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Improving the Performance of On-engine Automation Hardware Development Projects in Wärtsilä:

WCD-20 Project as a Case Study.

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ABSTRACT

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The design and development of a new product is a focal point of competition and due to rapid technological development and strong global competition, companies are compelled to design better products efficiently and shorten the development lifecycle. These intense competitions are forcing organizations to improve and optimize their processes to meet the increasing demand of high-quality products at lower costs. The aim of this thesis was to investigate the factors that greatly influence the performance of hardware development projects and how the performance of these projects could be improved in the target organization.

Data was collected through literature study as well as by reviewing internal documentations and observation from the case study company. A case study research methodology was chosen to collect the data from the target organization. In all, seven persons with hardware expertise were interviewed.

The study found that supplier involvement, organization culture and the firm’s development processes were some of the vital factors that influence the performance of their projects. However, early involvement of suppliers in the project, open and effective communication between the buyer and the supplier, a clear definition of project scope, a clear definition of roles and responsibilities of project team were some of the vital factors in improving the performance of hardware development in the target organization. Finally, an Agile Stage-Gate model hybrid framework was deduced and proposed for the target department.

Hardware, Design, Product Development, Agile, SAFe, Project Performance

Keywords

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LIST OF ABBREVIATIONS

A&C	Automation and Controls
ALM	Application Lifecycle Management
AR	Action Research
ART	Agile Release Train
ATEX	ATmosphères EXplosives
CD	Customer Delivery
DEVOPS	Development and Operations
HALT	Highly Accelerated Life Test
HW	Hardware
ICT	Information, and Communication Technology
IPMA	International Project Management Association
JIT	Just In Time
LNG	Liquefied Natural Gas
MPS	Marine Power Solutions
NPD	New Product Development
OD	Operational Development
PM4DEV	Project Management for Development
PMBOK	Project Management Book of Knowledge
PMI	Project Management Institute
PQAP	Part Quality and Assurance Plan
PO	Product Owner

PSD	Product and Solution Development
R&D	Research and Development
RDE	Research, Development and Engineering
RoHS	Restriction of Hazardous Substance
SAFe	Scaled Agile Framework
SW	Software
SG	Spark Gas
TRS	Technical Requirement Specification
TQC	Total Quality Control
WBS	Work Breakdown Structure
WCD	Wärtsilä Coil Driver
WIP	Work In Progress
WPAP	Wärtsilä Part Assurance Process

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1 INTRODUCTION

Project management maturity level appears to be strong in Wärtsilä. Interestingly, about 50 percent of businesses in the company is conducted through projects. This means project management is recognized as an essential element of the company and it drives the strategy and vision of the company to fulfil the customer needs more effectively and efficiently.

The design and development of a new product is a focal point of competition and due to rapid technological development and strong global competition, companies are compelled to design better products efficiently and shorten the development lifecycle (Clarkson & Eckert, 2005). These intense competitions are compelling organizations to improve and optimize their processes to meet the increasing demand of high-quality products at lower costs (Clarkson & Eckert, 2005). According to Bojesson (2015), highly technological companies in the past two decades, have particularly developed sophisticated models, process descriptions, structures and routines for how to steer and manage their often large and complex projects. New product development (NPD) processes are, however, not deterministic (Clarkson & Eckert, 2005) and therefore no single optimal process design is possible to find. In addition, NPD processes contains several interdependences among both task and people which requires effective coordination of activities and the opportunity to capture an incomplete information that evolves over time (Park & Cutkorsky, 1999).

In NPD environment, reduction of project lead times from conception to the final release of the product is seen in many industries as a way of increasing the competitive challenge and hence been a prioritized challenge for many industries (Griffin, 2002, Valle & Vàzquez-Bustelo, 2009, Minderhoud & Fraser, 2005). Minguela-Rata (2011) emphasized that innovation alone is not enough for a company to stay competitive and survive in a global business environment. However, the key driver for staying competitive and surviving in a business is the speed for which a company releases their products to the market, how efficient the development and production process are and how well the product meets the customer’s expectations. Due to this, technology managements are reconsidering their traditional way of designing new products and are continuously looking for new ways of working and practices of improving the organization and execution of such development processes to create outstanding products (Minguela-Rata, 2011). NPD efficiency has gain recognition in trying to achieve increased performance and in turn lead to competitive advantage (Bojesson, 2015).

The usual framework of a product development process is a multi-functional stage gate model approach. When more companies are increasingly implementing this process, organizations need to find ways to stay ahead of their competitors. They need to strategize and develop new methods and standards to work with product development and find means to continuously improve these standards. Project performance create business value to the company whiles meeting customer demands and expectations. It is a major decision to choose which quality principles and practices are to be considered and included when initiating a continuous program in product development environment.

Platform hardware team in Automation and Control department in Marine Solutions business unit, develop and maintain all the automation hardware components on Wärtsilä 4- stroke engines. Development of hardware components are usually done by project management process to secure good control, quality and effectiveness of the overall process. Development of a new automation hardware components (sensors, actuators, electronic modules and so forth) for use in a harsh environment is typically complex and a lot of collaboration and coordination between the supplier and Wärtsilä is required to ensure a smooth development process.

The overall purpose of this study is to analyze the case study project, Wärtsilä coil driver (WCD-20) ignition system development processes and contribute to better understanding of developing continuous improvement in the context of hardware development projects to ensure high value for the end user of the products.

1.1 Wärtsilä as an organization

Wärtsilä is a global leader in smart technologies and complete lifecycle solutions for the marine and energy market. The company has operations in over 200 locations in more than 70 countries around the globe with total employees approximately 18900 and an installed base of about 180000 MW. The core vision of the company is to create enabling sustainable societies with smart technology. The company has the marine solutions and energy solutions as the two main core business lines.

