efficient technologies by customers creates incremental improvements in these technologies that may eventually lead to a critical mass of innovations and possibly too radical improvements.

On the other hand, the market pull has been historically defined by marketing. The marketplace dictates the products that are to be supplied by a firm. In order to meet demand, a firm must constantly strive to increase performance and customer satisfaction. Market push is also a not-so-traditional term that addresses the creation of markets through marketing-driven efforts that, along with technology pull, can lead to the creation of technological standards that define and enable the emergence of new markets (see Tables 3 and 4).

Table 3: Technology Push and Pull: Relative Technology Dominance Perspective

	Market Pull	**Market Push**
Technology Pull	------------------	Technology Satisfying Market Seeding
Technology Push	Market Satisfying Technology Seeding	-----------------------

Table 4: Technology Push and Pull: Relative Market Dominance Perspective

	Market Pull	**Market Push**
Technology Pull	------------------	Technology Satisfying Market Seeding
Technology Push	Market Satisfying Technology Seeding	-----------------------

The DTAPM framework presented in this dissertation also helps to strike a balance between technology-push/pull for manufacturing organisations.

2.5 Technology Space Mapping (TSM)

One of the essential aspects to be considered in the management of technology is the transfer of the most appropriate technology to the organisation. (Grange & Buys, 2002). Technology space maps are a method of clarifying complex technical issues in such a manner that officials can quickly and easily gain a broad outlook of the current and future environment from a technologist's perspective (Simjee, 2008).

Pretorius (2001) offers a real-world application for the value of technology space maps, designating that evaluating a firm's technological capability is vital in maintaining its competitive position in global markets. De Wet (1992) proposed the concept of a technology space map as a tool for simply communicating technical issues. For the corporate strategy to encircle the technological issues communication loops between the officials and technologists are necessary.

TSM is the description used most in the subject of technology. It consists of two dimensions specifically, system life cycle and system hierarchy. Nevertheless, the technology space map can be customized for specific needs in order to provide information that is essential for a specific organization or industry. The TSM is illustrated in Figure 4 (De Wet, 1992).

		System Life Cycle Phases					
		Research	Design	Develop	Produce	Maintain	Use
System Hierarchy Level	User System						
	Prod. System						
	Product						
	Subsystem						
	Component						
	Material						

Figure 4: TSM indicating the system hierarchy and system life cycle

The TSM can be applied in a variety of technology management conditions. It provides an audit of the present status of the technological capabilities within a firm and provides a means for the planning of future requirements in line with an organization's goals and objectives. Furthermore, the TSM provides a holistic vision of a company thereby allowing for technology gaps to be identified and provides a platform for these gaps to be addressed (Simjee, 2008).

2.6 Defense Acquisition System (DAS)

DAS is the management process by which the Department of Defense provides effective, affordable, and timely systems to the users. It consists of phases containing major activities and associated decision points, during which a system goes through research, development, test, and evaluation (RDT&E); production; fielding or deployment; sustainment; and disposal as shown in Figure 5 (US DODD 5000.01, 2007).

In a broader context, defense acquisition could be defined as a process of defense products’ life cycle management from the moment requirements are defined, through research and development, manufacturing or purchasing, use in operations, exploitation and maintenance, to disposal. In a more restricted context, defense acquisition is related to the process of acquiring defense products whether by producing or purchasing them—in order to generate defense capabilities that are appropriate to the defense missions and level of ambition outlined in a nation’s defense policy. In both contexts, defense acquisition plays an essential role in achieving the goals set forth in a larger defense policy, since it is intrinsically related to the development of defense capabilities, which are the basis of the armed forces’ missions and task implementation in the national, regional, and global contexts (Caforio, 2018).

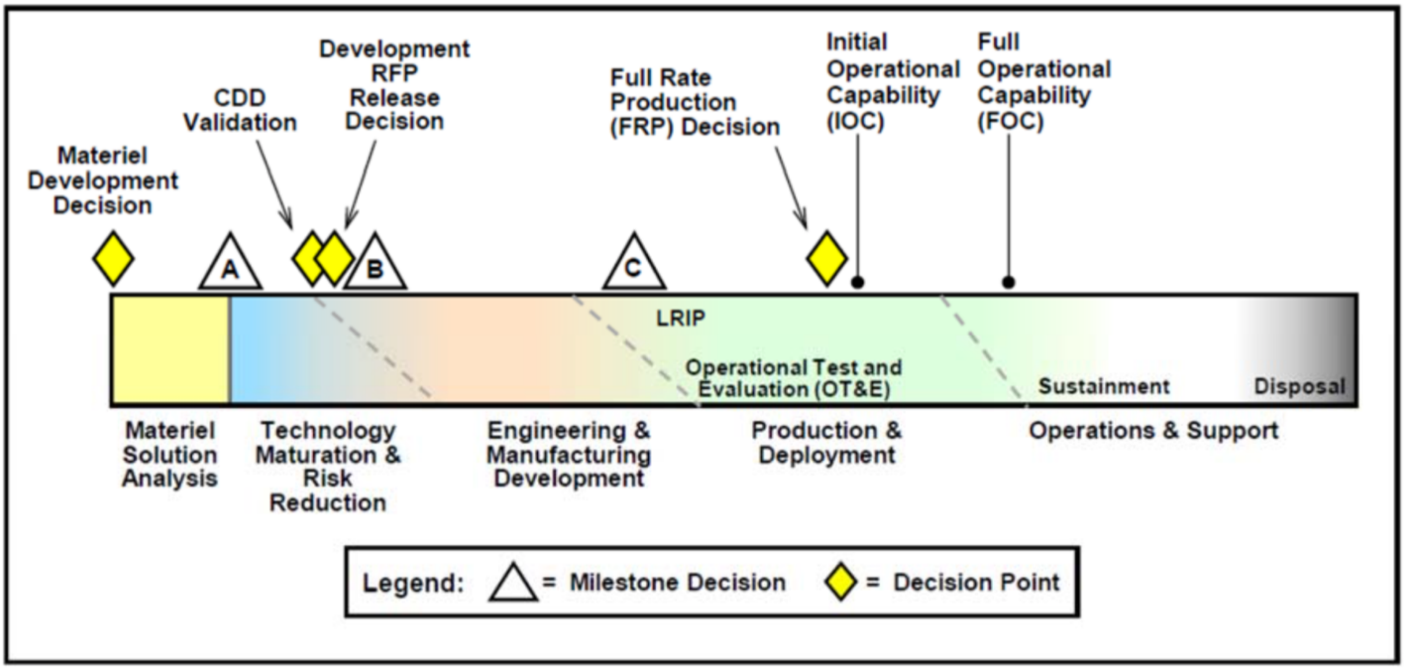


Figure 5: US DOD Acquisition life cycle

Although this definition was defined by the US DOD representing technology development, there are different approaches for the DAS worldwide. Many countries are looking at the big picture of acquiring the needed technologies. In this context, five main acquisition models mainly used by defense systems acquisition authorities are listed.

1. Direct Procurement
2. Production under License
3. Joint Production
4. International Consortium
5. Indigenous Development

Topcu et al. (2015) have summarised the above DAS models from the Turkish experience perspective. They presented a good comparison of each model against certain criteria (Table 5).

Table 5: Comparison of the Acquisition Models Employed in Turkey

	Contribution to the National Economy	Eligibility Criteria (Requirements)	Supply Cost	Supply Time	Supply Risk	Life Cycle Cost	Technology Acquisition
Direct Procurement	---	+	+++	+++	+++	---	---
Production Under the License	--	+	++	++	++	--	--
Joint Production Model	++	++	-	+	+	++	++
International Consortium	+	+	-	-	+	+	+
Indigenous Development	+++	+++	--	--	-	+++	+++

As the Table 5 shows, the indigenous developments are contributing positively to the national economy even though it is risky and takes a lot of time and cost. In contrast, the direct procurement has the least contribution to the national economy and has no risks and save money and time.

In Japan the situation is different. The acquisition should be based mainly on domestic development, that will be directly connected to foster and maintain defense production and technology bases of Japan in the case that such equipment are difficult to be introduced from overseas because we should not depend on other countries to introduce them (MODJapan, 2016).

Back to the adopted DAS from the US DOD, this section will review the essential elements in the US DAS; Capabilities-Based Assessment (CBA), Capabilities Gap Assessment (CGA), and Analysis of Alternatives (AoA). Some maturity metrics and trade off analysis also will be discussed.

2.6.1 Capabilities-Based Assessment (CBA)

Before 2002, the US DOD had a "requirements process" to determine needs. However, there was widespread dissatisfaction with this process, as evidenced by the memo issued by the Secretary of Defense shown in Figure 6 below (US DOD JCIDS, 2015).

March 18, 2002 7:17 AM

TO:	**Gen. Pace**
CC:	**Paul Wolfowitz** **Gen. Myers** **Steve Cambone**
FROM:	**Donald Rumsfeld**
SUBJECT:	**Requirements System**

As Chairman of the JROC, please think through what we all need to do, individually or collectively, to get the requirements system fixed.

It is pretty clear it is broken, and it is so powerful and inexorable that it invariably continues to require things that ought not to be required, and does not require things that need to be required.

Please screw your head into that, and let's have four or five of us meet and talk about it.

Thanks.

Figure 6: Memo from the Secretary of Defense that began JCIDS

Predictably, a considerable amount of activity followed (led by the decision to banish the word "requirement" from the new process). This effort resulted in three principles that form the foundation of the Joint Capabilities Integration and Development System (JCIDS):

- Describing needs in terms of capabilities, instead of systems or force elements.
- Deriving needs from a joint perspective, from a new set of joint concepts.
- Having a single general or flag officer oversee each DOD functional portfolio.

The CBA is the JCIDS analysis process (Figure 7) that includes three phases: the FAA [functional area analysis], the FNA [functional needs analysis], and the FSA [functional solutions analysis]. The results of the CBA are used to develop a JCD based on the FAA and FNA or ICD based on the full analysis (US DOD JCIDS, 2015).

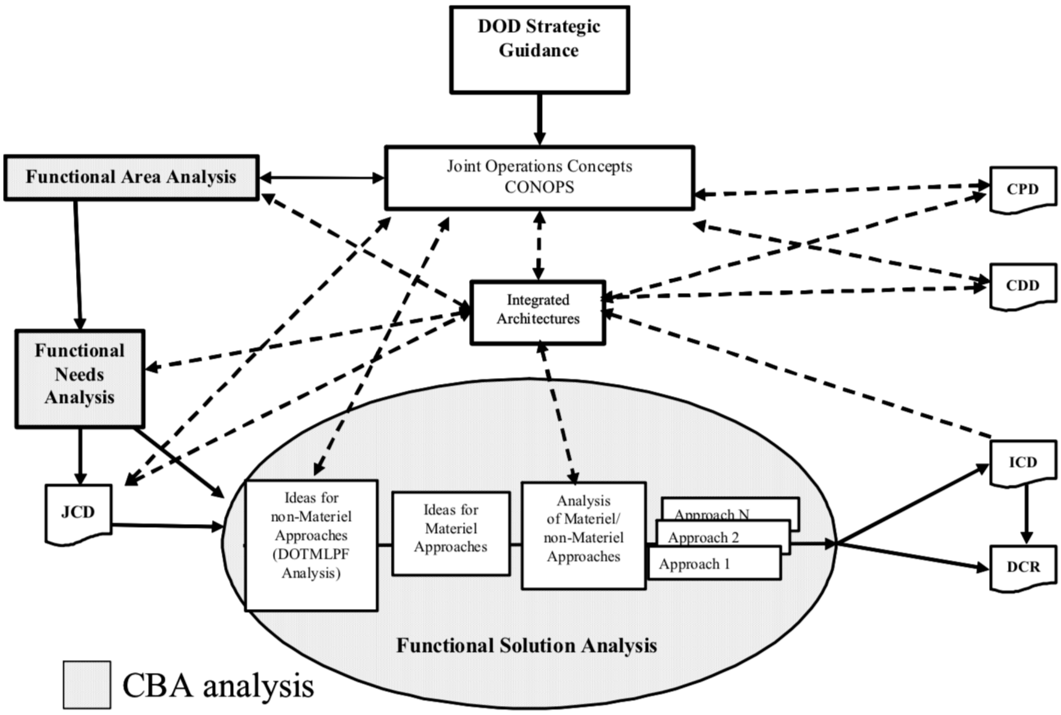


Figure 7: JCIDS analysis process

Figure 7 shows the major elements of a CBA: The Functional Area Analysis (FAA), the Functional Needs Analysis (FNA), and the Functional Solutions Analysis (FSA). Figure 8 reduces Figure 7 to the simplest depiction possible.

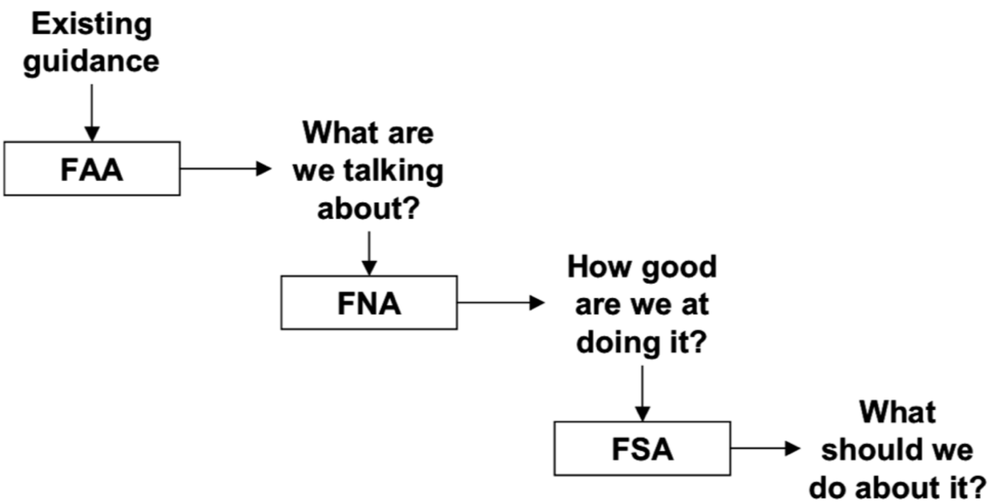


Figure 8: Simplified diagram of major CBA inputs, analyses, and outputs

2.6.2 Capabilities Gap Assessment (CGA)

A capability gap is the inability to execute a specified course of action. The gap may be the result of no existing capability, a lack of proficiency or sufficiency in an existing capability solution, or the need to replace an existing capability solution to prevent a future gap (US DOD JCIDS, 2015).

Rubemeyer, Noble, and McKeague (2013) prepared a technical report for the U.S. Army Training and Doctrine Command (TRADOC) Analysis Centre. They proposed a gap assessment method that addresses some important questions: (1) How much capability is good enough? (2) Is the gap mitigated? (3) If so, by how much?

Also, they distinguish between qualitative, quantitative and industrial capabilities.

- The qualitative gap is a capability gap that does not have a quantifiable attribute or has a quantifiable attribute in which technical, performance or operational study data are unavailable.
- The quantitative gap is a capability gap that has a quantifiable attribute and associated technical performance, or operational study data available for the comparison of alternatives.
- Defense industrial capabilities are the skills and knowledge, processes, facilities, and equipment needed to design, develop, manufacture, repair, and support DoD products. Defense industrial capabilities include private and public industrial activities.

2.6.3 Analysis of Alternatives (AoA)

The AoA is an analytical comparison of the operational effectiveness, suitability, risk, and life-cycle cost of alternatives under consideration to satisfy validated capability needs (usually stipulated in an approved ICD). Other definitions of an AoA can be found in various official documents (US DODD 5000.01, 2007).

The purpose of the AoA is to help decision-makers understand the trade space for new materiel solutions to satisfy an operational capability need while providing the analytic basis for performance attributes documented in follow-on JCIDS documents.

The results of these analyses can serve as the basis for addressing requirements sufficiency issues such as (OAS, 2016):

- Identifying the sensitivity of specific assumptions, parameters, measures, or other variables that, when altered, significantly change the relative schedule, performance, and cost- effectiveness of the alternatives—in other words, what are the cost, schedule, and performance drivers?

- Recommending changes to validated capability requirements that appear unachievable, operationally unnecessary, or undesirable from a cost, schedule, risk, or performance point of view.

- Identifying critical or essential parameters and attributes that have the potential to be Key Performance Parameters (KPPs), Key System Attributes (KSAs), Additional Performance Attributes (APAs), or Other System Attributes (OSAs).

- Identifying the point at which further investment provides little additional value for specific alternatives.

- Identifying areas where additional investigation is likely warranted, and why.

- Identifying the capability requirement threshold/objective values that require further exploration.

2.6.4 Make vs Buy (Trade-off) Analysis

At the national strategic level, “Make vs Buy” decisions are be adapted to “local manufacture vs import” decisions. Öncü, Oner, and Başoğlu (2003) have raised questions, such as: should a country buy a new system or modernize the existing one? Moreover, should a country import new systems, or should countries finance local development and manufacture needed systems? Their research concluded that there were no studies about “local manufacture vs import”. Those strategic decisions initiate them to develop a multi-criteria decision model for military systems acquisitions and have it used by Turkish decision makers (Figure 9). This model depicts the important factors affecting decisions. It was developed from a questionnaire to people who work in various stages of the procurement cycle in the Ministry of National Defense and Turkish Land Force Headquarters.