The marine solutions improve the businesses of its marine and oil & gas industry customers by providing innovative products and integrated solutions that are safe, environmentally sustainable, efficient, flexible, and economically sound. Being a technology leader, and through the experience, know-how and dedication of its personnel, it has the capacity to customise solutions that provide optimal benefits to its customers around the world. The marine solution is responsible for developing different 4-stroke engine portfolios for both shipping and power generation applications.

In addition, the energy solution sector provides a broad range of environmentally friendly solutions such as flexible internal combustion engine-based power plants, utility-scale solar PV power plants, energy storage and integration solutions as well as a liquefied natural gas (LNG) terminals and distribution systems.

Also, the services sector, which is an integral part of marine and energy solutions business lines supports its customers throughout the lifecycle of their installations by optimising efficiency and performance. The company's strategy is to increase its growth and profitability by providing advanced technologies and lifecycle solutions to its marine and energy markets customers (Wärtsilä annual report, 2017).

1.2 Research problems

The Marine Power Solution (MPS) section in Marine Solution Business line is responsible for a continuous development of products to enhance the functionality of the 4-stroke engine portfolios. MPS has a well-developed project management process that serves as a guideline and a requirement for product and solution development projects. Every project delivered in the organization is mandated to adhere to the process to achieve the project objectives.

Platform hardware team have the core competence to develop and maintain automation hardware components for the 4-stroke engines. This means continuous hardware development products are inevitable. The component is developed in close collaboration with suppliers and other internal stakeholders. The final product must meet Wärtsilä's technical requirement specification before the component is fully released for use on production engines. In most situations, the automation hardware components on the engines are designed through projects. The projects are managed by project managers and have team members from different functional organizations with diverse responsibilities thus careful coordination and collaboration is needed to have an effective cross-functional team.

However, in most cases hardware development projects starts without the full kitting in place. The functionality of the new component on the engine is often considered lightly prior to the project. The integration of the new component into Wärtsilä automation system must be clearly defined in the ideation of the project. Also, Wärtsilä has well experienced experts in research, development and engineering department, however, getting the right pool of human resources from different functional organizations for hardware development projects in some cases is a challenge. These are some of the challenges that is presumed to be consistently affecting the performance of hardware development projects.

1.3 Research objectives and questions

The scope for this study is to analyze the current situation at how the current hardware developmental projects are conducted and whether the project management process for products and solution development projects are working. Also, this research will examine the strength and weakness of the existing project management processes for smaller projects.

Clearly this thesis aims to

- Access automation hardware development projects and identify specific areas where advances could be made to improve the process.

- Increase the knowledge of how the project performance in hardware development context can be improved.
    - Investigate factors which affect performance on various levels of the projects.
- Verify if the SAFe agile method is suitable for hardware development.
- Develop a framework that could support and increase the effectiveness in HW product development

To address the aim and objective of this research, the study answers the following questions:

RQ1: What factors influence hardware development project performance?

RQ2: How can hardware development project performance be improved?

1.4 Research structure

The thesis is structured and organized into seven chapters. The first chapter introduces the topic and background information on how the study is conducted. The research objectives and questions are clearly defined in this chapter.

The second chapter explains the theoretical framework for the study. Projects and project management principles are introduced in general. Also, project performance improvement practices, project success criteria and resource planning are covered in this section.

Furthermore, chapter three summarizes the findings from the literature review. Chapter four introduces the research methodology used in conducting this study. It gives details about how the project problem is approached, how data and information is collected and how the data is processed in the end.

The fifth chapter examines the case study project thoroughly. Also, this chapter gives more thorough of the project management processes currently used for hardware development projects in the target organization.

Moreover, a conceptual framework will be deduced based on the analysis of the findings from both the theoretical framework and the empirical results. The findings obtained from the interviews conducted are presented in chapter six.

Finally, chapter seven will discuss in detail the results of the empirical data from the study. Also, the findings from the empirical study will be compared to the observations made in the synthesis of the theoretical framework. This chapter will summarize the findings from this research. Also, the contribution of this thesis work to academia will be highlighted. Finally, conclusion on how the study could contribute practically to the target organization is also emphasized.

2 LITERATURE REVIEW

The purpose of this chapter is to describe the theoretical framework which is relevant for this study by presenting an overview of previous research. The starting point of this study is to analyze how NPD projects performance in research and development (R&D) environment can be improved to ensure that business organization stays competitive whiles end users get value for their investment. The chapter is divided into four parts as presented in Figure 1: project organization, project team resourcing, project performance and improving performance.

The first part, project organization gives overview of different organizational processes and features of NPD projects. Project team resourcing allocation analyzes how to develop a human resource plan, acquire project team, develop project team and manage project team. In addition, the impact of human resource allocation to a project is deduced. Project performance and improving project performance are related to the research questions. In the project performance part, relevant concepts are outlined to comprehend what is included in the performance of NPD projects. The last section, improving performance, covers areas that increase the understanding of factors critical to improving project efficiency.

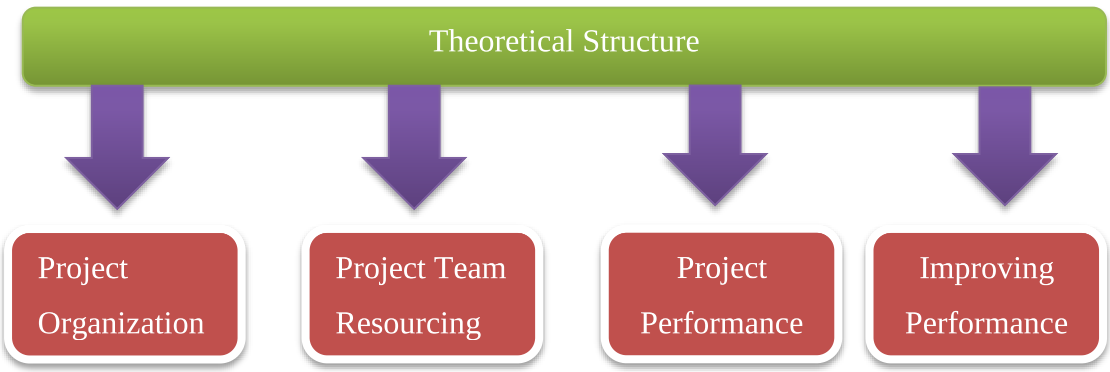

Figure 1. An Overview of the theoretical framework.