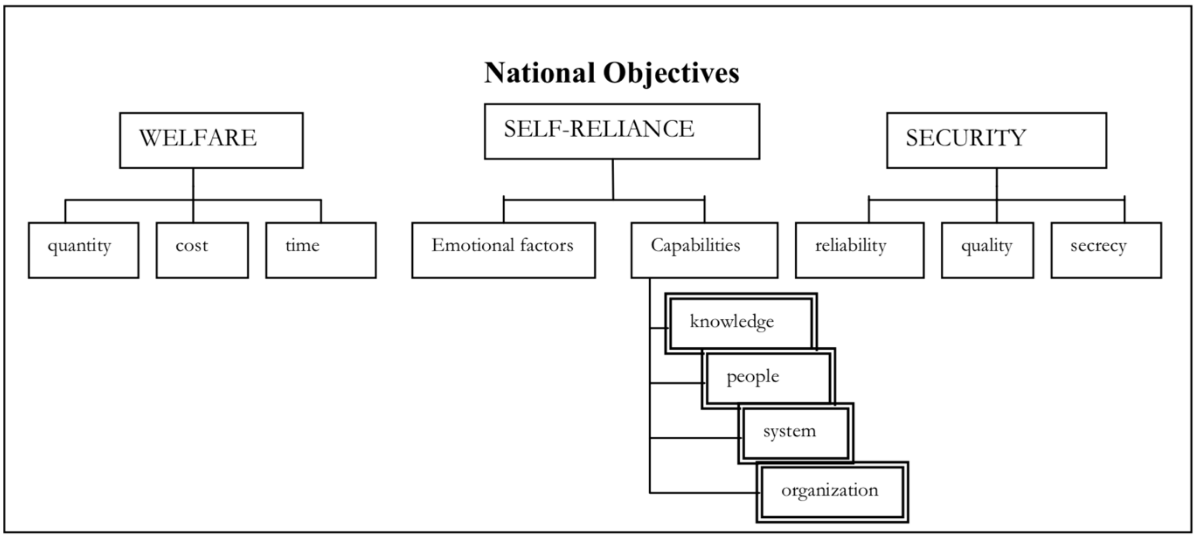


Figure 9: A Model for National Objectives Related with the Decision Factors

Zenz (1976) believes that the “make vs buy” problem arises as a result of unsatisfactory vendor performance, poor quality, delivery problems, unreasonable vendor price increases, the addition of a new products or substantial modifications of an existing one, changes in sales volume and related variations in plant capacity, reduced sales, and idle plant, equipment and manpower. The economists consider the “make vs buy” issues from a cost perspective, but the real strategic vision requires officials to see the big picture and consider the development of the indigenous capabilities for their national interests.

2.7 Maturity Assessment

In recent years there have been a lot of interest in metrics such as the Technology Readiness Level (TRL), System Readiness Level (SRL), Manufacturing Readiness Level (MRL), Integration Readiness Level (IRL) and other metrics as avenues to measure maturity and readiness of systems and technologies. The right maturity assessment techniques at the right time can enable government agencies and contractors to produce products that are cheaper, better, and made faster by closing knowledge gaps at critical decision points (Azizian, Sarkani, & Mazzuchi, 2009)

2.7.1 Technology readiness level (TRL)

In 1974, NASA had to conceive of a scale to measure the maturity of their technology, and they formally defined the scale in the 1990s which consequently gained widespread acceptance. This is known as the Technology Readiness Level (TRL). TRL is a useful metric in the decision-making process of selecting new technologies; it is a maturity scale from the start until the end product. This scale has strong points, as well as its precise controls. The definition of every level is shown in Table 6.

Table 6: Technology Readiness Levels Definition

TRL	Definition
1	Basic principles observed and reported
2	Technology concept and/or application formulated
3	Analytical and experimental critical function and/or characteristic proof-of-concept
4	Component and/or breadboard validation in laboratory environment
5	Component and/or breadboard validation in relevant environment
6	System/subsystem model or prototype demonstration in a relevant environment
7	System prototype demonstration in a space environment
8	Actual system completed and "flight qualified" through test and demonstration
9	Actual system "flight proven" through successful mission operations

*Source: US DOD

"The movement from a certain level of readiness (TRLX1) to another level (TRLX2)" is the Technology Transition, while the degree of difficulty to move on was characterized by NASA with a five-level scale symbolized with (R&D3) shown in Figure 10. Accordingly, if we want to be precise about the technology transfer definition, we can define it as the ownership transfer of a TRL(X). Therefore, we can clarify the vague definitions of the two concepts previously mentioned as follows.

Technology Transfer: is licensing intellectual property (IP) of a particular technology at a certain readiness level TRL(X) to the party who has the resources and desire to develop, use and exploit this technology from that readiness level to an advanced readiness level of this technology.

Figure 10: Degree of Difficulty

If the licensing IP is in the level between TRL1-TRL3, we are talking about technology development from the start between the academic sectors such as universities, R and D centers and scientific institutions. While, if the IP is in the level between TRL4-TRL6 we are talking about technology adoption from an academic side to the industry sector, while if the readiness level of the technology has developed further, the selling IP will move between the industry sectors as a technology acquisition, whether it is a national transfer or international technology transfer (ITT).

According to Sauser, Gove, Forbes, and Ramirez-Marquez (2010) the benefits of using TRLs include that it:

- provides an ontology by which stakeholders can evaluate component technologies;
- provides for a component TRA;
- initiates a discussion among the stakeholders to consider other factors;
- provides a mechanism whereby the process can be easily repeated during development;
- is easy to understand and use; and
- conveys a great deal of information in a project's status and its relative risk in the lifecycle of the project.

2.7.2 Manufacturing Readiness Level (MRL)

The basic goal of all acquisition programs is to put the required capability in the field in a timely manner with acceptable affordability and supportability. To be successful, the two key risk areas of immature product technologies and immature manufacturing capability must be managed effectively. Manufacturing readiness metrics in combination with technology readiness metrics can help acquisition program managers deal with these risks (Manufacturing Readiness Level (MRL) Deskbook, 2011). The definition of every level is shown in Table 7.

MRLs have been recognised as providing a common language and standard to:

- Assess the manufacturing maturity of a technology or product for its future maturation.
- Understand the level of manufacturing risk (Morgan, 2008).

Table 7: Manufacturing Readiness Levels Definition

MRL	Definition
1	Basic manufacturing implications identified
2	Manufacturing concepts identified
3	Manufacturing proof-of-concept developed.
4	Capability to produce technology in a laboratory environment.
5	Capability to produce prototype components in a production relevant environment.
6	Capability to produce a prototype system or subsystem in a production relevant environment.
7	Capability to produce systems, subsystems, or components in a production representative environment
8	Pilot line capability demonstrated; ready to begin low-rate, initial production
9	Low-rate production demonstrated; capability in place to begin full-rate production
10	Full-rate production demonstrated and lean production practices

*Source: US DOD

2.7.3 Integration Readiness Level (IRL)

Integration Readiness Level is a metric that is used to evaluate the integration readiness of any two TRL-assessed technologies (Sauser et al., 2010). They believe it is critical to consider physical properties of integration such as interfaces or standards but also interaction, compatibility reliability, quality performance, and common ontology when the two pieces are integrated. Sauser et al. (2010) stated in their paper the strengths and weaknesses of this IRL.

Its strengths include:

- It is based on open, widely accepted standards (ISO/OSI).
- Technology readiness is included in the overall assessment.
- Subjective assessment is made on technical data (however, this can also be considered a weakness).

Its weaknesses include:

- Requires a Work Breakdown Structure (WBS)/System architecture to be complete and accurate before the assessment.
- Requires a TRL assessment before the IRL assessment
- Lacks the ability to assess criticality and R&D effort
- Requires a more quantitative algorithm to reduce integrations into a single assessment for complex, net-centric systems.
- IRL does not evaluate cost and schedule.

2.7.4 System Readiness Level (SRL)

Authors (Magnaye, Sauser, Ramirez-marquez, & Acquisition, 2009; Sauser et al., 2010) have discussed the expansion of the TRL and the maturity scale concept to the system approach. Tetlay and John (2009) believe that SRLs have been developed as a project management tool to capture evidence, and assess and communicate system maturity. They defined SRL as a set of nine steps from concept in-service across a set of systems engineering disciplines. The rationale behind the SRL developed by Sauser, Ramirez-Marquez, and Tan (2008) is that in the development lifecycle, one would be interested in addressing the following considerations:

- Quantifying how a specific technology is being integrated with every other technology to develop the system.
- Providing a system-wide measurement of readiness.

The SRL is not user-defined, but is instead based on the outcomes of the documented TRL and IRL evaluations through mathematically combining these two separate readiness levels, a better picture of overall complex system readiness is obtained by examining all technologies in concert with all their required integrations (Magnaye et al., 2009).

$$SRL = IRL\ x\ TRL$$

$$\{SRL1 \quad SRL2 \quad SRL3\} = \begin{pmatrix} IRL_{11} & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_{22} & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_{33} \end{pmatrix} \ x \ \begin{pmatrix} TRL_1 \\ TRL_2 \\ TRL_3 \end{pmatrix}$$

$$Composite\ SRL = \frac{1}{n}\left[\frac{SRL_1}{m_i} + \frac{SRL_2}{m_i} + \frac{SRL_3}{m_i}\right]$$

$$= 1/n^2[SRL_1 + SRL_2 + SRL_3]$$

Where;

$\frac{SRL_1}{m_i} = SRL\ for\ technology\ 1$,

'n'= number of technologies

'mi' = number of integrations of technology

2.8 Conclusion

Whilst the essence of this literature review was studying different models and tools that have been used in many different applications; it has shown obviously that all the discussed models and tools have been used effectively in the defense industry. This usability drives the researcher to use it as the elements of the intended framework that he will develop in the next chapter.

Portfolio management, technology management, technology space mapping, defense acquisition system and its phases and documentations, and maturity assessment metrics. Bringing it all together and visualize the global picture; The researcher believes that those elements have conceptual relationships, since some of them have already been used in the defense acquisition system, and others have been used as supportive tools to enhance the efficiency of this system. The notion of developing conceptual relationships is to develop an integrated framework serving as a strategic road map for the technological projects' portfolio.

Recalling the problem statement of this research, this framework will work as an effective tool to manage and control different technological projects, that need an effective acquisition system, to achieve the strategic objective of having indigenous self-sufficient defense industry. The next chapter will discuss the reviewed models and identify a relationship that will require synthesis and model the defense technology acquisition portfolio management (DTAPM) framework. That the author believes it will help in identifying the gaps in technological capabilities and provide an appropriate approach to fill those gaps.

Therefore, the problem to be solved in this research is; the lack of a formal defense acquisition system in MOD applicable to KSA.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The previous chapter explored some strategic practices in the defense sector. These practices motivated the researcher to present a strategic framework for use by high-level authorities. This chapter presents a description of the research process. It provides information concerning the method that was used in undertaking this research as well as a justification for the use of this method.

Ideally, this paper would select a case study of any one of the Saudi MOD projects, and evaluate the obstacles, deficiencies, and the lack of critical strategic decisions. Unfortunately, no such resources are available either due to confidentiality or due to the lack of historical documentation of the system. From the start, this research intended to formulate a conceptual framework with the focus on technology transfer, and developing into technology acquisition.

The study proposes a strategic framework informed by the literature review and analysis. Interviews (face-to-face, emails, telephone calls) were also conducted to collect information from primary sources for verification. This chapter will discuss all the actions and decisions that the researcher has taken, and the rationale behind these actions. Moreover, it discusses how the participants were selected for interviews and questions were generated.

3.2 Research design

To exemplify the suggested methodology, the researcher derived a research methodology process diagram depicted in Figure 11. Figure 11 shows the research approach which was started at the formulation of the research question in the first chapter, hereafter the focus shifted to a specific problem. The literature study in chapter 2 helped to explore previous research done with regard to the problem statement.

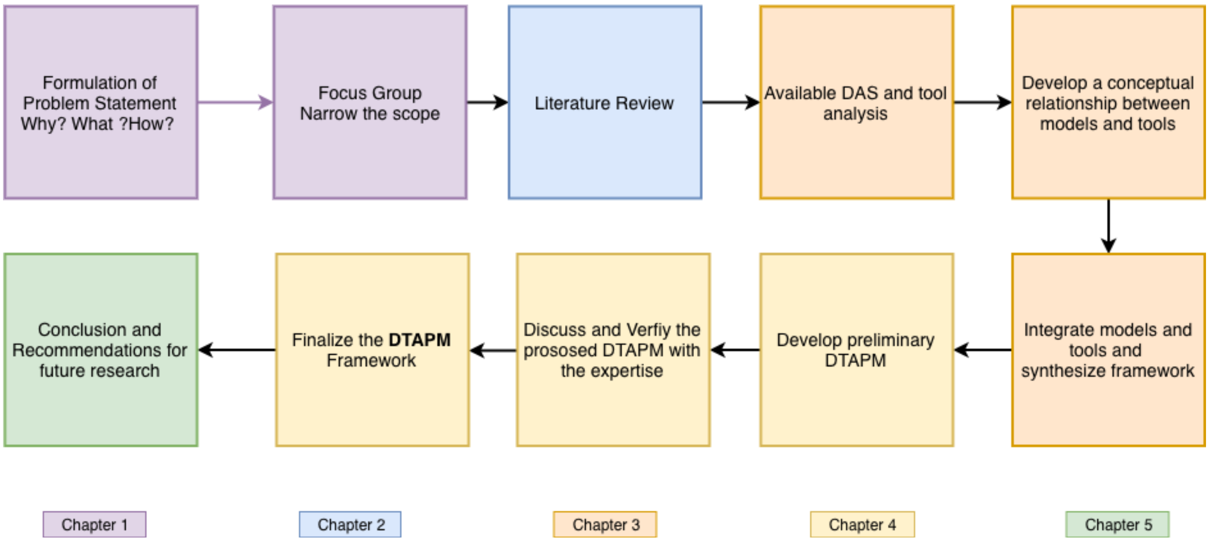


Figure 11: Research process diagram

The author then found a means to develop a good solution and present a decision-making framework (DTAPM) that consists of some models and tools that have an integrated relationship, to build a unitary structure which will be discussed in this chapter. Before finalizing the developed framework, the verification stage will take place in the next chapter with the expertise to review and verify if this newly developed framework can be valid. Finally, the researcher will conclude recommendations and future studies in the last chapter.

3.2.1 Problem Identification

Identifying strategic problems is not a straightforward approach. It requires a lot of reading about the situations and identifying the gaps. In order to get to the root of the causes, one has to look at the situation from a high level perspective. The author collected data and inputs from various sources: observation, publications, handbooks, interviews, TV broadcasting and so on. All these inputs were analysed to visualise the real situation that caused the problem.

3.2.2 Situation Analysis

As discussed in the first chapter, Saudi MOD needs were formed to align with the new vision that the government is aiming to achieve. This is a thriving economical vision which relies on the development of indigenous capabilities that necessitates the officials to set strategic objectives.

The researcher visited all the official websites related to the Saudi MOD, trying to get an understanding of the MOD's vision and mission, listing their strategic objectives, scrutinizing their publications and conferences in order to visualize their perspective. All these practices have enabled the researcher to look through the MOD's eyes to see the bigger picture and identified the gaps.

It was evident that the gaps were created due to some strategic decision-making mistakes. At the time, it might not have seemed like a significant failure, but in the long run it was not successful in satisfying the desired needs. These strategic decisions can be taken properly, with effective technology management.

The author believes that there was no clear defense industrial strategy (DIS) for the MOD. This lack of sharp DIS resulting in mismanaging technology transfer (TT) projects. Moreover, the author recognised that the MOD had no formal defense acquisition system (DAS) after communicating with GAMI officials. Consequently, the researcher has decided to propose a solution to this problem.

3.2.3 Solution Proposal Foundation

The author established a conceptual foundation related to his findings; this conceptual scope was the lens through which the research problem should be evaluated. The theory of the concept was based on connecting the strategic efforts with the technical issues, in the sense of collaboration that will lead to finding the real gaps. Therefore, a conceptual framework was proposed as a solution. This conceptual framework will work as a roadmap for officials who need to take proper strategic decisions.

The researcher was exposed to many models and tools that used in the technology acquisition management in the defense industry sector; From the technology acquisition channels and its critical elements, through the technology maturity assessment metrics, to technology management tools and frameworks. Furthermore, the researcher got to know closely about many defense acquisition systems, especially the US DOD acquisition system, which all the other defense sectors in many countries use to drive their systems.

This kind of exposure has provided the researcher with insight into the conceptualization of a decision-making framework that consists of a tailored defense acquisition system linked to system mapping sheets that will give critical inputs for deciding where to focus and implement the proper technology management.

The elements that formed the conceptual framework were integrated in a way that facilitates designing a smooth working process for the assigned tasks according to the stated strategies. The integration suggested by the researcher is aimed at finding a shared area between the strategic officials and the technicians from the industrial sites. This was performed according to the "adapt to adopt" concept, to synthesize the proposed solution into a decision-making framework.

Building on this foundation, the researcher turned toward his suggestion and formulated his proposed framework; namely the Defense Technology Acquisition Portfolio Management (DTAPM) framework.

3.3 Research Tools

In order to perform this research, the researcher has to develop a methodology for the development of a conceptual framework. This section shows how this kind of framework was developed and integrated, and the refined DTAPM framework. While the author does not want to discuss philosophical issues here, he acknowledges his subjectivity while applying his methodology; nevertheless, he assumes that the mechanisms he excerpts with it, are part of an objective reality. The researcher's proposal based on some analysis and synthesis, the next two points are highlighting them.

3.3.1 "Adapt to adopt" concept

Like any researcher, finding pre-existing models or tools is helpful in measuring variables in a study. There are two methods that the model can be used in research.
On the one hand the model can be understood almost literally, also called adopting the model. On the other hand, the researcher can adapt the model.

In the defense industry, the US acquisition models proposed by the US DOD are pre-tailored frameworks. The researcher thus intended to adapt this model to adopt it for the Saudi MOD for their needs. Here, the researcher suggests slight alerting changes before the adoption process can be done. One of the main elements in the proposed DTAPM framework is the "System Space Map". It was adapted from the "Technology Space Map" (see section 2.5). The TSM was proposed as a two-dimensional matrix, the system life cycle and the system hierarchy. The researcher adapted this matrix to be used in the defense industry sector, and changed the traditional system hierarchy to the weapon system hierarchy used in the defense acquisition system. Also, the adaption in the second dimension for the system life cycle has remained in the same context of the defense terminology.

3.3.2 Conceptual Synthesis

This qualitative research has identified many variables (elements) from the literature that are related to the topic. The researcher has isolated the most critically needed elements (from his point of view) to combine them into a tailored structure that expectantly will satisfy the required objectives. A synthesis of the research findings as obtained through non-empirical data will highlight different elements that constitute a conceptual decision-making framework. These elements link the strategic level with the technical level, as discussed in chapter 2. The following section will discuss the idea of integrating multi concepts into one framework.

The elements that formed the DTAPM framework are models, documents and metrics tools. The researcher presented these models and tools as they can be integrated into one framework. The model used primarily that represents the backbone of the framework is the DOD US acquisition system model shown in Figure 12.

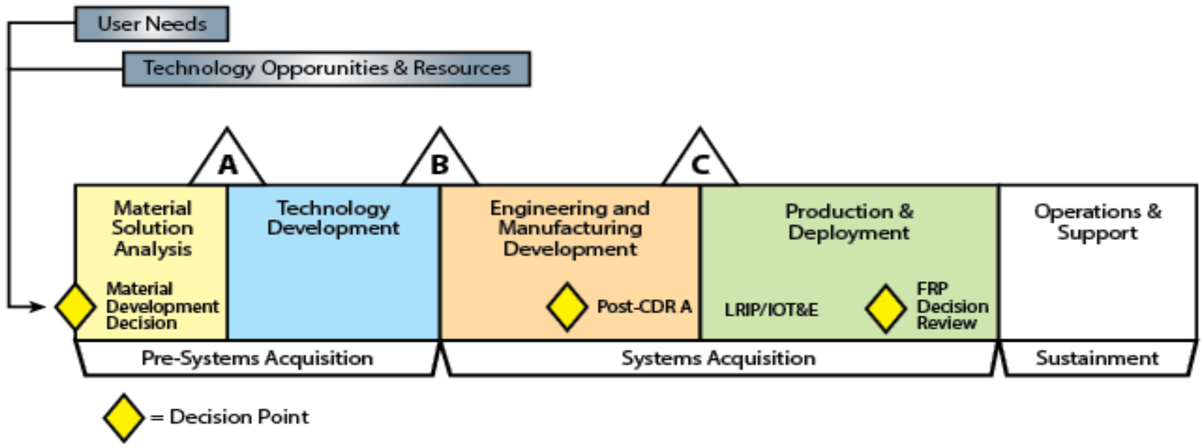


Figure 12: US DOD Acquisition Life Cycle

As Figure 12 shows, the US DAS consists of five major phases:

- Materiel Solution Analysis (MSA);
- Technology Maturation and Risk Reduction (TMRR);
- Engineering and manufacturing development (EMD);
- Production and Deployment (PD); and
- Operations and Support (OS).

Every phase in the DAS has a specific purpose on which the decisions are based on to proceed the next milestone in the development process. The purposes of the US DAS phases are the following (US DODD 5000.01, 2017):

Purpose of the MSA Phase: Conduct the analysis and other activities needed to choose the concept for the product that will be acquired, to begin translating validated capability gaps into system-specific requirements, including the Key Performance Parameters (KPPs) and Key System Attributes (KSAs). Also conduct planning to support a decision on the Acquisition Strategy for the product. AoA solutions; key trades among cost, schedule, and performance; affordability analysis; risk analysis; and planning for risk mitigation are key activities in this phase.

Purpose of the TMRR Phase: Reduce technology, engineering, integration, and life-cycle cost risk to the point that a decision to contract for Engineering and Manufacturing Development (EMD) can be made with confidence in successful program execution for development, production, and sustainment.

Purpose of the EMD Phase: To develop, build, and test a product to verify that all operational and derived requirements have been met, and to support production or deployment decisions.

Purpose of PD Phase: Produce and deliver requirements-compliant products to receiving military organizations.

Purpose of OS Phase: Support over the system life cycle, operational needs, technology advances, evolving threats, process improvements, fiscal constraints, plans for follow-on systems, or a combination of these influences and others may warrant revisions to the product support strategies.

3.3.2.1 The Strategic Components of DTAPM

The DTAPM framework has employed the exactly named phases which represent the system engineering life cycle for any system/product development matching the needs derived from the national strategic vision, see Figure 13.

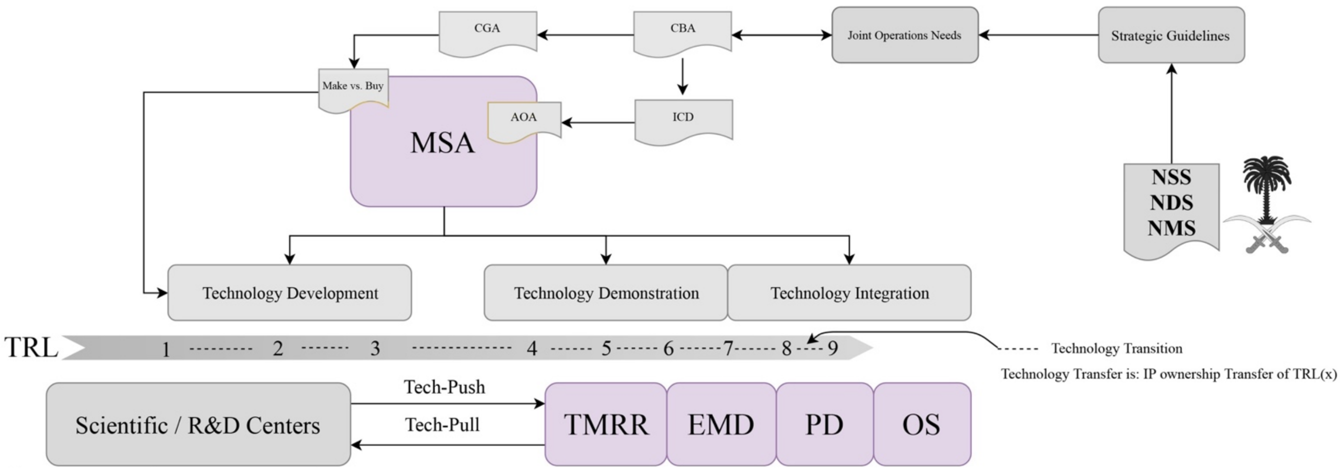


Figure 13: US DAS phases (purple blocks) in DTAPM

The tailored amendment that the author created is meant to study the MSA plus the trade-off analysis of whether to manufacture or purchase, thereafter the officials can make strategic decisions on what the next step should be. This is shown in the presented DTAPM framework just after MSA block; the flow diagram splits into three different approaches of Technology Acquisition; Technology Development, Technology Demonstration or Technology Integration (Figure 14).

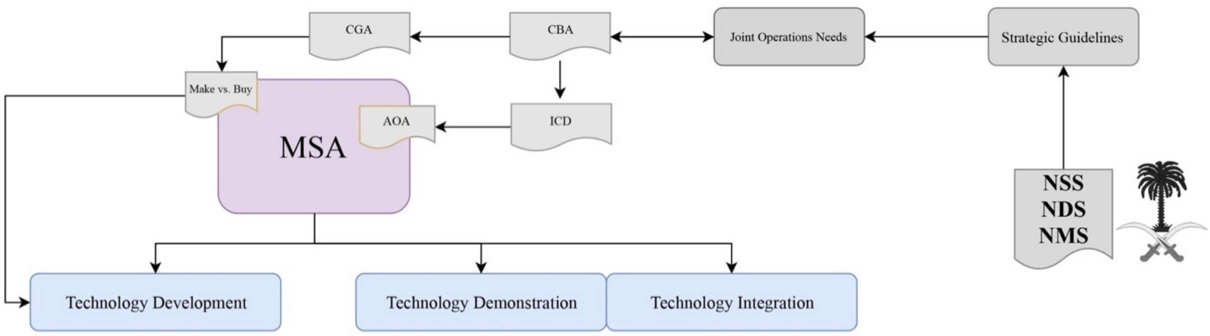


Figure 14: MSA-based decisions Technology Acquisition Options (in blue colour)

One of the very useful tools that will add value to these kinds of decisions are the maturity assessment metrics, recognisable just beneath the three different options of Technology Acquisition; the TRL scale (Figure 15), which measures the technology readiness level of a particular technology. As previously discussed in this paper, the best technologies can be selected that meet the system requirements by examining the maturity of its readiness.

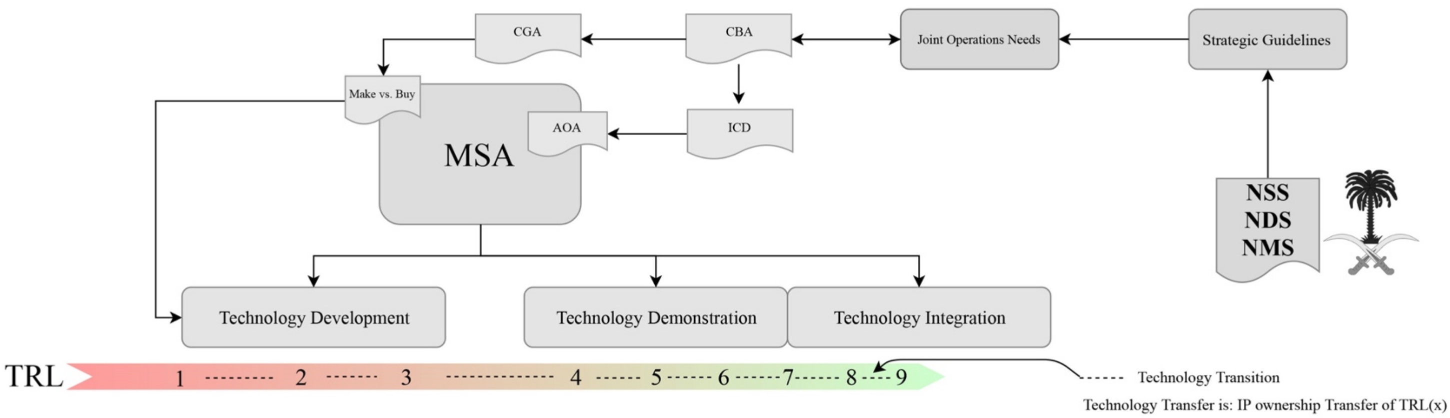


Figure 15: TRL in DTAPM

The researcher also believes that connected channels to the scientific sectors should exist. This proposed framework is meant to be a broad strategic tool for decision making in capabilities management. Therefore, the technology push-pull model (see section 2.4.2) has also been utilized in this framework (Figure 16), to integrate all the maturation life cycles of the technology, from the start through service until disposal.

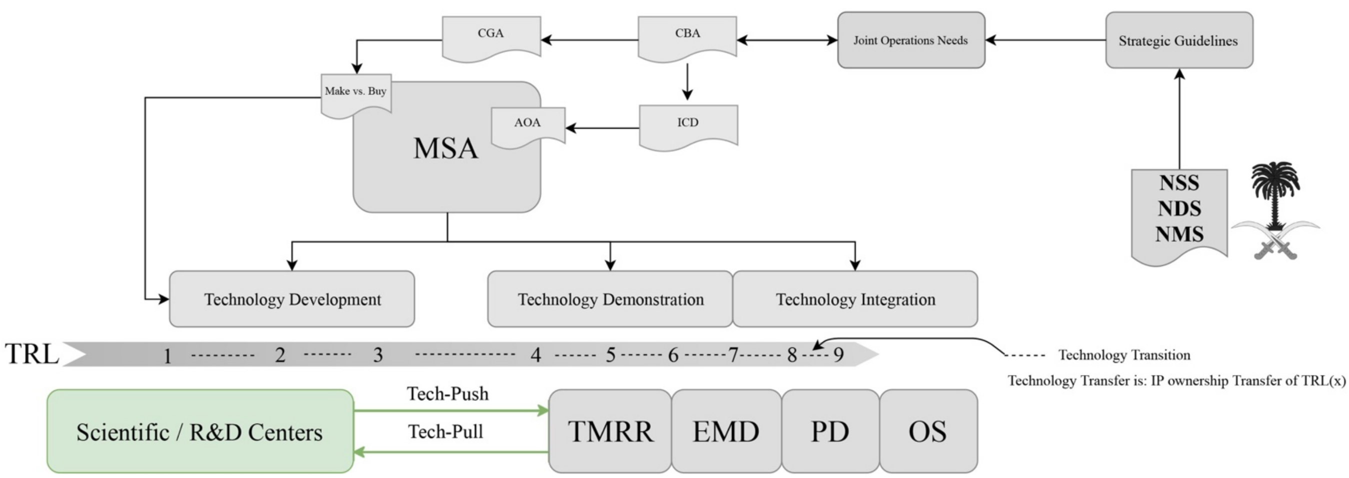


Figure 16: Technology Push-Pull Model (green colour) in DTAPM

The critical decisions in capabilities management should use many inputs from different analytical studies. The standard documentation from the US DAS concerning corresponding capabilities management has been applied in this framework (Figure 17). The researcher realizes that in his proposed solution - conversely to the US models that emphasize to start every technological project from scratch - a study is needed to be additionally exploited in this framework, which is the trade-off analysis of “Make or Buy” decisions. This input will be a critical feed to the strategic actions toward the technology acquisition alternatives.

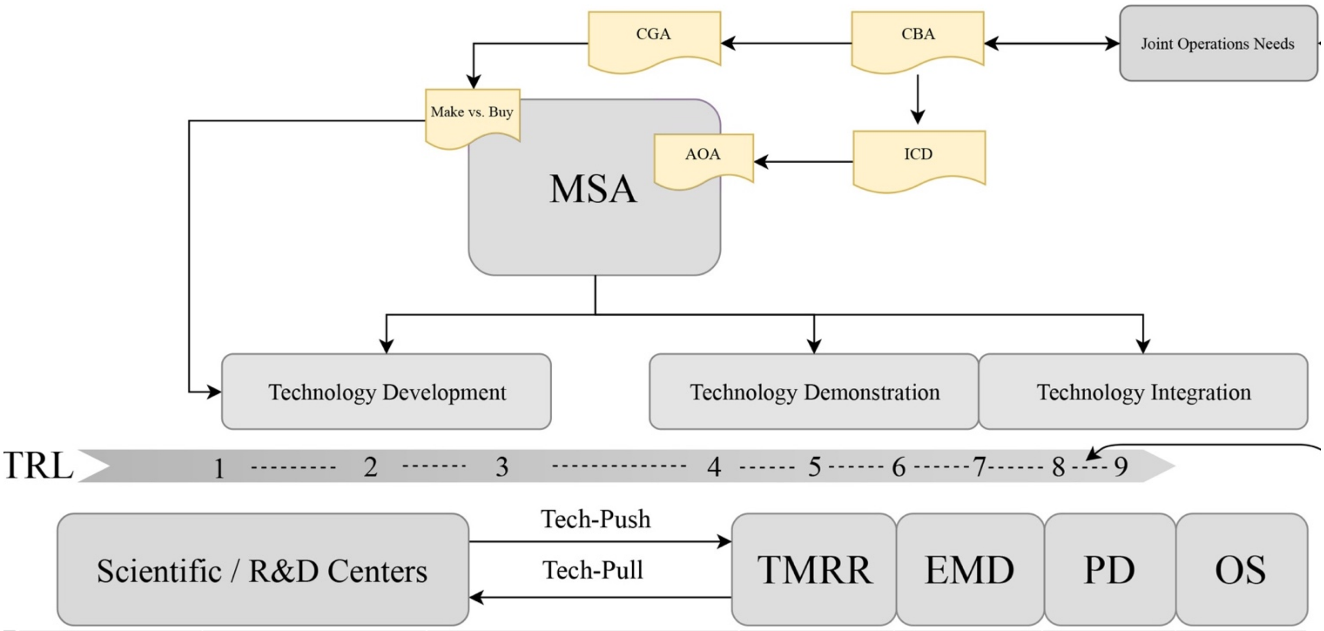


Figure 17: Analytical studies documentations (yellow marked) in DTAPM

The strategic guidance from the government steers the direction of the development, this happens with the alignment to the national security strategy (NSS) which guides the national defense strategy (NDS), resulting in the formation of the national military strategy (NMS). All these strategic guidelines will generate the needs of the Joint Operations (JO) that are aligned with the national strategies. As shown in Figure 18, the proposed framework considers the strategic directions from the SA MOD that formulates the Joint Operations Needs which drives the needs from joints perspective concerning capabilities.

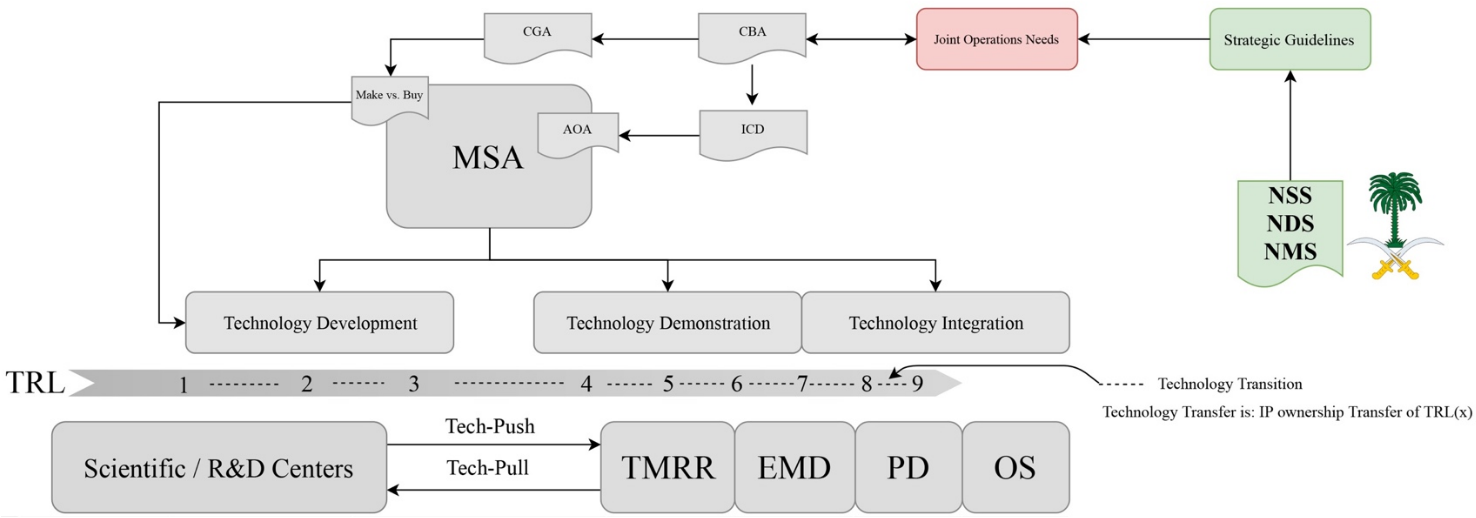


Figure 18: Joint Operations Needs and National Strategies (green and red coloured) in DTAPM

3.3.2.2 The Technical components of DTAPM

As previously stated, one of the crucial aspects to be considered in the management of technology is the transfer of the most appropriate technology for the organisation (Grange & Buys, 2002). The desired framework connect the strategic efforts to the technical works. The researcher aimed to find that channel. After that, some technical mapping tools was reviewed and the Technology Space Map (TSM) was used in the suggested solution. TSM is the most usually used description of the technology space. It consists of two dimensions specifically, system life cycle and system hierarchy (see Figure 4 in Chapter 2).

Because TSM is a customizable tool, the researcher allocated the defense industry systems terminology to this tool. In the system life cycle dimension, the same phase names of the US DAS are used that are already used in the strategic side of this framework as shown in Figure 19. Moreover, in the second dimension which is the system hierarchy, the researcher employed the exact military weapon system hierarchy (see Table 9).