2.1 Project organization

The development of a new product is a complex process and usually involves the contribution of many disciplines (Sosa & Mihm, 2007). The more complex the product, the larger the number and arguably the heterogeneity of the people in the development effort (Sosa & Mihm, 2007). For example, Airbus involved several thousand individual contributors into the development of its fleet airline A380 (Sosa & Mihm, 2007) and Automobile manufacturing firms also involve several hundreds of people in the core development plus additional hundreds that indirectly contribute through their network of suppliers (Sosa & Mihm, 2007). These example shows that no single person carries a new product development on his or her own. Considering how many people from different disciplines are involved in NPD projects, the fundamental question is how can these people be organized to maximize a successful product development?

The project management for development (PM4DEV), defines project organization as a structure that facilitates the coordination and implementation of project activities. The project organization defines the human infrastructure and identify roles and responsibilities for each position to effectively manage the project activities. In addition, it creates an environment that foster the interactions within project team members with a minimum amount of disruptions, overlaps and conflicts (PM4DEV, 2016). The project organization and resources requested for the project delivery needs to reflect the project objectives (IPMA, 2006). This means if the project objective requires a project delivery within a brief period, then more resources and large organization may be needed. In a situation where a project is carried out over an extended time-frame with a constraint budget, the resource provided may be limited with a small organization (IPMA, 2006).

According to IPMA (2006), the processes and decision models that are managed and applied in an organization must be properly designed, well implemented, continuously improved and based on experience. The project organization has a shorter life and changes quite rapidly as the project evolves through its life-cycle. In some situations, it is possible and preferable to relocate the project organization to ensure all the people involve are near.

A properly designed project organization chart is key to project success. The organization chat shows where each person is placed in the organization structure and it creates a strong relationship among the project manager, the project team members, the development organization, the project, the beneficiaries and other stakeholders PM4DEV, 2016).

According to Bojesson (2015), a project represents unique, complex and time-limited processes of interaction, organization and management and the term project has come to describe temporary organizations. Organization developing new products faces two fundamental challenges: decomposition and integration. The overall design efforts need to be broken into individual task and most importantly work on these tasks needs to be integrated into overall design (Sosa & Mihm, 2007).

Project organization can be classified into three groups; functional organization, projectized organization and a matrix organization. The advantages and disadvantages of each type of organization is clearly outlined in the next sub-chapters.

2.1.1 **Functional organization**

A functional organization as shown in Figure 2 is a traditional structure where the organization is divided based on the functions performed by that group of people or team such as Human Resources, Marketing, Information Technology, Product Management, Finance and so forth. Usually, in a functional organization a project manager is a team member among the functional area, and he does not have the title of a project manager. The functional manager will control the budget and the team member acting as the "project manager" will be coordinating and expediting project activities rather than having project management responsibilities. In addition, the resources for the project must be negotiated for with the line manager and the accessibility of those resources will be based on business conditions. The project manager has almost no powers and any escalation needed must be reported to the functional manager. Projects conducted in functional organization usually takes long.

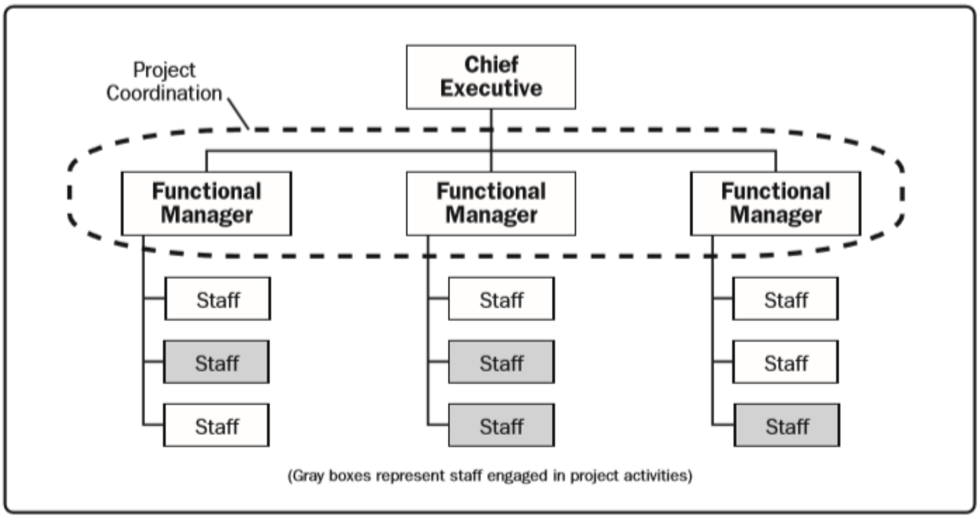

Figure 2. The Structure of a Functional Organization (PMI, 2013).

2.1.2 **Projectized organization**

In a projectized organization as depicted in Figure 3, majority of the organization's resources are involved in project work and the project work is usually conducted for an external customer. Individuals of different technical or functional expertise are grouped into organizational sub-unit responsible for one platform to develop one product or service (Sosa & Mihm, 2007). Moreover, the project manager has greater independence and authority and usually a full-time member of the organization. The project manager has a pool of project resources available to them such as project coordinators, project schedulers, business analysts and plan administrators.