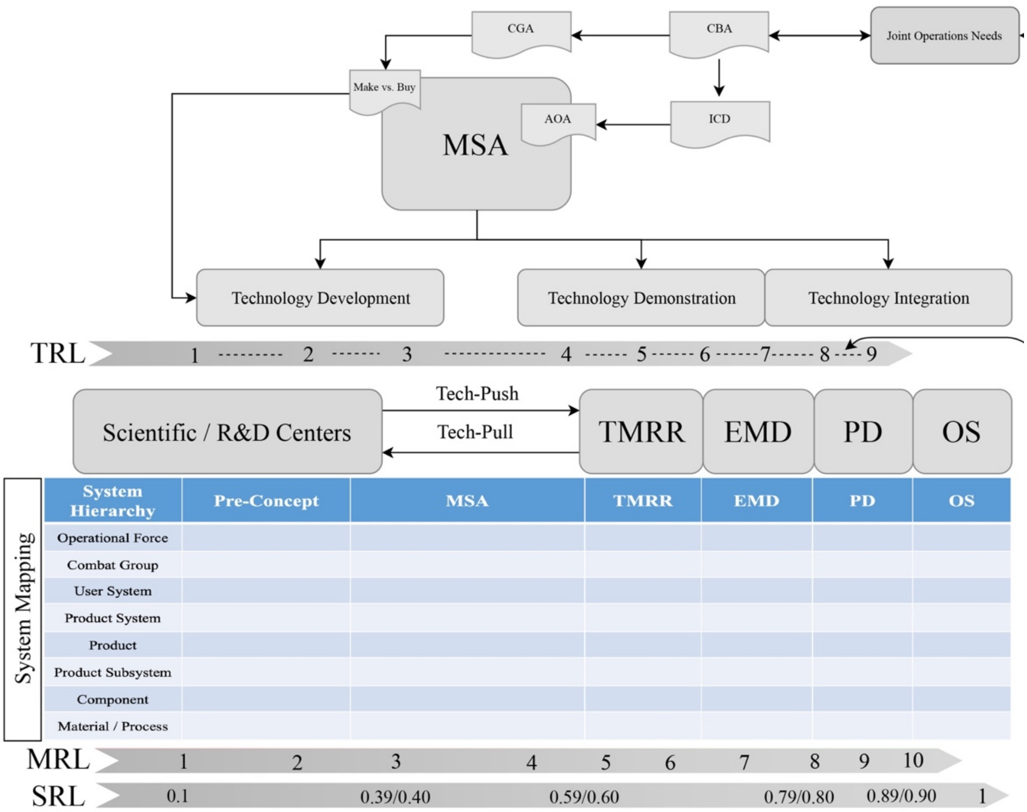


Figure 19: TSM (blue colour) in DTAPM

The key concept in the DAS is derived from systems theory, which defines a hierarchy of systems and subsystems as shown in Table 9. The acquisition takes place at all the levels of the hierarchy and each level supplies to the next higher level. The Ministry of Defense is primarily responsible for system acquisition at levels 8, 7 and 6. Manufacturers are responsible for acquisition of level 5 systems, while the suppliers in the industry are the acquiring parties at the lower levels. Hence, the author has given every acquisition level a certain colour as can be seen in Figure 20.

System Lifecycle / System hierarchy	Pre-Concept	MSA	TMRR	EMD	PD	OS
Operational Force						
Combat Group						
User System						
Product System						
Product						
Product Subsystem						
Component						
Materials / Processes						

Figure 20: Acquisition levels in TSM

Table 8: Weapon System Hierarchy

System designation	Level	Configuration Example		
		Army	Air Force	Navy
Operational force	**8**	National Defense Force	National Defense Force	National Defense Force
Combat grouping	**7**	Joint Combat Force	Joint Combat Force	Joint Combat Force
User system	**6**	Operationally ready regiments, battalions etc with main equipment, facilities, personnel and own logistic support systems	Aircraft, facilities, personnel and support systems of SA Air Force squadron	Naval vessels, facilities, personnel and support systems of Naval Fleet and bases
Product system	**5**	Tanks, infantry fighting vehicles, artillery guns, AA guns, simulators and own logistic support equipment	Aircraft, weapons, flight simulator and logistic support equipment	Ships, submarines, weapon systems, simulators and logistic support equipment
Product	**4**	Tanks, infantry fighting vehicles, artillery guns, AA guns etc	Aircraft	Ships and submarines and platforms
Product subsystem	**3**	Platforms, engines, radars and radios	Engine, airframe and avionics	Hulls, main propulsion systems, combat suite and subsystems
Component	**2**	Instruments, transmitters and receivers	Instruments, turbine blades, undercarriage	Instruments, propellers and sonar transducers, PC boards
Characteristic/ materials/ process	**1**	Castings, aluminium, titanium, carbon fibre	Castings, aluminium, titanium, carbon fibre	Castings, aluminium, titanium, carbon fibre

After the primary technical tool in DTAMP is adapted to the defense industry, the researcher supports this useful tool with the maturity metrics. The manufacturing readiness level will be a beneficial assessment to the technical managers to evaluate their manufacturing capabilities in the industrial sites. In the second chapter the Integrating Readiness Level also highlighted that this metric is also needed to calculate the whole system readiness level. Manufacturing Readiness Level (MRL) and the System Readiness Level (SRL) scales are employed in the framework as Figure 21 indicates.

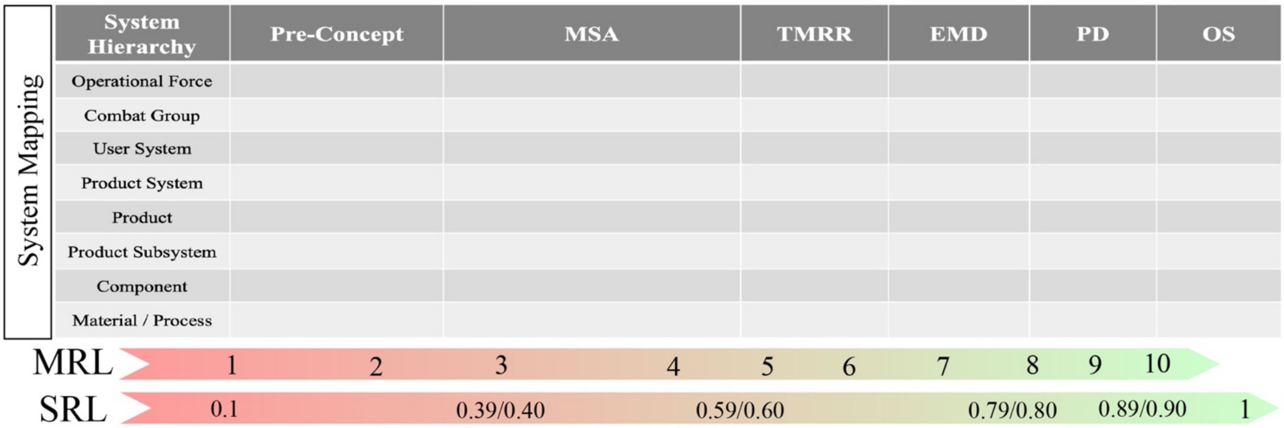


Figure 21: Maturity Metrics linked to TSM in DTAPM

Finally, all the discussed figures (from 13 to 21) has integrated into the proposed solution by this dissertation and forming a framework for decision-making purpose in selecting proper projects to fill the technological gaps in the local defense industry in Saudi Arabia. The researcher believes that this framework can work as a defense acquisition system, and can facilitate managing the technological programmes and its related projects in the form of portfolio management. Therefore, the researcher called it the "Defense Technology Acquisition Portfolio Management" DTAPM framework (Appendix A).

3.4 Research Verification

The proposed framework contains elements (models/tools) that have already been used and verified by different personnel in a different sector. However, this framework has to be verified as a whole and feedback from experts is needed. Because the defense industry sector is almost the same and have similar issues globally, this research will verify the framework with knowledgeable people in the same environment available in South Africa. Figure 22 depicts how the verification process in this research took place.

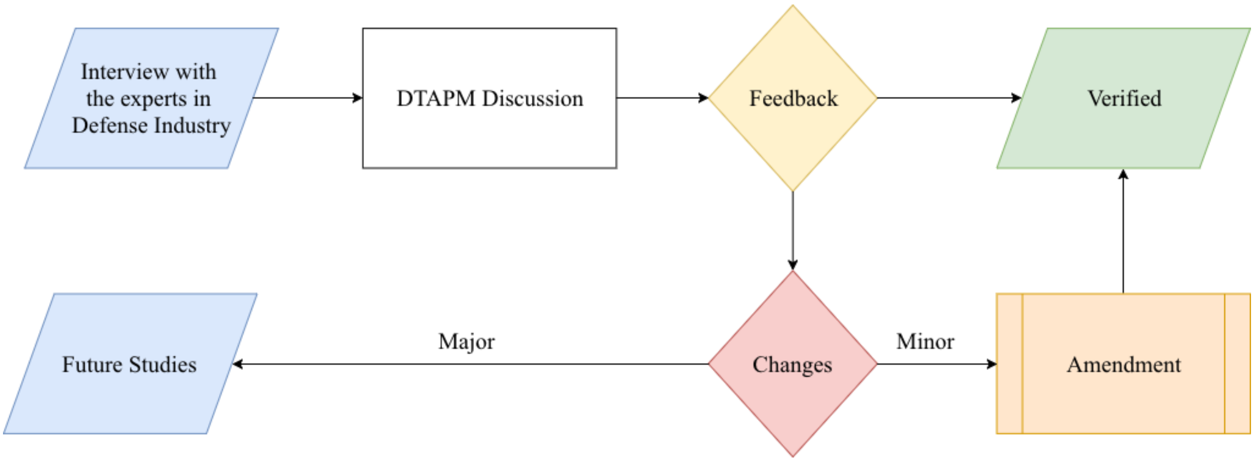


Figure 22: Research Verification Process

Validation is not part of the scope of this research because it is not required in an option-B dissertation, however, some aspects of a proposed validation process will be discussed in Chapter 5. Therefore, this framework will just be verified in this paper. The usability and sustainability of this framework are very difficult to test because it is hard to get data due to the confidentiality of the information of any project in the defense industrial sector. Because it is a high-level framework, the implementation might be very risky; also, it has not been tested yet. The verification process was partially done in the second chapter, since all the used elements in this decision-making framework have been used before. However, the researcher needs to obtain feedback from related environment experts, which will be discussed in the next chapter.

3.4.1 Interviewees selection

Selecting the interviewees in such a qualitative strategic study like this paper is not an easy task. The researcher consulted his supervisors and mentors in the working place in order to identify the type of participants necessary to do the research. Specific sets of criteria were identified according to which participants were chosen. This was necessary in order to ensure that the participants could contribute to the research and help answer the research question. Certain inclusion and exclusion measures were identified, taking care to ensure that inclusion criteria was not simply the opposite of exclusion criteria, and vice versa. This is necessary in order for the maintenance of proper standards and to ensure that the sample is appropriate to address the problem statement.

Seeing that this research is done in the defense industry, the inclusion criteria was that the participant needed to be involved in the related industry, have experience of weapon system development, and his current or previous position had to be in the industry. The exclusion criteria helped to eliminate people who were in positions with a high level of confidentiality or who had never dealt with any projects connected to Saudi Arabia.

Using the criteria mentioned above with networking efforts, the author interviewed the following experts (in alphabetic order).

Prof. Adriaan Sparrius: Owner and founder of Ad Sparrius System Engineering and Management (Pty) Ltd. In South Africa, he is considered as the godfather of system engineering. His degrees include: BSc BEng (Electronic Engineering) University of Stellenbosch. Master of Science in Electronic Engineering (MSEE) University of California, Berkeley. Master of Business Leadership (MBL) (cum laude) University of South Africa. Awarded the Graduate School for Business Leadership’s Council medal for the best student. Extraordinary Professor at the Graduate School for Business Leadership, UNISA. Developed and taught postgraduate courses in engineering management, logistics management and system engineering. Became an independent lecturer and consultant in 1986, specializing in engineering management, project management, system engineering and related fields such as integrated logistic support, specification practices, quality assurance, logistic support analysis, software engineering and reliability engineering. Consultant to numerous individuals, organizations and projects in both the public and private sectors. Offers a series of regular training courses and seminars on engineering management. More than six thousand persons have completed one of his course modules lasting one week. Performs in-house training for one of the defense pioneer manufacturers in South Africa.

Mr Francois Marais: System engineer, professional consultant. Received his BSc BEng (Mech.) in1969 and his MEng (Mech) cum laude in 1973. Certified in project management from 1982 (South-eastern Institute of Technology, Huntsville, Alabama, USA). Served on the AIAA Committee for solid rocket propulsion (1982-1986). Certificate in Systems Engineering, 1988 (Ad Sparrius). Project manager for development of propulsion and detonic subsystems for 2nd generation Air-Air Missile at Kentron South. Departmental manager responsible for the development of launchers, fire control systems, propulsion, fuzing and warhead systems for guided and non-guided rocket-propelled weapons (air-air, surface air, anti-armour missiles, anti-tank and artillery rocket systems, as well as minefield clearing systems). Assisted with the establishment of related technologies at Somchem. International marketing manager with focus on offset programs for Somchem. In this capacity liaised with the major defense industries of Brazil, France, UK, Germany, Sweden and Italy. Executive manager responsible for missile and rocket subsystems and the establishment of related technologies at Rheinmetall Denel Munition.

Mr Louis du Plessis: External ballistician and professional consultant. Received his BEng Hons. (Aeronautics), University of Stellenbosch, 1979. An M.Eng (Aeronautics), University of Stellenbosch, 1985. Employed in the armament industry starting as a bursary student with the Armament Board, that later became Armscor and eventually split into Armscor and Denel in 1993. He was employed with (what became) Rheinmetall-Denel Munitions until his retirement in 2017. In 2017 he started the company ABallistics, doing consultancy work and training mainly in the field of external ballistics.

Mr Willie Verster: He joined Rheinmetall Denel Munition in 2007 where he held various positions after he served a total of 20 years in the SANDF as a technical officer: munitions. He currently holds the position of the Executive Manager for Demilitarization Plants and Testing Facilities in the Plant Engineering Division. He attained a National Diploma in Explosives Technology and later a Higher National Diploma in Explosives Technology - Technicon Pretoria, 1994. In 2013 he obtained an MBA from the North-West University. Verster is currently doing research for his PhD degree at the NWU in Engineering Management.

3.4.2 Interview questions

Two types of interviews were conducted: structured interviews, where emails were sent to the interviewees, and semi-structured, face-to-face interviews (dialogue driven). The first type was taken with Mr Marais due to the geographical distance, so, it was easier for the researcher to communicate with the expert via electronic mail. Fortunately, the other experts were available at the researcher's work place. Although most of the questions that the author had prepared did not mention the DTAPM framework specifically, all the questions were intentionally asked to satisfy a specific concept or element that the author had utilised in the DTAPM framework.

Prof. Ad Sparrius was exposed to the DTAPM in an unstructured interview, and he critically reviewed it and gave beneficial feedback in and open discussion about DAS.

Mr Francois Marais, the expert system engineer, was asked the following questions:

- What is successful technology acquisition?
- What is the DAS?
- Who is responsible for establishing DAS?
- What are the critical elements/factors of the DAS?
- Maturity metrics have been used widely in technology management, such as TRL (technology readiness levels), MRL (manufacturing readiness level) and SRL (system readiness level). How do maturity metrics affect the DAS?

- The key concept in the DAS is derived from systems theory, which defines a hierarchy of systems and subsystems as shown in Table 9. The acquisition takes place at all the levels of the hierarchy and each level supplies to the next higher level. The Ministry of Defense is primarily responsible for system acquisition at levels 8, 7 and 6; Defense sector manufacturers are responsible for the acquisition of level 5 systems, while the suppliers in the industry are the acquiring parties at the lower levels. How do you think we can establish effective channels between those officials responsible through all levels of the weapon system in DAS?

Mr Du Plessis has been involved in technology transfer and gains knowledge about technology transfer programs to South Africa in the late 1970s and 1980s. That International Technology Transfer (ITT) project was an urgent and need driven, while

South Africa was in a war situation that necessitated them to have a defined capability to address the perceived threats. An interview with regards to Mr Du Plessis' ITT experience was requested. The main points were discussed in this interview.

- The national need is the main drive that formulates operational needs. How do you think we can acquire the necessarily capabilities effectively?
- Was the SANDF at that stage having DIS (defense industrial strategy)? To what extent do you think it is important to have DIS?
- Can you highlight (without exposing details) the main objectives of this ITT project?
- What were the main factors of that ITT failure?
- Why did it go to the procurement process? Was it supposed to be ITT?

Mr Willie Verster was involved in excellent international technology transfer (ITT) experiences from South Africa to Saudi Arabia. The main points discussed in this dialogue interview were:

- Mortar and Artillery Projects were more like manufacturing matured technologies. How do you evaluate those experiences?
- Where in the process of Technology Acquisition (TA)? (Development/ Demonstration/ Integration).
- Do you consider this experience a technology transfer or machinery transfer?
- How the knowledge about the acquisition system of the receiver (KSA) contributes to the success of the TA?
- If you would have to do this again, will you change your strategy to improve the process?
- It has been said that development is always the best option, at which level do you think the procurement is better?
- The R&D program was following those ITT projects, do you consider this program a "gap filling" project that was urgently needed for the local Saudi capabilities?

3.5 Summary

In this chapter, the research design was illustrated, and the conceptual foundation of the methodology was explained. This chapter also discussed how the researcher approximately determined the gap created by the problem, i.e. how the situation was analysed and the problems were identified. Moreover, a discussion followed of the synthesis of the strategic decision-making framework and the concept used by the researcher to develop this framework. A summary of this chapter is presented in Table 10 by highlighting the major decisions made in order to conduct this research.

Table 9: Major decisions made in this Research

Level of decision	Choice
Research strategy	Multiple Reviews
Research Techniques	Participant observation, semi-structured interviews, group discussion, documentation analysis.
Organizations	Defense Industry
Sub-units of Analysis	Acquisition system Technology Management Strategic Planning
Timeline	July 2017 – March 2019
Subject	Developing the DTAPM

CHAPTER 4: DISCUSSION AND FRAMEWORK DEVELOPMENT

4.1 Introduction

In the previous chapters, the need to find a strategic tool was explained as well as technology and portfolio management through a thorough literature review with the focus on some models and tools that have already been used in the defense sector. Therefore, it was necessary to develop a framework that can evaluate the current technological capabilities and clarify the big picture of the indigenous situation and make the proper decisions for success.

This research endeavours to contribute to the new drive in the Saudi MOD in order to enhance the indigenous capabilities, by developing a strategic framework for the decision-makers in the MOD. This deliverable will try to solve the stated problem in the first chapter which is the lack of a formal Defense Acquisition System (DAS) for the Saudi MOD. Therefore, the researcher is proposing a tailored DAS that suits the needs and objectives of the new development plans, namely the “Defense Technology Acquisition Portfolio Management” (DTAPM) framework.

This chapter discusses the developed DTAPM framework. The discussion will highlight the importance of having such a tool to facilitate technological projects management in a very complex industry (defense industry), and how the acquisition is different from purchasing and procurement processes. Also, the author will highlight the international technology transfer channel, and how DTAPM may facilitate the national technology transfer. At the verification stage, this explains the researcher’s efforts to execute this process, through interviews with experts to finalize the DTAPM framework. Finally, this chapter will discuss the experts’ feedback and summarize the results.

4.2 The DTAPM framework

The DTAPM framework was visualised in the mind of the researcher after he was exposed to many DASs in different countries worldwide. The proposed solution was developed after the exploration of critical aspects and dimensions involved in technology acquisitions decisions. Due to the nature of his work, the researcher was exposed to many technology transfer projects in the defense industry in Saudi Arabia. He found that many of these projects were initiatives, and the absence being able to look at the big picture affected critical decisions. Albeit the selection of some projects was appropriately chosen, the maturity of the technology needed for this project failed due to underestimating the capability gap assessment which clarifies the technological situation in the local capabilities. These kinds of assessments have been considered in the suggested DTAPM framework (Figure 23) along with other studies including the trade-off analysis between buying or manufacturing the needed technology to fill the gaps.

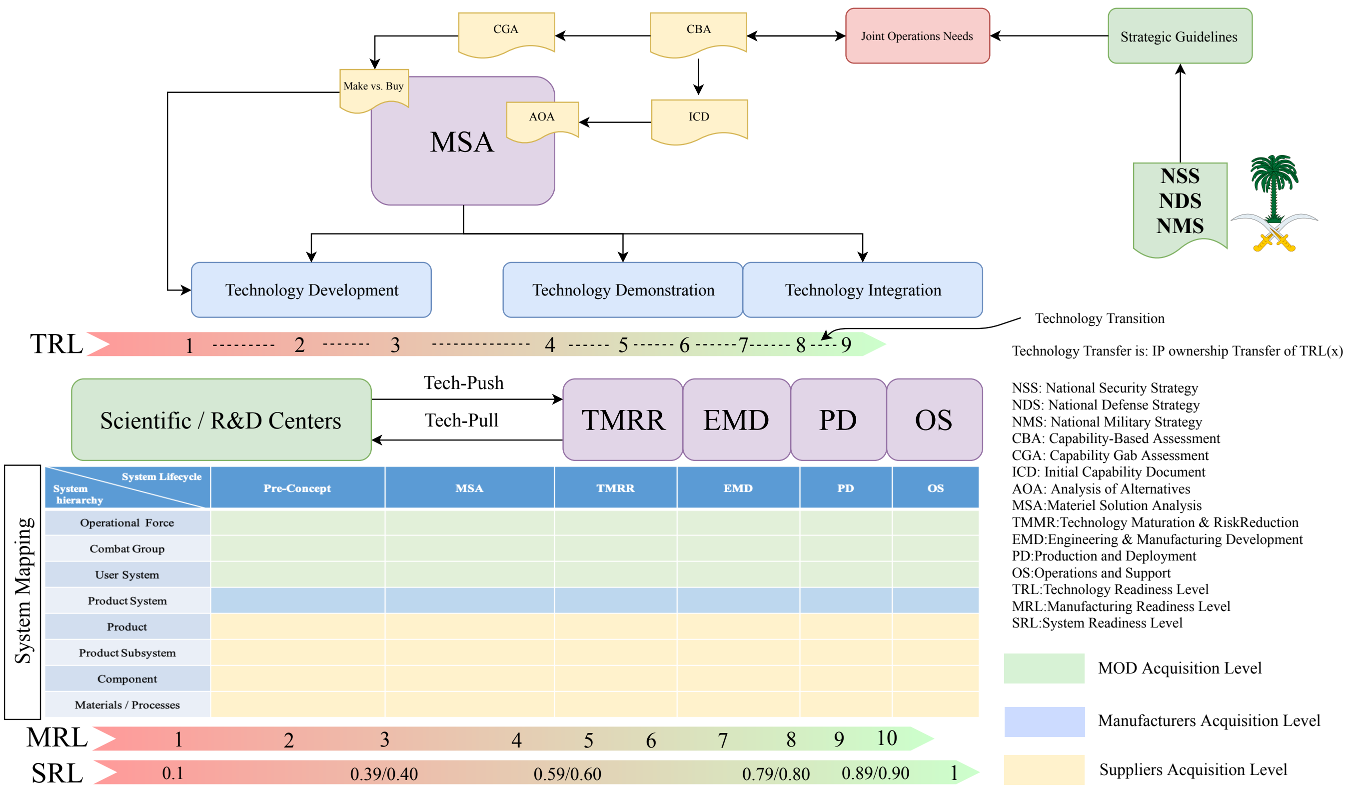


Figure 23: DTAPM

The researcher perceives that an excellent strategic decision should acknowledge the broad vision when looking for improving the national industry. Therefore, the concept of technology transfer was used in his model.

This transfer could be international; however, the national technology transfer from the local industry or science sectors is the main capability that the government is looking for. The DTAPM will inform the officials of what local industrial project they should support in order to acquire the needed technology with the indigenous capabilities.
The TRL scale, shown just beneath the technology acquisition options (development /demonstration/integration) is a very useful flexible metric and can depict the instant maturation of any particular technology after Technology Readiness Assessment (TRA) is done. This will map the whole available technological capabilities and reveal the gaps. In the other side of DTAPM, we can recognize two different metrics: the MRL scale which measures the manufacturability, and the SRL scale which represents the readiness level of the whole weapon system after integrating the TRL, MRL and IRL.

Between those metrics, there are system mapping matrix sets. It maps the system in two dimensions; the system life cycle and the system hierarchy. In future studies, the researcher would like to add a third strategic dimension to make this matrix more plausible.

The concept of adding this system mapping matrix to the acquisition system is to link the strategic officials with the technical people in the industrial sites. The critical decisions of selecting the proper technology at the proper maturation will take the input from both sides; the strategic analysis and the technical analysis. The implementation of the DTAPM is out of the scope in this research. However, the whole business plan and procedure will be involved in future work.

Project managers should use the system mapping matrix to give a technical input to the strategic managers, to have a proper image of what capabilities they have and what they have not, and what they can manufacture and what they cannot. Then, the strategic officials can measure all these inputs against the national needs. As mentioned in the previous chapter, the used TSM matrix has covered all the acquisition levels; the MOD level, the manufacturers level, and the suppliers or OEM's level.

4.3 Technology Acquisition in DTAPM

Upon investigation, it was revealed that the previous technological projects related to the defense industry in Saudi Arabia, focused on the machinery transfer from the manufacturer to the local facilities. This kind of technology acquisition can be in the range of maturation between TRL6 to TRL9, which is expressed in the DTAPM in the advanced stage of demonstration to the integration of the acquired technologies. Accordingly, this process cannot be described as a "technology acquisition", it can either be purchase or procurement processes.

Moreover, here, we must understand what we need from the supplier; are we going to buy their products or services which are available off-the-shelf (commercial needs-based, i.e "purchasing process")? Or are we going to buy equipment or services that will fit a known system which needs modifications of further development (technical needs-based, i.e. "procurement process"? Alternatively, do we need to acquire the whole life cycle capabilities, which requires not only a high degree of technical expertise but extensive expertise and overall strategic capabilities, including commercial, technical and strategic needs (the "acquisition process").

Inevitably, the acquisition process is the only way for any organization aspiring to develop its technological capabilities. It must be considered as the basis for the two other mentioned processes, see Figure 24.

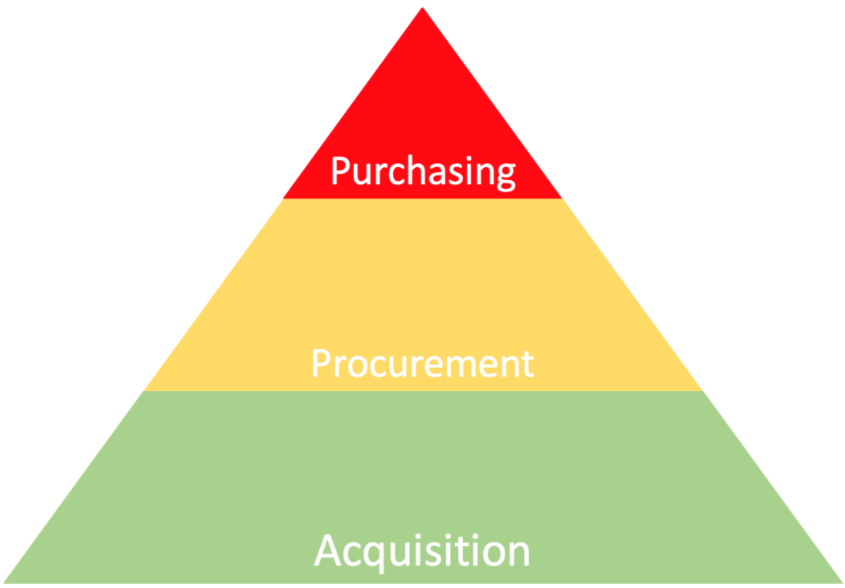


Figure 24: Acquisition, procurement and purchase relationship

4.4 Technology Acquisition Channels

The proposed DTAPM may integrate with the technology transfer channels, or here in this framework context, it is called the technology acquisition channels. Before highlighting those channels, a brief reminder of the definitions on technology acquisition and technology transfer is needed. The technology transfer is merely the transfer of the ownership of a specific technology IP at a specific maturation level (TRL). That transfer can even be at the purchase level. Whereas the technology acquisition has the capabilities to develop, demonstrate and integrate the whole life-cycle of a specific technology.

Considering the DTAPM, it contains both strategic and technical approaches, but as a whole, it is more strategic. Although the system mapping matrix (which represents the technical part of DTAPM) is technology-driven, the final decision of the feedback of this matrix should be strategic. For example, if the feedback from the technical people at a certain system level and maturation shows a gap in the indigenous capabilities, this will never necessitate (red block) from a strategic point of view. This block may be yellow or even green if the purchasing is a better option from a cost-effectiveness perspective. For that sake, the researcher aims to add a third dimension in future studies to consider the strategic dimension in this matrix.

DTAPM widens the lens further because it considers all the national industrial sectors as the indigenous capabilities. So, if any national industrial site can fill a certain gap in the defense industry, the block here will be green also.

The international technology transfer (ITT) through many different channels, can be very beneficial, especially for win-win situations. However, the national strategic plans are aiming to develop and maintain national technology transfer (NTT). In the ITT collaborations, the researcher suggested a model for the defense ITT collaboration through the “partnership” channel as illustrated in Figure 25.

This model shows what the partnership might look like in the defense technological development collaboration programs. There should be scientific collaborations as well as industrial collaborations between local and foreign parties. Both governments should facilitate these collaboration activities with incubators to process the efforts into tangible results.

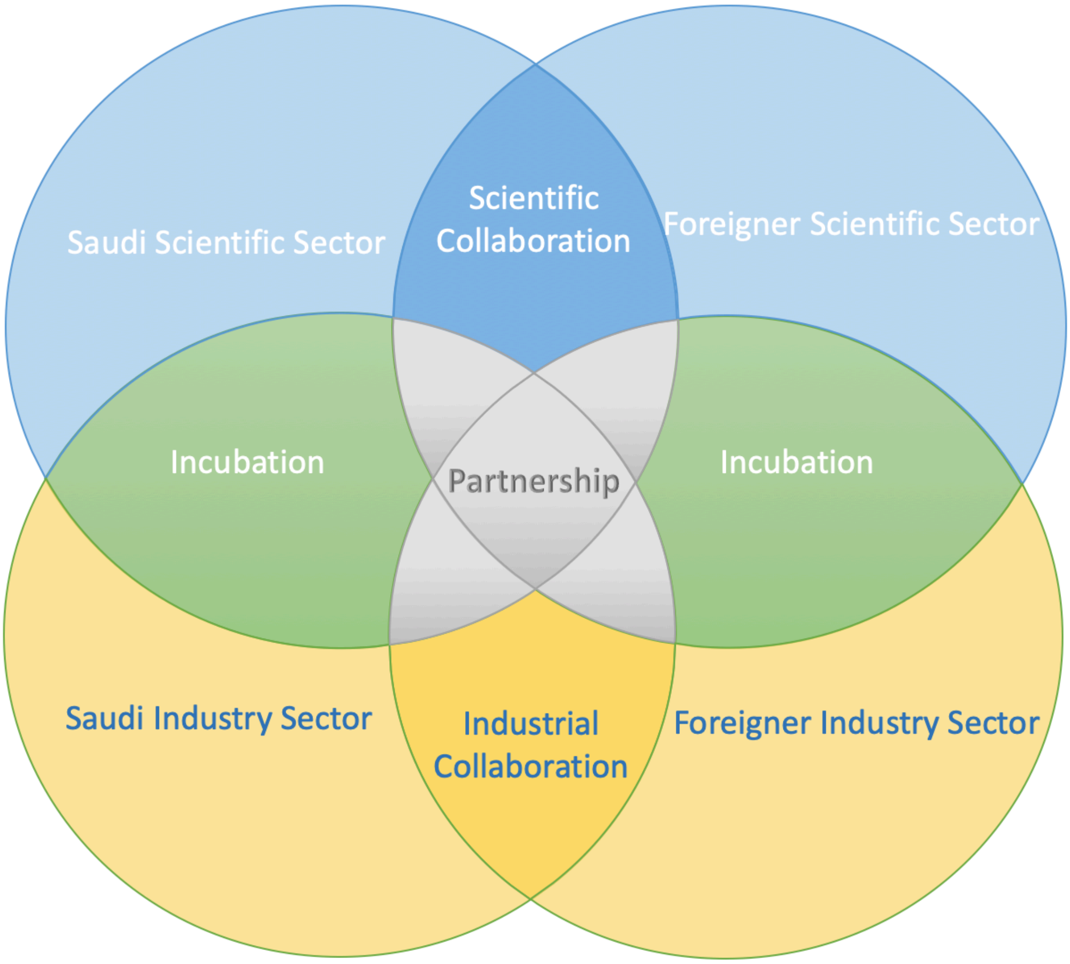


Figure 25: International Defense Partnership Model

The technology transfer channel in this partnership model can be a "joint venture" channel. Many authors and researchers have discussed the technology transfer channels through their various perspective. In this research, the researcher has illustrated some TT channels on two dimensional charts (Figure 26); the vertical axis represents the technology maturation and scaled by the nine TRL levels, and the horizontal axis represents the acquisition sources whether if it is national or imported (internal or external), differentiate between the trade and investment spaces.

Figure 26: Technology Transfer Channels Chart

The previous technology transfer projects in the defense sector in Saudi Arabia were deviated to the right lower corner according to this chart. It was mainly purchased or obtained through procurement activities, and sometimes it goes advanced through "licensing contracts". Moreover, this chart shows these channels set in the commercial side as a "trade" relationships. The ambitious national plans are targeted at balancing these relationships and taking it towards in the investment space, the space that will create a competent industrial environment, and establish a rigid foundation for true industrial development.

The new DTAPM framework suggested by the researcher will help the decision-makers in the Saudi MOD to calibrate this deviation. This chart (as proposed by the researcher) can also be used as a tool to create more channels primarily in the investment space. These channels also, may not be limited to ITT; and it can be NTT or let us say it should be to satisfy the national strategic needs and objectives. The national collaboration may take different aspects in the scientific or industrial sectors. In this regard, one can also develop a national model for collaboration between the available indigenous capabilities as the researcher has imagined in the proposed partnership model.

If the partnership model (Figure 25) is mapped on the technology transfer channels chart (Figure 26), one recognizes the researcher's idea about how technological collaboration works. This transparent mapping (Figure 27) reveals the big picture of international technology transfer.

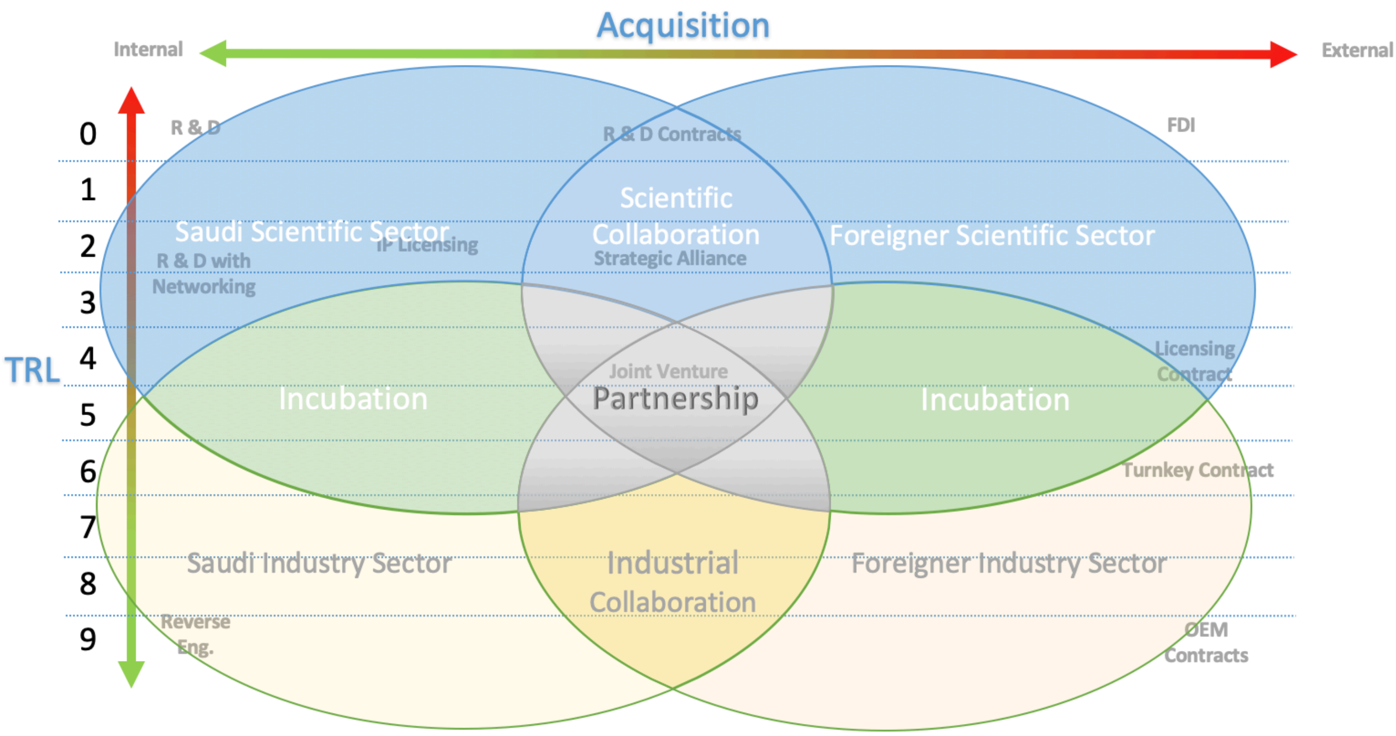


Figure 27: Partnership model mapped on the ITT chart

From the outputs of the DTAPM, the researcher believes that we can create more NTT channels to fill the capability gaps by collaborating with the scientific and industrial sector using the (Push-Tech model) used in the DTAPM. Moreover, by measuring the available capabilities in the sense of what we need, what we have, and what we can manufacture. Metric tools like those in the DTAPM like TRL and MRL are used and aligned with the national strategies guidelines, after highlighting all the aspects that one believes to be critical elements in the proposed DTAPM framework. In the next section, I will discuss the verification of the DTAPM as a part of this research.