In addition, the project manager has the authority and control over the budget and any escalation issues will be reported to the sponsor and potentially to the project management organization leadership. Sosa & Mihm, (2007), explained the three key drawbacks that threating the effectiveness of this organizational set up. Firstly, they believed it is difficult for the overall organization to build technical excellence as a result of sparse communication flow outside the organizational zone with individuals with similar technical background. Also, they argued that the lack of communication could cause difficulties in project coordination. The final drawback they highlighted was the constant working with same people all the time, which can lead to mental stress causing team ineffectiveness in the long term.

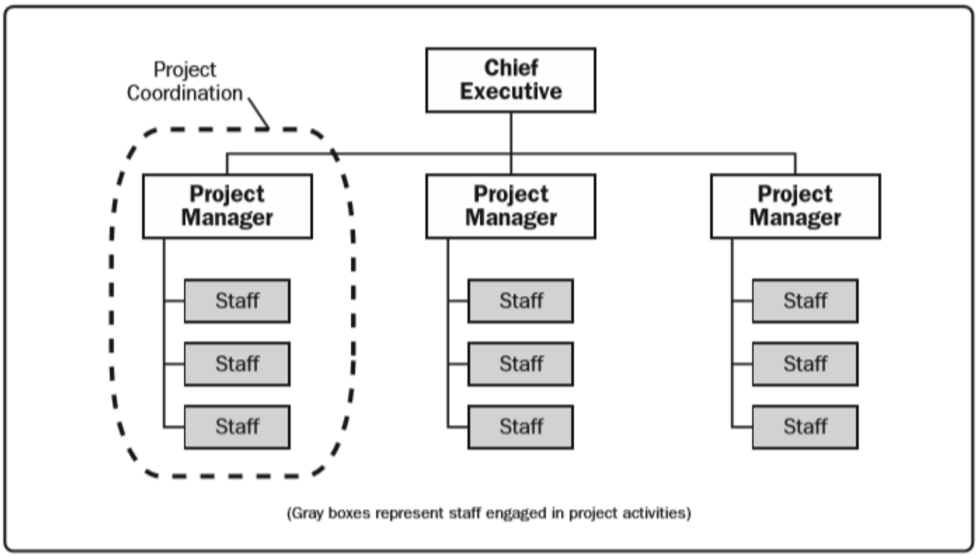

Figure 3. The Structure of a Projectized Organization (PMI, 2013).

2.1.3 **Project matrix organization**

The matrix organization as shown in Figure 4, through to Figure 6 reflect a combination of functional and projectized characteristics (PMI, 2013). The primary objective of the project matrix organization is to overcome the challenges in the projectized organization. Matrix organization can be classified as weak, balanced or strong depending on the relative level of power and influence between a functional manager and a project manager (PMI, 2013).

Weak matrix organization maintain many of the features of a functional organization. The role of the project manager is typically like a coordinator as indicated in Figure 4. Project coordinators have some power and authority to make some decisions but reports to a higher-level manager (PMI, 2013).

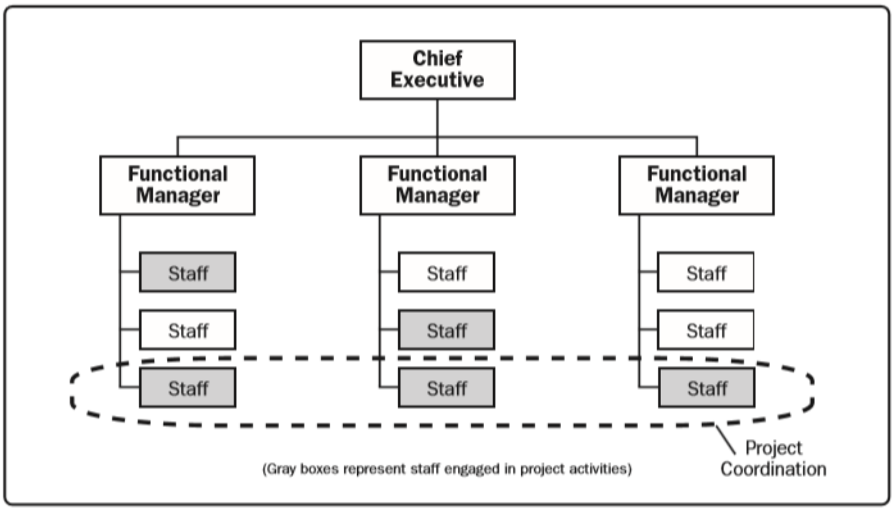

Figure 4. The Structure of a Weak Matrix organization (PMI, 2013).

However, strong matrix organization have many of the characteristics of a projectized organization. They have full-time project managers with significant authority and a full-time administrative support staff (PMI, 2013) as shown in Figure 5.

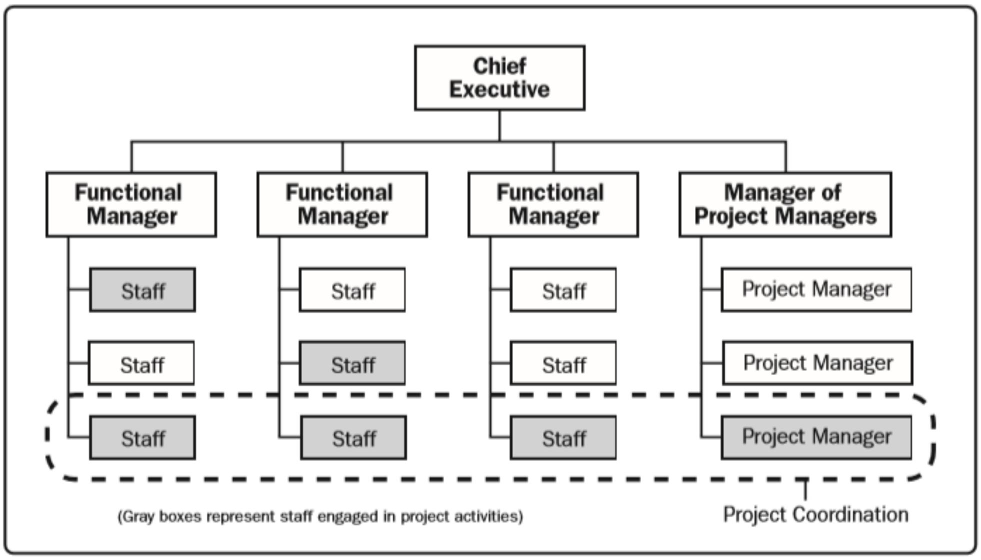

Figure 5. The Structure of a Strong Matrix Organization (PMI, 2013).

Finally, the balanced matrix organization recognized the need of a project manager. However, it does not grant the project manager the full authority of the project and project funding (PMI, 2013). The structure of this organization is shown in Figure 6.

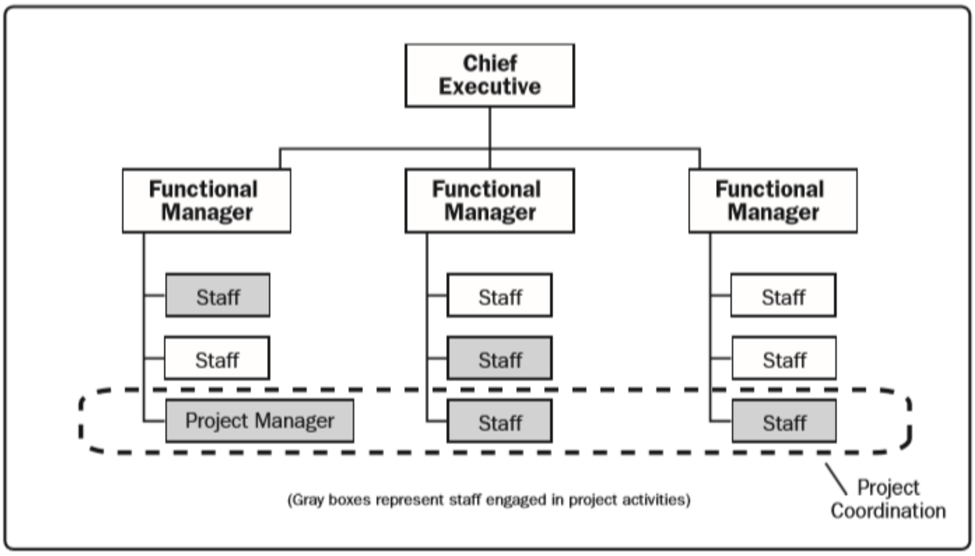

Figure 6. Structure of a Balanced Matrix Organization (PMI, 2013).

Organizational structure is a business environmental factor which can affect the availability of resources and influenced how projects are conducted. Table 1 depicts key project-related characteristics of the major types of the organizational structures.

Table 1. Influence on Organizational Structures on Projects (PMI, 2013).

Organization Structure / Project Characteristics	Functional	Matrix			Projectized
		Weak Matrix	Balanced Matrix	Strong Matrix	
Project Manager's Authority	Little or None	Low	Low to Moderate	Moderate to High	High to Almost Total
Resource Availability	Little or None	Low	Low to Moderate	Moderate to High	High to Almost Total
Who manages the project budget	Functional Manager	Functional Manager	Mixed	Project Manager	Project Manager
Project Manager's Role	Part-time	Part-time	Full-time	Full-time	Full-time
Project Management Administrative Staff	Part-time	Part-time	Part-time	Full-time	Full-time

2.2 Research and development management

According to Frascati manual (2002), research and development is the capability to conduct different type of research and use innovative ideas for product and technology development. The traditional distinction between research and development has gradually vanished and has been integrated in the entire system as a management volume

(Mikulskiene, 2014). Research and technology has been used extensively by both public and private organizations to generate innovative ideas and improve technological innovation in several aspects of our society.

In the past century, R&D management as an innovation stimulator has witnessed the evolution of five generations, characterized by simultaneous progress of handling R&D activities. The complex attitude to the effective management of R&D according to a wide variety of management targets turns the R&D management process into multidimensional tasks (Mikulskiene, 2014). Every new generation add extra managerial obligations to the manager's duties (Mikulskiene, 2014).

Scientific research has shown that two main models exist for the evolution of R&D management. Roussel et al., 1991 classified R&D management into three generations based on the recognition of R&D strategies, organizational forms, financial criteria and mechanism of accountability. Table 2 shows the R&D management generation model proposed by Roussel.

Table 2. R&D management classification according to Roussel (1991).

Generation	Period	Characteristics
The first generation	1950-1960	Independent strategy of R&D Independent scientific laboratories R&D activities Real organisations
The second generation	1970-1980	Partly strategic competitive environment Needs-oriented R&D and risk-sharing R&D budgeting Differentiation of R&D activities Binary system of R&D management while centralisation and decentralisation is aligned. Matrix organisation Peer review evaluation process
The third generation	1990-	Holistic approach Partnership Market oriented Project management to R&D Target oriented evaluation and assessment

Subsequently, Rothwell, 1994 proposed classification of five generations of R&D management. His model focused on technological innovation in start-up companies and proposed five generations of innovation and provided R&D management generational classification from the 1950s onwards. He realized that each new generation was a response to a notable change in the market. He went ahead to explain the connections between economic growth, industrial expansion, more intense competition, inflation, stagflation, economic recovery, unemployment and resource constraints.