4.5 The verification of DTAPM

As mentioned before, the DTAPM has been partially verified because all the elements (models/tools) that formed this framework are already used and implemented in various sectors. However, this newly proposed framework has to be verified as a whole. At the verification level, all that is needed is feedback from experts who work in the defense industry field, while the validation process requires the implementation of the DTAPM which is considered as a future study.

Feedback was gathered by interviewing selected experts who have similar experiences. The researcher drafted questions that guided the experts in sharing their ideas and not just to evaluate the DTAMP. It was expected of them to mention Technology Critical Elements (TCEs) or the successful factors of technology acquisition. Thereafter, the researcher evaluated the TCEs and success factors gained from the interview and checked whether the DTAPM covered those elements and factors, or not. The framework that had to be verified worked as a DAS roadmap. The experts are not allowed to get involved with these kinds of projects, but they are allowed to read it. Three aspects of the DTAPM will be discussed: the strategic, technical and the implementation aspects. This discussion will highlight the critical factors and elements that the experts realised from their previous involvement in different development projects in the defense industry. Additionally, we can consider the expert's' feedback as a verification strengthening tool, and it will also be used as a critical input for the validation process in future studies.

4.6 Interview feedback discussion

This discussion aims to elicit the attitudes and perceptions of the experts whom the researcher interviewed the concepts and elements used in the DTAPM by the researcher. Interviewees were asked different questions for the sake of satisfying a certain concept in the proposed framework.

The strategic part of the DTAPM (Figure 28) was highlighted by Mr Du Plessis through his reading of the ITT experiences that he got involved in. He believes that this strategic decision framework should ensure:

a. The correct decision is taken.
b. The technology to be transferred addresses a real need and fills a real gap.
c. The process of TT to embark on is sufficiently funded.
d. The best strategic partner is selected for this TT process.

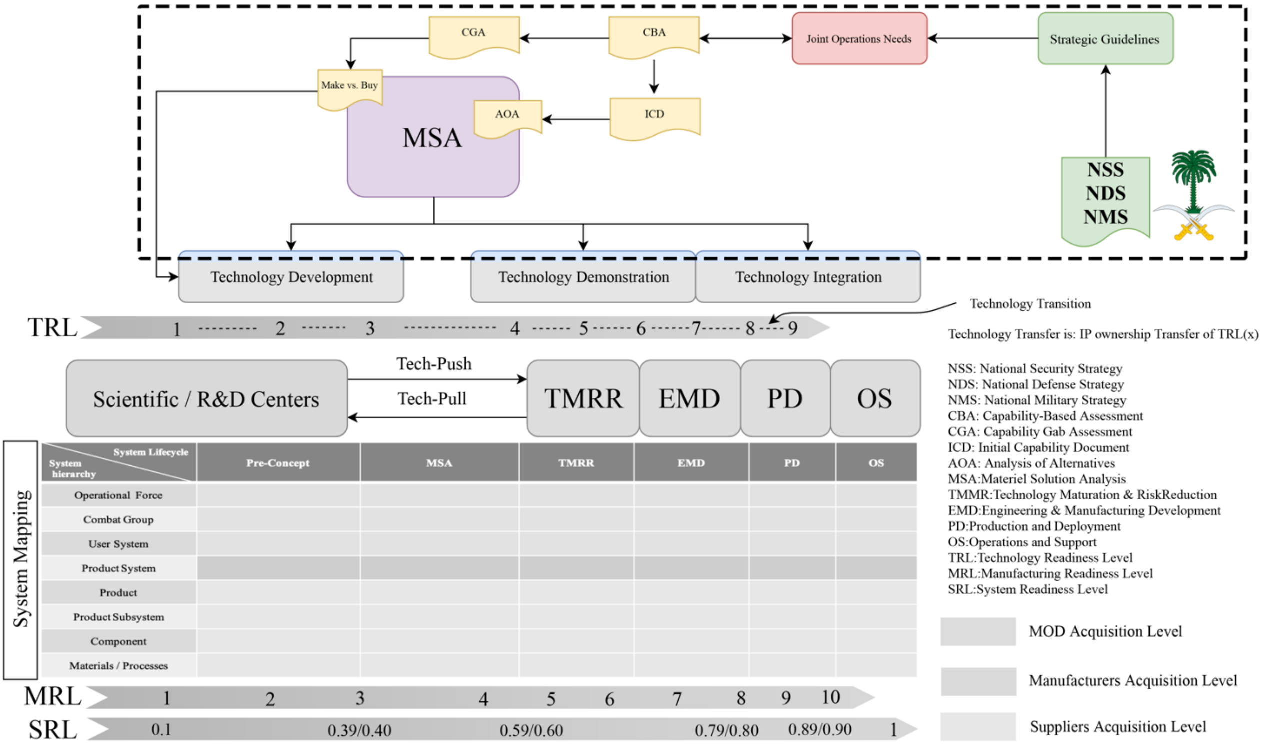


Figure 28: Strategic Part in DTAPM

"*The perceived national (military) needs are formulated within strategic groups between selected political and military leaders. This is usually based on real needs to address prevailing national threats and the build-up of defence power acting as a deterrent"* Mr Du Plessis says. Mr Verster thinks the decisions in the Saudi projects should always be strategic and not economic at all, because they will never cover the cost of the manufactured ammunitions, and he said: *"The concern is to be strategically independent of defending themselves depending on the strategic and political situations".* Additionally, Mr Du Plessis emphasized the importance of having an industrial defense strategy (DIS) to execute the tactical processes without top-level centralization for the decisions taken. He mentioned: *"In your proposed DTAPM, I see that happening on a strategic level in the top part of your diagram up to the point where the "material solution" is selected in your so-called MSA. This is the driving decision from which the Technology Transfer is driven".* The DIS will facilitate the communication between the strategic officials and the technical people in the production.

This communication issue raised a question in the researcher mind: according to a white paper published by the South African Defense Force, the responsibilities of different acquisition levels in the system hierarchy Table 9, is assigned to different entities. Mr Marais has disagreed with this statement, and he replied: *“These levels are created by the defense force branch of service (Army, Navy, Air Force) based on lower-level systems depending on what force structure is decided upon to counter a threat”.* He believes that all the acquisition levels should be done through one entity responsible for the DAS. From his system engineering perspective, Mr Marais reacted to the technical part of the DTAPM (Figure 29). He deems that *“it is essential that the technical decision makers understand the application and the practical application of the maturity metrics, in order not to allow contractors to supply products based on immature technology (TRL) or immature manufacturing processes (MRL) that have not been qualified to prove that these processes can consistently produce items that comply with their respective technical specifications”.*

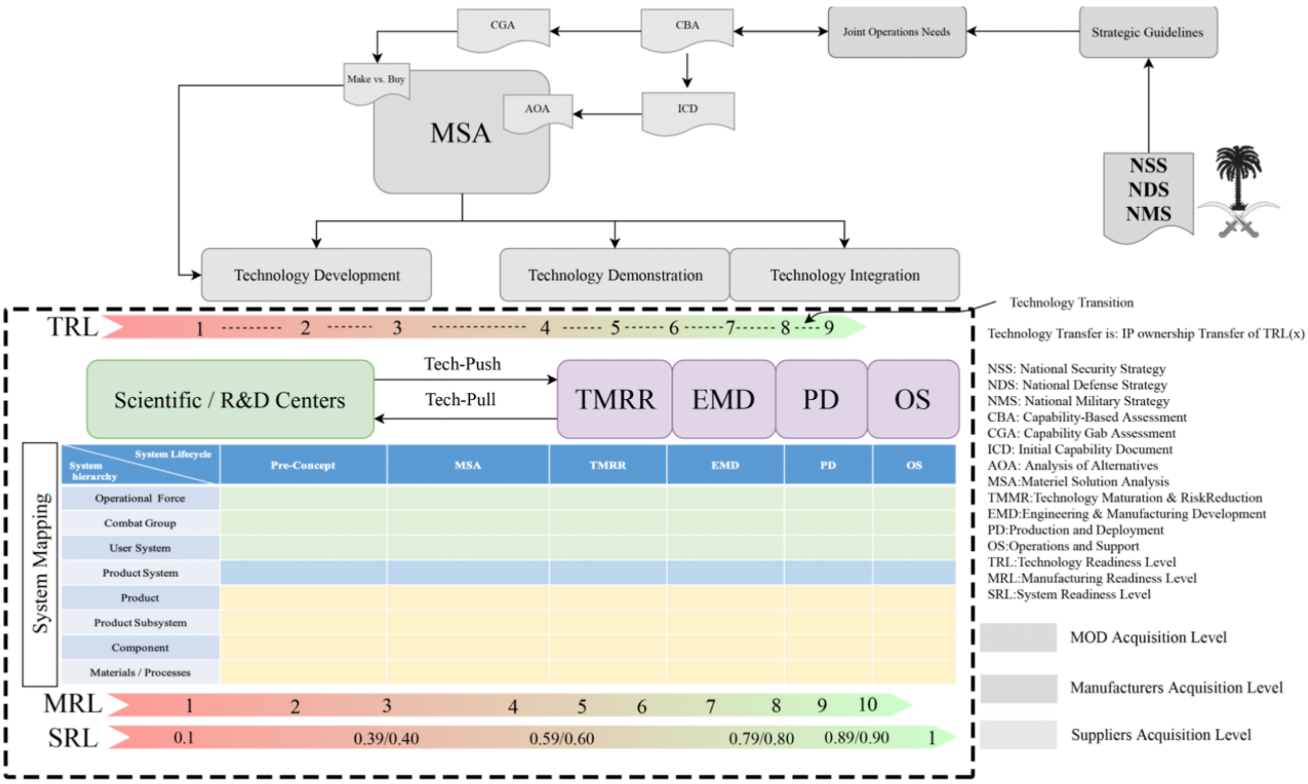


Figure 29: Technical part in DTAPM

Mr Marais considers maturity needs evaluation is the technical projects managers responsibilities for the acquisition to ensure that they gather a project team of professional engineers who can do all these kinds of maturity assessments. The Saudi engineers are very professional and well educated in various disciplines for different industrial sectors, the question here being, are they good in the defense acquisition systems?

Mr Verster has dealt with the Saudi defense industry individuals many times; he sees that the Saudis have the vision of where they want to be, but they do not understand how to express it, and how to define it clearly because it is a field that they do not have the necessary knowledge in. He adds, "*the Saudi client did not have the clear ability to specify what they exactly need in engineering terms. That area can be improved in the future, and I think your proposed framework will contribute towards this improvement"* Mr Vester comments.

For the whole developed framework, Mr Marais as a professional system engineer comments that a successful technology acquisition is achieved when:

i. A proper assessment has been done on future technological requirements that will specifically support the countries' future defense readiness prior to acquiring the technology.
ii. Creation of an in-country appreciation for the benefits that the specific technology holds for application in defense.
iii. Successful application of the technology or the ability to apply this technology in support of defense acquisition or own product development has been achieved.

It is worth to mention that the above points highlighted by experts, have already been incorporated in the DTAPM. The beneficial usage will be at the assimilation of this framework by a professional team that can implement it properly.

Mr Sparrius has highlighted the DAS and spoke about the technology maturation, he said that the DAS should only incorporate the technology with TRL equal to six or higher (Figure 30). Also he believed that the technology maturation processes at early stages should not interfere with the DAS process and that will be very risky.

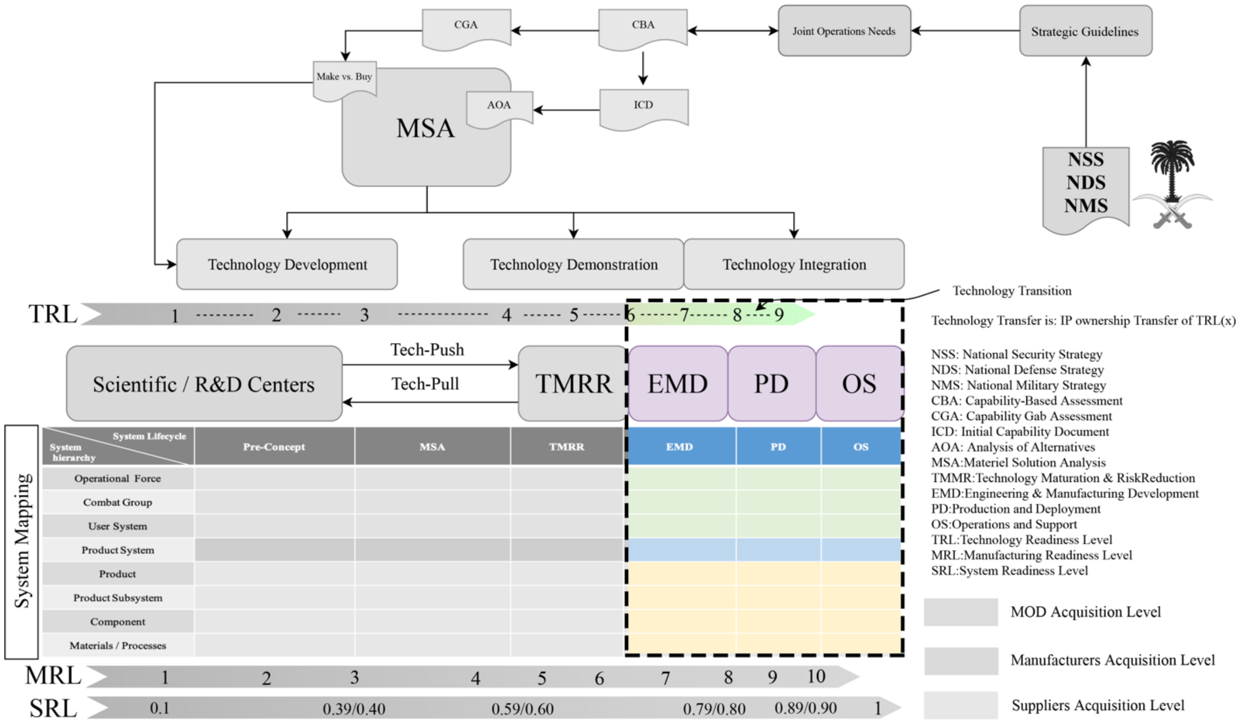


Figure 30: DAS in DTAPM

He also put emphasis on the evolutionary DAS where capability is developed and delivered in increments. He believes that this is the most effective way to develop weapon systems. Incremental development allows for future capabilities to be added to a system as upgrades in improved technology or other increases in operational capabilities to meet a desired state.

From his technical perspective, Prof. Sparrius commented on the DTAPM as a good start but does not end there, *"you cannot incorporate all the elements in one diagram"* he said. The researcher agrees with this point; however this research does not propose a DAS, as much as it is a strategic framework that it should see the whole picture from the bird's eye view. The purpose of this framework is not to run a successful DAS; it is just a tool to evaluate the current technological capabilities.

All of the interviewed experts have highlighted and discussed different aspects that have been integrated into in the DTAPM framework. In the sense of the verification purpose, we can prove that this DTAPM framework does not need any changes at this stage. Nevertheless, the valuable feedback from Prof. Sparrius is to improve this single diagram and generate all the other aspects that cover the whole DAS, will be considered in future studies. If we just magnify the small bounded part shown in Figure 30 which represents the DAS in our framework, we will find many areas that we can work in.

The implementation of this framework will show its validity and its sustainability in future work. This implementation will consider all the previous criticized comments from the experts. At this stage, the researcher has decided to leave the proposed DTAPM as is, because any further improvement should be made along with different expertise who hopefully will cooperate with the researcher shortly to improve this tool and its viability and usability.

4.7 Summary

This chapter was devoted to a detailed discussion on the developed DTAPM framework. The discussion drew attention to the importance of having a roadmap framework for the decision-makers to manage the technological program effectively. Hence, the strategic orientation concept was applied in this framework. This chapter also provided a glimpse into the difference between the purchase, procurement and acquisition processes.

Besides the deliverable (DTAPM), the researcher also presented a model of effective collaboration in the international partnership. Harmoniously, he illustrated the popular ITT channels in two-dimensional chart then linked it with the partnership model, to visualise every channel contribution to the indigenous development and how we can localise them to NTT.

Hereafter, this chapter discussed the verification process and how the researcher selected the methodology of the verification and the justification of his selection. Additionally, the selections from the interviews were discussed with inclusion and exclusion criteria and how the researcher generated the questionnaire.

Finally, in this chapter, the feedback of the interviews were discussed and highlighted the important issues related to the proposed framework. The researcher has taken these comments from experts and compared it with the concepts that have driven his synthesized framework. Then as Figure 22 depicts how the process of the verification goes, we can say that the DTAPM framework (Figure 23) is now verified.

CHAPTER 5: CONCLUSION AND FUTURE DIRECTION

5.1 Introduction

In the preceding chapter, the developed DTAPM framework was critically discussed. Thereafter the discussion turned to the verification process by gathering Technology Critical Elements (TCE's) and influential factors for technology acquisition (TA) by means of interviewing three experts in the defense industry field. The validation process is the implementation of this framework and because the implementation may take years in the defence industry, we can only speculate to the outcomes and not prove it. However, the developed framework and its elements and concepts have been tested and verified by defense experts in this field.

The verified framework is the final DTAPM enclosed in **Annexures A** of this research, which has been developed by the researcher who has put forward and suggest a tool towards a tailoring defense acquisition system, that will facilitate the strategical missions for the officials in the Saudi MOD.

The purpose of this chapter is to discuss the significance of the research study in a very complex industry (defense industry) that needs an advanced tailored acquisition system and how the deliverable of this study can be very beneficial to the contribution of establishing the needed acquisition system. Also, linking the objectives that were revealed at the beginning of this research and how this study defined it and tried to satisfy its means. Recommendations are also made for both further research to be undertaken and what actions should be taken by the government towards the stated objectives. Attention is given to future research by the researcher and a final conclusion is made.

5.2 The complexity of the Defense Industry

Everyone exposed to the DTAPM framework will describ it for an instant as a very complex framework. The researcher did not intent on making it complicated. Nevertheless the nature of the modern defense industry requires all these multi-disciplines to interact to form an excellent defense acquisition system.

We need to maintain and develop the necessary understanding and capability to lead and sustain the acquisition structure within Saudi MOD. This cannot be outsourced or contracted out. If we are to thrive in constructing truly relevant defence forces, we therefore, need a system that is currently outside our armed forces' power to deliver. We need an agile and adaptable acquisition system able to deliver both equipment and services rapidly and as needed to enable a wide range of kinetic and non-kinetic campaigns.

This study started reviewing the "best practices" in the DAS systems and how they manage the defense industrial complexity, and many countries' defense departments have recognized the US DAS system as the best practised one, and they adopted it then tailored it according to their organizational structures and their needs. This paper also adopted then adapted the US DAS system and linked it to the TSM and some metrics to evaluate the capability gaps.

The proposed DTAPM is not simply a DAS system; it can be a very excellent tool to visualise the real big picture of the situation for such a very complex system. It can be beneficial for both strategic and technical leaders, to take the proper decisions regarding the instant and long-term needs. Moreover, it can map all the weapon systems and measure its availability, manufacturability, and what it needs to be linked to scientific sectors for further development and if it could be outsourced through procurement levels.

5.3 Major Readiness Objectives

The researcher believes that the objectives of this research are obtainable with this proposed framework. The DTAPM is a capabilities-based planning tool; if it is implemented properly, it can satisfy the strategic and the technical objectives. It is the commencing point in identifying, and suggesting solutions for gaps and shortfalls in operational military capabilities. The results can provide value-added information to the decision-makers.

If we think about the capabilities that we need to have to satisfy the national objective to have the indigenous competences to build our arms, we will consider major readiness objectives that we have to meet to acquire major capabilities. The researcher's mind map thought about these capabilities are illustrated in Figure 31. These major readiness objectives; Human Readiness Level, Innovation Readiness Level, System Readiness Level and Cost Effectiveness Level are very critical to implement DTAPM effectively.

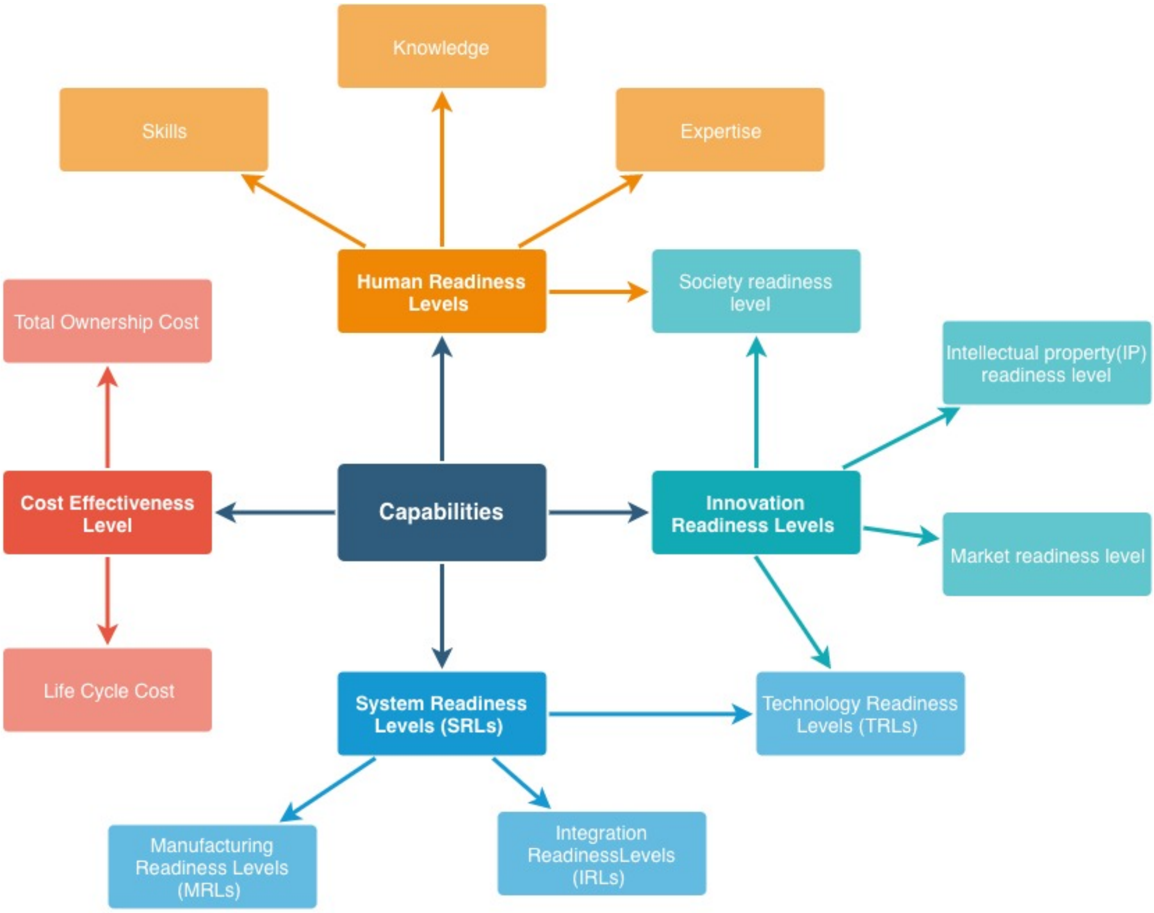


Figure 31: Major Capabilities needed

5.4 Interviewed experts’ contribution

Besides their feedback on the questionnaire, the researcher used this information to verify some concepts utilized in his deliverable. The experts have contributed excellent ideas and thoughts from their own experience.

Mr Marais gave his opinion of how a successful DAS should be:

i. a system that timely assists in identifying threats to a countries’ sovereignty;
ii. timely acquires or establishes the optimum capability (technology or armament or defense systems) to counter a future threat; and
iii. maintain technological or defensive/offensive capability.

As such it requires:

i. A competent technical workforce (engineers, scientists, QA practitioners, logistics experts) that are capable of researching international technological tendencies, new developments in weapons and ammunition.
ii. Engineers and scientists who are well versed in defense systems, ammunition systems and operational doctrine.
iii. Engineers and technicians that understand logistic support and will ensure that the defense force will receive a comprehensive logistic support package as part of the weapon system procurement.
iv. Competent procurement and contracting organisation with well-defined tender and procurement procedures and standards.
v. Experienced contract lawyers that know international law and can best protect the interest of the user.
vi. Competent auditors that can properly do a due diligence process on a prospective supplier to ensure that the supplier will be able to fulfil the conditions of the supply contract and not go into liquidation before complying with the conditions of the contract.

Mr Marais emphasised the need for competent human resources as a crucial requirement for the DAS. Prof. Sparrius also commented (once he was exposed to this study) that we cannot take the human component out of the scope if we want to make a successful DAS.

This is one of the major components that the researcher demonstrated in his mind map as Figure 31 shows and has recommended it as a future study.

5.5 Recommendations

From the researcher's studies, through many literature and manuals, he was exposed to some crucial elements that he believes the Saudi MOD must have. One of the needs stated in the problem statement of this research having a formal defense acquisition system. There are national strategies for security, defense and military. Moreover, it has been announced in the Saudi MOD official website. However, the gap here is that there is no defense industrial strategy (DIS).

Currently the researcher's key recommendations are:

- Establish defense acquisition board (DAB).
- Launch a formal Defense Acquisition System (DAS).
- Inaugurate Technology Transfer Office (TTO).
- Introduce a clear Defense Industrial Strategy (DIS).
- Start-up a Defense Industrial Cluster complex.
- Set-up Defense Standardization Program for the industry.
- Establish Saudi Defense Acquisition University.
- Qualify good system engineers with a professional defense system engineering training program.
- Do the right things at the right time with the right people.

For future research, the researcher recommends:

- Science and Technology Program Budget Activities for the Saudi MOD.
- Technology needs assessment for the Saudi Military Forces.
- Techno-economic study for establishing Defense Industrial Cluster.
- Major Capabilities Readiness, see Figure 30.

5.6 Future work

For the sake of being more practical, the researcher intends to work with the officials concerned in his working place or in any department related to the defense industry in Saudi Arabia, to cooperate towards the establishment of a formal defense acquisition system.

The DTAPM is meant to be a strategic framework, and works as a road-mapping for the decision-makers in the MOD, however, the technical side of this proposed framework can be very useful if it well utilised through effective procedures and processes. The researcher is suggesting tasks to do in the work environment:

- Set a presentation for the officials to explain the DTAPM.
- Develop a capable team assigned to the DTAPM.
- Study the implementation of DTAPM.
- Develop business plan and workflow for DTAPM.
- Add a third dimension to the technology space map in the DTAPM.
- Conduct workshops to discuss the possibility of developing the DTAPM for further studies.
- Activate the collaboration between the scientific sectors and R&D centres with our technical projects.
- Incorporate the side outputs (Figures 25, 26 and 31) with the main deliverable the DTAPM framework.
- Involve national and international expertise for consulting.

5.7 Final Conclusion

Defense Acquisition Systems are continuously reformed even in the pioneer countries in the defense industry. A lot of manoeuvrability of technology acquisition processes is needed. Hence, the strategic orientation concept was applied to develop a framework that can be reformed and has a flexible structure that allows creative adaption and processes can be tailored as the need arises.

Moreover, provide the ability to develop a variety of defense acquisition strategies. This framework was developed by the author for the use of the Saudi Arabian MOD in helping to establish DAS since there is no formal DAS.

The implementation of such a proposed framework is very risky and takes years to prove its validity and sustainability. However, the researcher is convinced that this DTAPM will work. This convinction is based on the fact that all the used models and elements in his framework have proved its usability and validity in different sectors and also in defense.

The human factor is essential, and it has a critical impact on the success of this framework. Effective change management is important with the military people who have fixed norms and values and who are very rigidly resistant to change. Human-related components were out of this research's scope. On the other hand, the researcher has suggested that someone should study these components. Nevertheless, organizational environments also have a critical impact, and mismatching human expectations may lead to failures.

The financial factor was also out of this research's scope, as the main objectives are strategic, and the cost issues will be highly supported in this phase of the national development plans to improve the local content. The problem is with the level of TA that will be supported, for example, something like a space program, will consider as national pride and will get financed and many opportunists support this program, and it is not as effective as the medium ammunition development which may be ignored financially.

Every national vision, and so the Saudi vision, is looking for a nation that can produce and enhance their food, medicine and armament. Political involvement always lead to TA failure, and the situation compels the countries to be self-independent to defend themselves. This paper tried to contribute to the strategic plans that aim to acquire the needed indigenous capabilities to be self-independent in the armament industry. The main deliverable is DTAPM. This framework provides a strategic decision-making roadmap for the use in the Saudi Arabian MOD.

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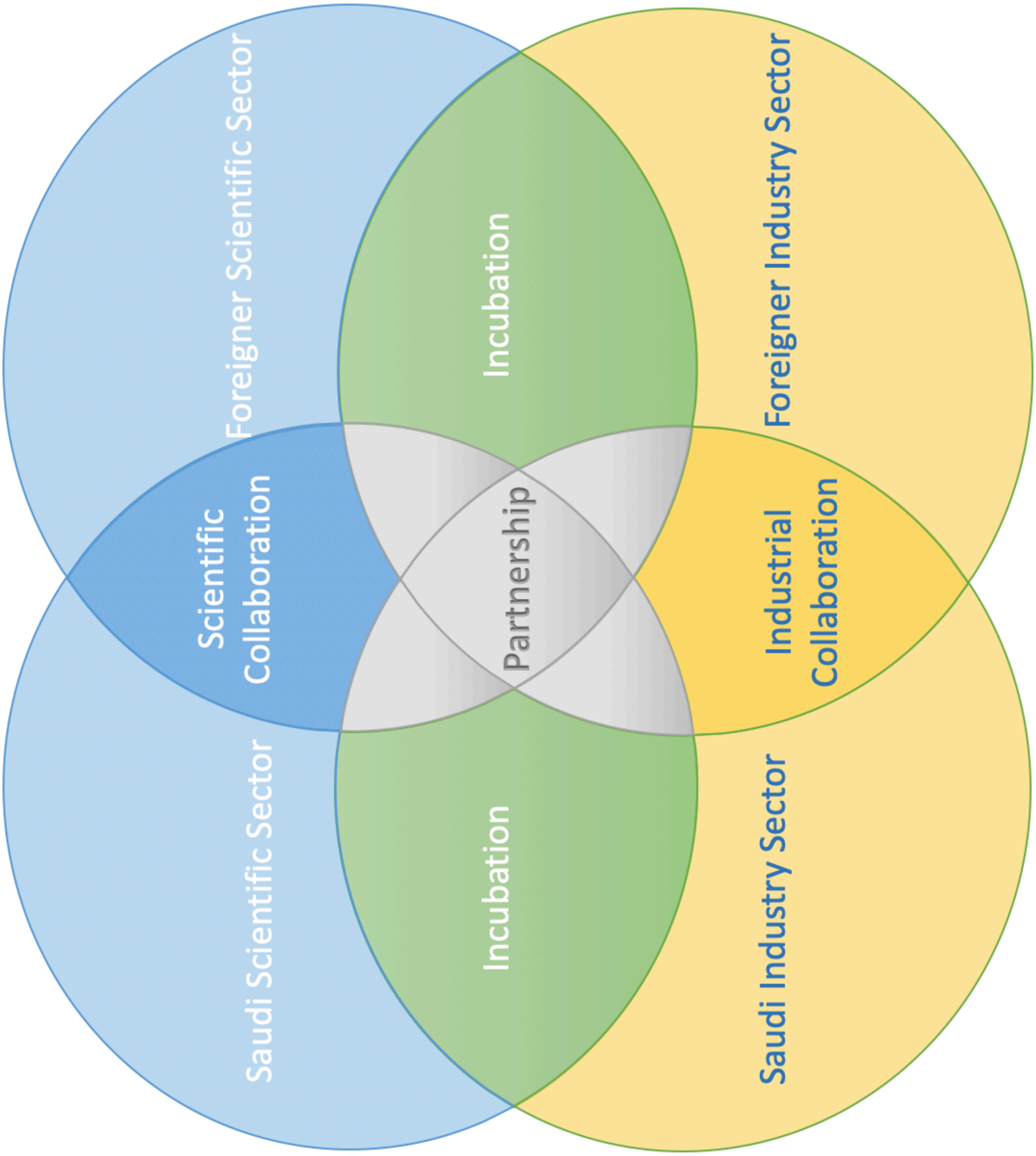
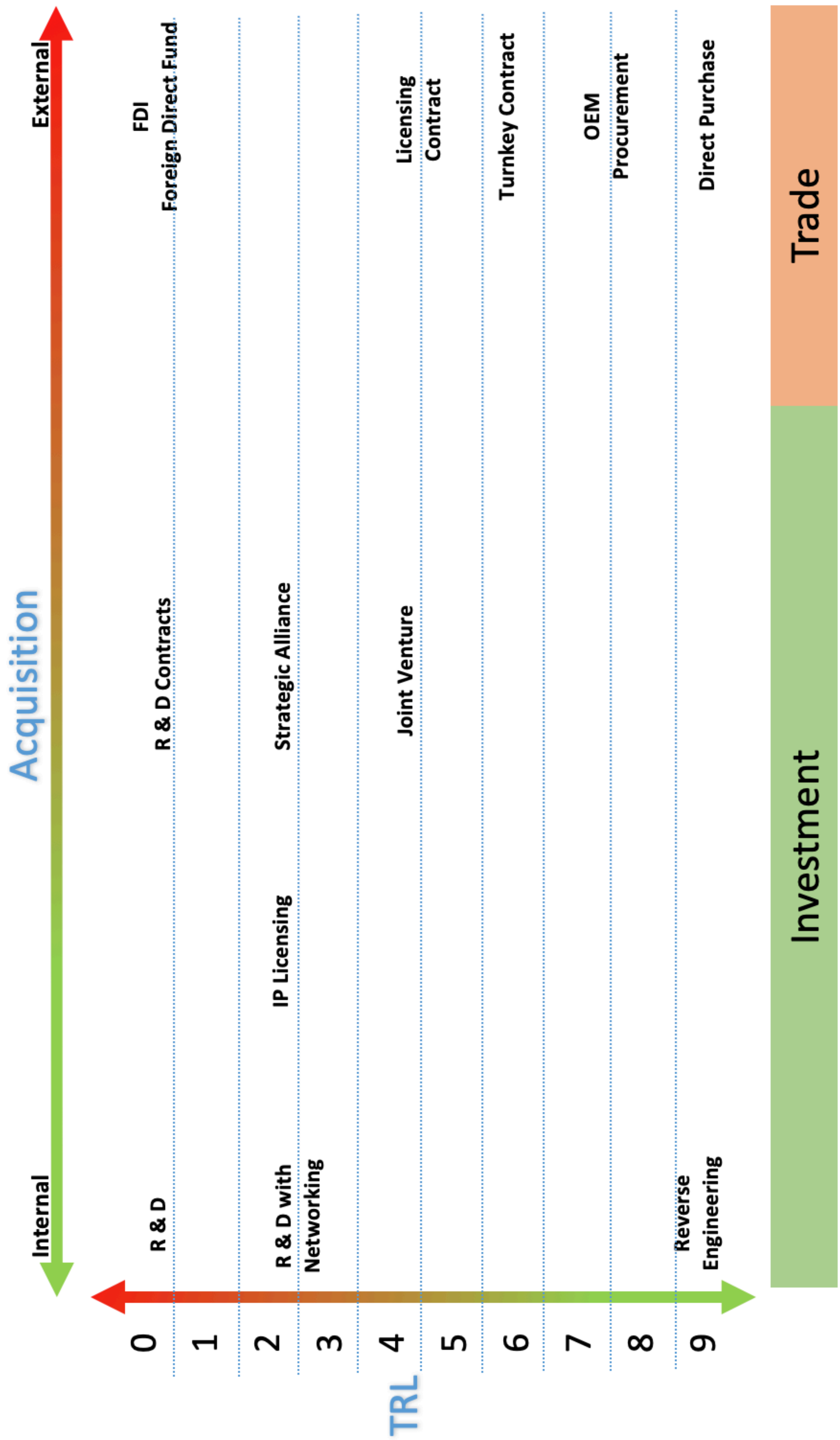
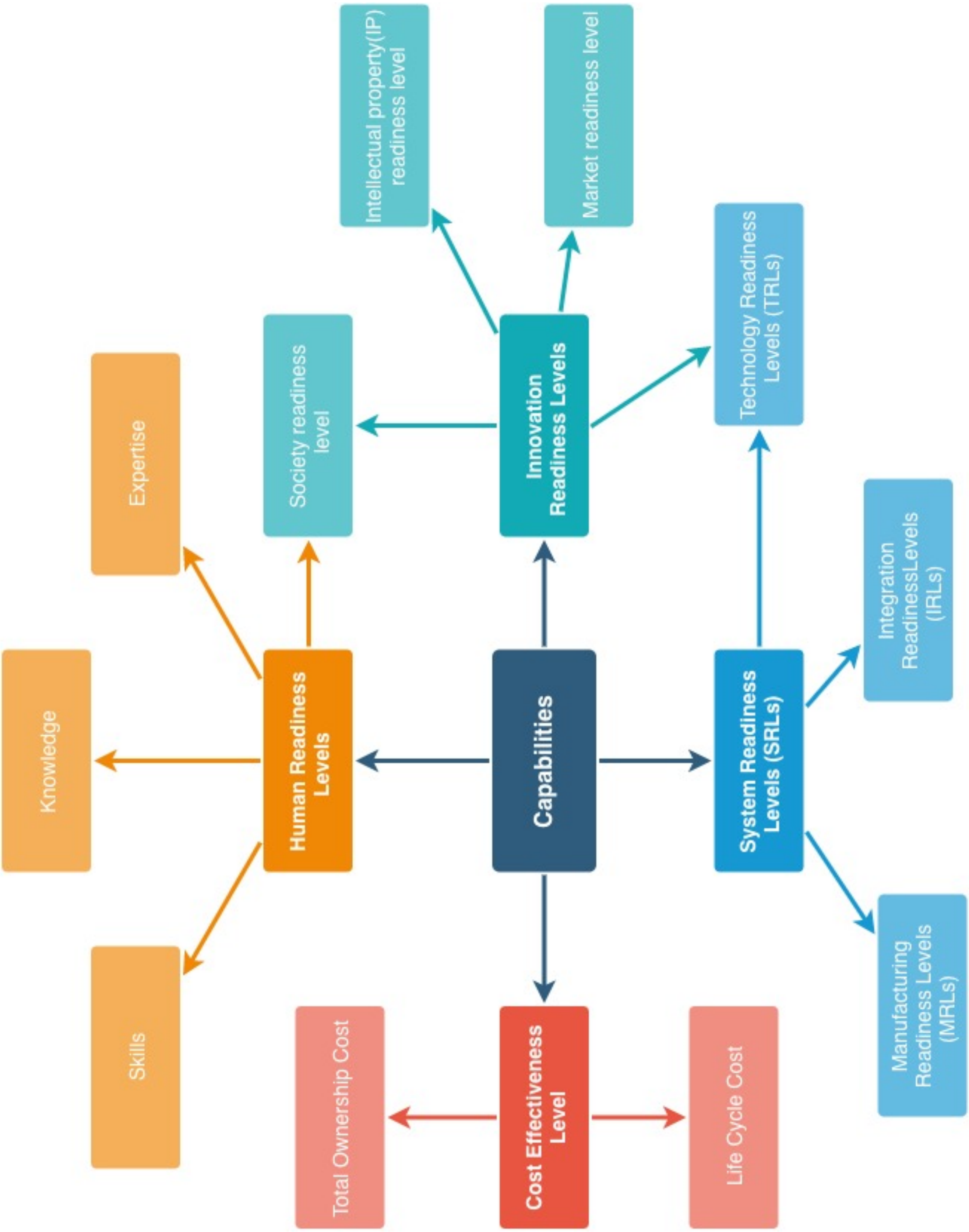
ANNEXURE A: INTERNATIONAL DEFENSE PARTNERSHIP MODEL