Table 3. R&D management classification according to Rothwell (1994).

Generation	Period	Characteristics
The first generation	1950-1960	Technology development Linear model of innovation
The second generation	The end of sixties	Primacy of needs Market-oriented innovations
The third generation	1970-1980	Synergetic model Chain Linked Model
The fourth generation	1980-1990	Integrated model Horizontal and competed innovation
The fifth generation	1990	System and networking models Flexible innovation process

The first-generation R&D management evolved after the Second World War. The importance of R&D was conceptualized, and new industrial development was based on R&D knowledge. That period is well known for the creation of new industrial sectors such as semiconductors, pharmacy, computer industry, electronics and other new materials. Traditional industrial sectors such as steel and textiles heavily relied on new technology. That was a period when well-being was accepted as a productive use of R&D outputs, thinking that social problem will be solved simultaneously together with R&D. That determined understanding about linear development of R&D, when R&D was at the first stage, led by new technologies and finished by new products (Mikulskiene, 2014). That period is characterized by corporate R&D laboratory creation and it was the time when new technologies were created. The main task of R&D management is to increase productivity and quality of R&D outputs

The second generation started in the sixties and ended in the seventies. The demand and supply balance became stable in the market, the competition increased and became the main driver for R&D orientation to the market. Short-term goals became dominant in the face of long-term objectives of fundamental R&D. The linear R&D management model was still active but complemented by the element of marketing for the starting and closing phases. R&D labs were integrated into the whole organizational system and became equally important structural division as any corporate division (Mikulskiene, 2014).

The third generation R&D management model started in the seventies and lasted up to the eighties. The two-oil crisis that bedeviled the global market in the seventies were the reason for high inflation and increased unemployment. That situation pushed to reorient R&D management. Companies were compelled to integrate project management into R&D management. Portfolio management and project development became the main challenges for R&D.

The fourth generation relates to the eighties and the nineties when strong corporations were gaining power. The economy was in a permanent positive development. Strong industrial giants such as Honda, Toyota and Sony made progress with R&D during this period. Stakeholder role was recognized as important while's end users or customers were not the dictators in R&D targets. Suppliers and other stakeholders were seeking to be invited to the R&D management pool. The multifunctional and multidimensional content was integrated into R&D management.

Finally, the fifth R&D management generation is well-known for the broader understanding of R&D management activities. Globalization and rapid creation of new technologies is responsible for the fact that companies which were competitors in the past started to share investment into R&D in the future and build partnership clusters. The list of R&D stakeholders was expanded again. New players were recognized as valuable contributors to R&D. A researcher is not a single stakeholder in front of producers, dealers, users and suppliers. Global companies, such as Microsoft, Netscape and Dell became prominent players in the R&D market. The cluster and corporation among companies assisted optimizing investments into R&D.

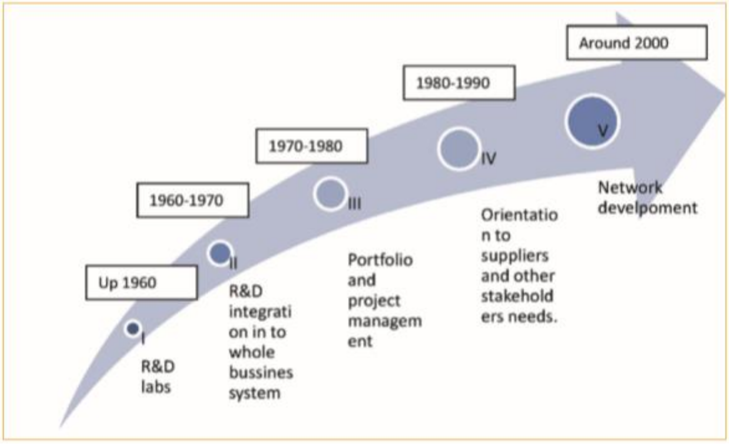

Figure 7. The Evolution of R&D management generation.

2.3 Project and project management processes

The number of projects, programs and portfolios are increasing throughout the world (IPMA, 2006). In the past three decades project management has developed tremendously and increased in visibility (IPMA, 2006). More and various kinds of projects are now managed professionally. Construction and defense projects used to dominate the scene in the past. However, it is now common to find projects in information and communication technology (ICT), organizational development, product and solution development, production development, research, market changes, educational projects, legislation projects and many other projects from different sector of the economy (IPMA, 2006). This section highlights key differences between a project and a project management.

2.3.1 Projects

First, it is important to differentiate between the notion of a process model, a process and a project. Sommer et al., (2015), clearly defined a process model as a general view of the main activities of a project divided into phases. Also, they argue that the process itself is the unique series of interconnected activities involving several stakeholders across functions and organizations. However, the Project Management Institute (PMI) PMBOK Guide, (2013), describe a project as a temporary endeavor undertaken to create a unique product, service or result. It further pointed out that the temporal nature of a project does not necessarily mean short duration and does not apply to the product, service or result created from the project. Every project creates a unique product, services or result and though repetitive elements maybe present in some project deliverables, the repetition does not alter the fundamental uniqueness of the project work (PMI, 2013). A project is complex because its activities are typically not predictable (Artto et al, 2011). However, due to the uniqueness of a project, there may be challenges about the products, services and results that the project delivers and this cause problems to project teams hence it is necessary to have a dedicated planning towards a project compared to normal routine work. Projects are used today as a business in various industries, however, their significance, use and position can vary among different companies and industries (Artto et al, 2011).

A project can create

- "A product that can be either a component of another item, an enhancement of another item or an end item of itself.
- A service or a capability to perform a service. For example, a business function that support production or distribution
- An improvement in an existing product or service lines. For instance, a six Sigma project undertaken to reduce defects.
- A result, such as an outcome or document. For instance, a research project that develops knowledge that can be used to determine whether a trend exists, or a new process will benefit society" (PMI, 2013).