ANNEXURE B: TECHNOLOGY TRANSFER CHANNELS CHART



ANNEXURE C: MAJOR CAPABILITIES NEEDED



ANNEXURES D:

Interviews

Interview with Mr. Francois Marais

Part of the verification process for the thesis submitted for the degree in Master Of Engineering In Development And Management Engineering at the North-West University.

Thesis title: Development of a Defense Technology Acquisition Portfolio Management Framework.
Student (the interviewer): Raney Almehmadi
Student number: 27360253
Purpose: This interview's feedback will serve as a part of the verification process for the developed framework for decision-making purpose in selecting a proper projects to fill the technological gaps in the local defense industry in Saudi Arabia. The expected feedback are kind of giving Technology Critical Elements (TCE's) or stating successful factors for technology acquisition (TA). Thereafter, the researcher will evaluate TCE's and successful factors that gained from the interview and compare it if the DTAPM has covered those elements and factors or not. The researcher is trying to evaluate the developed framework by getting ingredients and identifying the critical elements and factors for successful Technology Acquisition Projects through Defense Acquisition System.

Questions

1. From your own personal perspective;
   a. What is the successful technology acquisition?
   b. What is the successful Defense Acquisition System (DAS)?
   c. Who is responsible for establishing DAS?
   d. What are the Critical elements/ factors of the DAS?

2. Maturity metrics has been used widely in technology management, such as TRL (Technology readiness levels), MRL (Manufacturing readiness level) and SRL (system readiness level). How are these metrics affect the DAS?

3. The key concept in the DAS is derived from systems theory, which defines a hierarchy of systems and subsystems as shown in the following table. Acquisition takes place at all the levels of the hierarchy and each level supplies to the next higher level. The Ministry of Defense is primarily responsible for system acquisition at levels 8, 7 and 6; Defense sector Manufacturers is responsible for acquisition of level 5 systems, while the suppliers in industry are the acquiring parties at the lower levels. How do you think we can establish effective channels between those official responsible parties through all levels of weapon system in DAS? (To find effective communications between the strategic officials and technical managers)

Answers:

1. Personal perspective:
    a. A successful technology acquisition is achieved when:
        i. When a proper assessment had been done on future technological requirements that will specifically support the countries' future defence readiness prior to acquiring the technology;
        ii. Creation of an in-country appreciation for the benefits that the specific technology holds for application in defence;
        iii. Successful application of the technology or the ability to apply this technology in support of defence acquisition or own product development has been achieved.

    b. A successful Defence Acquisition System is:
        i. A system that timely assist in identifying threats to a countries' sovereignty;
        ii. Timely acquire or establish the optimum capability (technology or armament or defence systems) to counter a future threat;
        iii. Maintain the technological or defensive/offensive capability.

    c. The establishment of the DAS is vested in the parliament as law giving body. The DAS is established by promulgating the legislation which gives the DAS its' legal authority;

    d. The DAS can be established as a separate organization that reports into the Ministry of Defence, or in certain fewer desirable instances, as part of the Defence force.

    e. It is established to translate the needs of the Defence Force into technical specifications that are used to either establish an in-country capability or will facilitate objective and fair acquisition from international suppliers. As such it requires:
        i. A competent technical workforce (engineers, scientists, QA practitioners, logistics experts) that are capable of researching international technological tendencies, new developments in weapons and ammunition;
        ii. Engineers and scientists that are well versed in defence systems, ammunition systems and operational doctrine;
        iii. Engineers and technicians that understand logistic support and will ensure that the defence force will receive a comprehensive

logistic support package as part of the weapon system procurement;

iv. Competent procurement and contracting organization with well-defined tender and procurement procedures and standards;
v. Experienced contract lawyers that know international law and are able to best protect the interest of the user;
vi. Competent auditors that are able to properly do a due diligence process on a prospective supplier to ensure that the supplier will be able to fulfil the conditions of the supply contract and not go into liquidation before complying with the conditions of contract.

2. Maturity metrics:

Irrespective of which maturity metrics (MOD, DOD, NASA, ESA and others) is used by the DAS, it is essential that the technical decision makers understand the application and the practical application of the maturity metrics in order not to allow contractors to supply products based on immature technology (TRL) or immature manufacturing processes (MRL) that have not been qualified to prove that these processes can consistently produce items that comply with their respective technical specifications. A system or system of systems is as mature as the least mature element. Maturity needs therefore to be proven tier by tier (level upon level). It is ultimately the responsibility of the technical project manager responsible for the acquisition to ensure that he gathers a project team of professionals that can assess all levels and all aspects of maturity.

3. Acquisition levels:
    a. I disagree with the statement that the MOD is responsibility for acquisition at levels 6, 7 and 8. These levels are created by the defence Force branch of service (Army, Navy, Air Force) based on lower level systems depending on what force structure is decided upon to counter a threat.
    b. The Defence Acquisition Organization, as procurement organization of the MOD, should do all acquisition (from System Level 2 or 3 to 5) on behalf of the Defence Force and in the process task international suppliers, local suppliers and Government companies such as SAMI. This is the only way that there can be consistency in standards and procedures in the best interest of the Defence Force.

Interview with Mr Louis Du Plessis

Part of the verification process for the thesis submitted for the degree in Master Of Engineering In Development And Management Engineering at the North-West University.

Thesis title: Development of a Defense Technology Acquisition Portfolio Management Framework.
Student (the interviewer): Raney Almehmadi
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Purpose: This interview's feedback will serve as a part of the verification process for the developed framework for decision-making purpose in selecting a proper projects to fill the technological gaps in the local defense industry in Saudi Arabia. The expected feedback are expected to give Technology Critical Elements (TCE's) or stating success factors for technology acquisition (TA). Thereafter, the researcher will evaluate TCE's and successful factors that gained from the interview and compare it if the DTAPM has covered those elements and factors or not. The researcher is trying to evaluate the developed framework by getting ingredients and identifying the critical elements and factors for successful Technology Acquisition Projects through Defense Acquisition System.

Questions

Mr Du Plessis, you have involved in technology transfer and gain knowledge about technology transfer programs to South Africa in the late seventies and eighties. That International Technology Transfer (ITT) project was an urgent need driven, while South Africa was in a war situation that necessitates them to have a defined capability to address the perceived threats. May I discuss with you the following points:

I. The national need is the main drive that formulate the operational needs. How do you think we can acquire the needed capabilities effectively?

II. Was SANDF at that stage having DIS (defense industrial strategy)? To what extent do you think it is important to have DIS?

III. Can you highlight (without exposing details) the main objectives of this ITT project?

IV. What were the main factors of that ITT failure?

V. Why it went to procurement process, instead it supposed to be ITT?

Answers:

I

The perceived national (military) needs are formulated within strategic groups between selected political and military leaders. This is usually based on real needs to address prevailing national threats, and the build-up of defence power acting as a deterrent. Nationalities are often also part of strategic alliances and the need might also be influenced by the required contribution towards such an alliance. In your proposed DTAPM, I see that happening on a strategic level in the top part of your diagram up to the point where the "material solution" is selected in your so-called MSA. This is the driving decision from which the Technology Transfer is driven.

So, to come back to your question: I think that there should be enough interaction with this strategic deciding process to ensure that:

e. The right decision is taken
f. The technology to be transferred address a real need and fill a real gap
g. The process of TT to embark on is sufficiently funded
h. The best strategic partner is selected for this TT process

II

I was never part of any strategic group neither did I have any direct insight to such a process, so my answer is solely based on observations and what I found in literature. My perception was that there was a strong alliance between the military leaders and a selected group of political leaders as well as academics and leaders from industry. The vision born in this group manifests itself even in legislation regarding the build-up of the military industry in South Africa to serve the national needs of the military. So, to answer your question: Yes, I think there was DIS with the will (political and military) to make it work and muster the resources to fund the process. The existence of such a DIS is necessary for implementation and execution on a tactical (day-to-day) basis without going back to a strategic level for every decision to be taken.

III

The couple of ITT projects for the transfer of technology to South Africa that I have knowledge of was linked to military systems and even lower down in the system hierarchy on the level of military products (ammunition for example). On the system level it was linked to design, manufacturing and integration of relatively complex systems involving hardware, electronics as well as software in both the functioning of the system, but also the operational procedures related to the integration of such a system with other systems. On the product level the focus was on identifying the materials and processes to manufacture and qualify the product with sufficient design to implement engineering changes where required.

IV

My perception of the main reasons why ITT projects failed are:

a. Political influences lead to a change in strategic needs and hence some ITT projects simply get cancelled
b. The ITT project is not sufficiently funded and hence the ITT project simply becomes a procurement of a system/product without establishing a national capability to design, manufacture and maintain it.
c. The people involved in the ITT project with the objective to acquire the necessary knowhow is not properly managed, get redistributed and assigned to positions where the knowhow is not assimilated in the national industry.

V

My perception on this is that:

a. Procurement is a fast way of acquiring a capability on a tactical level. It is a fast way to have something to show and even display on a parade.
b. Procurement might be considerably cheaper than establishment of a local manufacturing capability
c. On a strategic level procurement, however, does not lead to independence and is always linked to a nett outflow of capital.
d. Where ITT was done successfully (e.g. artillery in the case of South Africa), the country can become an exporter of both products and technology and hence turn the process around so that it become a means to obtain foreign revenue.

A few last ideas for successful ITT:

a. Identify the real gaps: “Know what you know and know what you don’t know” + “Know what your industry can and know what it can’t”
b. Select a real product for this ITT
c. Ensure there is a home base where the know-how associated with the ITT can be assimilated
d. Go through the process of design, manufacture, qualify and use of this product. Then embark on the home-grown new product.

Interview with Mr Willie Verster

Part of the verification process for the thesis submitted for the degree in Master Of Engineering In Development And Management Engineering at the North-West University.

Thesis title: Development of a Defense Technology Acquisition Portfolio Management Framework.
Student (the interviewer): Raney Almehmadi
Student number: 27360253
Purpose: This interview's feedback will serve as a part of the verification process for the developed framework for decision-making purpose in selecting a proper projects to fill the technological gaps in the local defense industry in Saudi Arabia. The expected feedback are kind of giving Technology Critical Elements (TCE's) or stating successful factors for technology acquisition (TA). Thereafter, the researcher will evaluate TCE's and successful factors that gained from the interview and compare it if the DTAPM has covered those elements and factors or not. The researcher is trying to evaluate the developed framework by getting ingredients and identifying the critical elements and factors for successful Technology Acquisition Projects through Defense Acquisition System.

Questions

- Mr Verster, you have involved in an excellent international technology transfer (ITT) experiences from South Africa to Saudi Arabia. May I discuss with you the ITT projects through the following points:

- Mortar and Artillery Projects were more like manufacturing matured technologies, How do you evaluate those experiences?

The technology transferred was matured technology, we also always use the latest technology. The idea was not to give something for the next level technology, but to transfer creditable manufacturing capability.

- Was it at which option of Technology Acquisition (TA)?
  (Development/ Demonstration/ Integration) (see Attached Figure 23)
  Integration.

- Do you consider this experience a technology transfer or machinery transfer?
  What was new, the introduction of these kind of manufacture to the Saudi labours. So we had to go to the change process in the people, to effectively train them to operate that machines to run the production.
  So, it was machinery transfer.

  No, it was not. The machines were the easy part, what is transferred, is the knowledge and capabilities to the people to build the ammunition with that machines. The documentations which describe how to do it was provided, the training of the people either it was a formal training or the on-site technical assistance. And that where the really values are.

- How the knowledge about the acquisition system of the receiver (KSA) contributes to the success of the TA?
  The Saudis have the vision of what they want to be, but they don't really understand how to express it, how to define it clearly, because it is a field that they don't have available knowledge about it. So, they don't know what really they don't know. There was always matters in negotiations, the Saudi client did not have the clear ability to specify what they exactly need in engineering terms. Actually, we found this with the majority of our clients. That area can be improved in the future, and I think your proposed framework will contribute towards this improvement.

- If you would have to do this experience again, will you change your strategy to improve the process?

Let me tell you something, the main difficult thing in these projects, is to manage the client expectations, which are changing with the development of the client's knowledge. However, I will ensure that military educated people has already defined the operational capabilities that they need. Also, as we have offered the latest matured technology, we did proven that it works, but at some stage we didn't test it in the full-scale operation, I think that possibly did not help us. And definitely deliver on time.

- It has been said that the development is always the best option, at which level do you think the procurement is better ?
  It is strategic decision and not a business decision. Because they will never cover the cost of that manufactured ammunitions. The concern is to be strategically independent to defend themselves depending on the strategic and political situations. And here we must mention that these strategic key aspects are not only in the military, it concludes civilians also in the national security strategy.

- "R&D program" was following those ITT projects, do you consider this program a "gap filling" project which urgently needed for the local Saudi capabilities?
  I think strategically , it was well timed brilliant program, because the MIC was at a certain time paralysed in term of doing something for the next level. This program reflect the good vision of the MIC managers and it was long time planned. The most important thing now is to have this team on the right track and have a clear objectives to work toward them. And give them challenges with all the tools to do it; budget, machines, facilities and computers with software. The group is too small, so they need more people like; draft men, analysts and test execution technicians more people to assist them to accomplish the targets. If they did not place in appropriate environment , they will disappear.

Sample of the interview request e-mails

From: **Raney Almehmadi** eng.raney@yahoo.com
Subject: Interview Participation Request
Date: 12 February 2019 at 13:21
To: Francois Marais francois.marais.home@gmail.com

Dear Sir,

Good day,

Hope this e-mail finds you very well.

I'm busy with a master studies. And I have developed a framework for decision-making purpose in selecting a proper projects to fill the technological gaps in the local defense industry in Saudi Arabia. I'm trying to evaluate my developed framework by getting ingredients and identifying the critical elements and factors for successful Technology Acquisition Projects though Defense Acquisition System. And I think you can contribute towards that.

If it is suitable for you to mention your name in my thesis, kindly, send me a brief of your experience that I may use it to introduce you in my paper.

The questions of the interview is attached (if you see there are more questions should be asked, please feel free to criticise and comment)

I honour your feedback whenever it's convenient according to your time frames.

Kind Regards,

Raney Almehmadi

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PDF

Interview with Mr. Marais.pdf