2.3.2 Project management in product development environment

The PMI PMBOK Guide, 2013 defines project management as the application of knowledge, skills, tools and techniques to project activities to meet the project requirements. PRINCE 2 also defines project management as the planning, delegating, monitoring and control of all aspects of the project and the motivation of those involved to achieve the project within the expected performance targets for time, cost, quality, scope benefits and risks.

Project management is accomplished through the following processes;

- Initiating
- Planning
- Executing
- Monitoring and controlling
- Closing

The project phases are segments within a project where extra control is required to effectively manage the completion of a major deliverables (PMI, 2013). The phase structure allows the project to be divided into coherent subgroups for ease of managing, planning and control. The number of phases, the need for phases and the degree of control applied depend on the size, complexity and potential impact of the project.

2.4 Traditional project model

The product development process in many development organizations follow a systematic process which is the traditional or waterfall model where product development progress cascades or flows over time as highlighted in Figure 8.

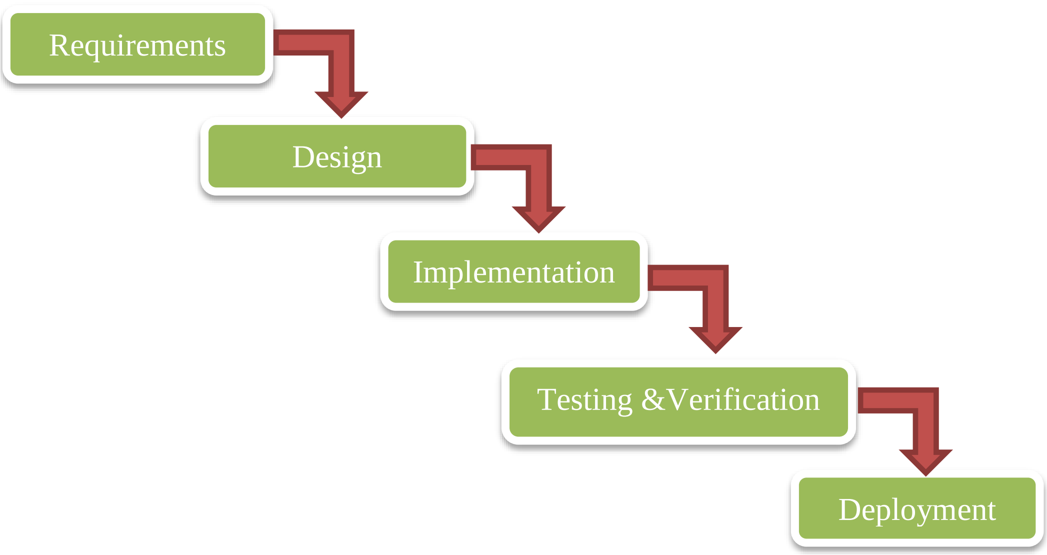

Figure 8. Traditional or waterfall project model.

Requirements are collected during the project planning phase before the actual development begins. The testing is conducted after the development phase is completed. The waterfall projects typically have three main setbacks, typically known as the triple constraints; which are time, cost and schedule. Typically, the traditional projects method used for new hardware development products have at least two of these setbacks causing delays in project deliverables. One of the drawbacks of this traditional method is the prolong time consumed during the planning phase of the project. A lot of efforts are consumed to gather all the needed requirements before moving to the design stage of the component. However, these requirements are changed or modified during the project life-cycle before the product is ready. Also, testing and validation of the product starts very late and since the product must be ready before testing is started any deviation found after the testing could cause a redesign of the component which can create scope creepage or impact the schedule of the project.

Figure 9 depicts the triple constraints in traditional projects.

Figure 9. The triple constraint in plan driven project.

The waterfall model or the traditional project management process usually uses the stage gate model to make the status of the project in the organization visible. The gate model process is used to enhance project control, decision making and communication between projects and also to synchronize between different tasks in product development.

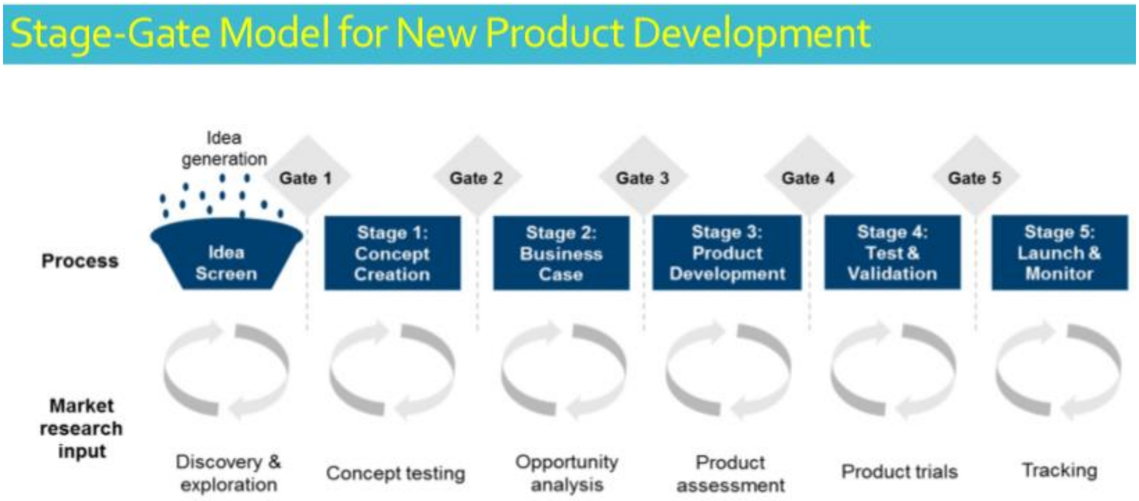

Figure 10. An example of a stage-gate model for new product development environment.

2.5 Agile project model

According to Agile alliance organization, Agile is the ability to create and respond to change. It is a way of dealing with uncertainties in a turbulent environment. The agile framework came into existence after a group of seventeen software consultants and practitioners gathered in 2001 to share and address issues that software developers faced. The outcome of this meeting was "Manifesto for Agile Software Development" (Beck et al. 2001). The agile framework has four core values and these values are clearly written at the back cover of the agile manifesto.

"We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

- **Individuals and interactions** over processes and tools
- **Working software** over comprehensive documentation
- **Customer collaboration** over contract negotiation
- **Responding to change** over following a plan

While there is value in the items on the right, we value the items on the left more."

In addition, the participants outlined the following twelve (12) principles to guide and support teams implementing and executing agility.

1. “Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
2. Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
3. Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
4. Business people and developers must work together daily throughout the project.
5. Build projects around motivated individuals. Give them the environment and support they need and trust them to get the job done.
6. The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
7. Working software is the primary measure of progress.
8. Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
9. Continuous attention to technical excellence and good design enhances agility.
10. Simplicity--the art of maximizing the amount of work not done--is essential.
11. The best architectures, requirements, and designs emerge from self-organizing teams.
12. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly”.

The agile framework was developed to address the shortfalls of the traditional project methodology approach used in developing products.

2.5.1 Agile methods in hardware products development

Agile learnings were developed to assist software development projects. They are fast-paced, iterative, people-centric, business value focused, adaptive to change, reflective and learning driven (Punkka, 2012). The agile framework acknowledges and emphasize the potential in supporting teams (Punkka, 2012). Today, the agile model is making ways into the hardware development projects. Many companies are looking into ways to apply agile model in hardware development projects (Laanti, 2016). However, not many studies have been conducted about agile model application for physical or hardware development projects. The few studies conducted on agile for hardware development, proves that agile principles can also be implemented for hardware development projects to some extent. For example, Punkka (2012) strongly believed that agile methodology can suit in developing embedded systems quite well. He believed embedded development requires combining views from different perspectives such as embedded software, electronics and mechanical design. According to him multiple views means strong dependencies.

The traditional development process recommends system requirement to be fully ready at the start of the project before a detailed plan is created. However, it is ridiculous to comprehend how many design and requirement changes that are implemented during hardware development projects using this traditional project management approach. The need for change in the traditional project is inevitable and hence the need for an empirical process designed for continuous collaboration and refinement of design and plans with different stakeholders (Punkka, 2012). Agile methodology is built with this mindset.

Agile model has high potential when co-designing hardware and software development projects. Both hardware team and software teams work together to make the product vision statement visible. The team further discuss the potentials and constraints of the project based on the integration requirements of the embedded system (Lima & Saotome, 2015).

2.5.2 **Scaled Agile Framework model**

The scaled agile framework (SAFe) is the world leading framework that empowers large and complex organizations to achieve the benefits of lean-agile software and systems development at scale. SAFe sustains and drive faster time to market, dramatic increases in productivity and quality, and improvement employee engagements (Scaled Agile Inc, 2018). The SAFe framework combines agile, lean product development, DevOps and system thinking. These combinations promote alignment and collaboration for multiple teams in organization to deliver. SAFe significantly improves business agility by increasing productivity, time to market, quality and employee engagement. The benefits of utilizing SAFe framework is enormous and based on the empirical study conducted by Scaled Agile Incorporation, the result can be summarized in the figure below.

Figure 11. The benefit of SAFe Agile Framework.

SAFe framework introduces five core competences of the Lean enterprise. These are Lean-Agile Leadership, Team and Technical Agility, DevOps and Release on Demand, Business Solutions and Lean System Engineering. Each of these competences is made up of a set of related knowledge, skills and behaviour that enables organizations to achieve their set objectives in a sustainably short term. Two of the most significant core competences are highlighted in the next paragraphs.

Lean-Agile Leadership – this describes how Lean agile leaders drive and sustain their organizational changes and operational excellence by empowering individuals and team to achieve the optimum potential. Lean-Agile Leadership is the foundation for SAFe because only the Managers, and leaders of an organization can set the correct enabling environment that can encourage high performing teams to continuously thrive to produce value. To champion the transformation agenda, the leadership in an organization needs to communicate effectively the strategy and vision to their teams. This means, providing relevant briefings and participating in programme increment planning. Also, they should demonstrate commitment to quality by ensuring that products are released without any defects. In addition, all work in the organization should be visualized and the leaders must take responsibilities for both success, mistakes and errors and always embrace for continuous learning. As leaders are the business owners in the organization, they should assist product owners and scrum masters to adjust scope by prioritization to ensure demand matches with capacity.

Team and Technical Agility – According to the Agile manifesto, continuous attention to technical excellence and good design enhances agility. Agile team should have critical skills and Lean-agile principles to be high performing, build high quality and well-designed technical solutions that support now and future needs. Agile teams should be cross functional and should possess all the skills required to build, test and deploy values in short iterations. SAFe agile team usually have the following characteristics;

- Use a blend of agile method, Scrum and Kanban
- Based their work on shorter iterations, apply user stories, plan for the upcoming iterations and organize daily stand up meetings to coordinate their work towards common goals
- Demo the working system at the end of the iteration and have retrospective on how to improve the process in the next iteration.
- Visualize and manage their flow of work in the Kanban system and assist in the bottlenecks and controls work-in-progress (WIP).

The agile teams work together in an organizational set-up known as Agile Release Train (ART). The release train bring all teams together to achieve the common goal of the organization. All teams in ART build, test, demo, deploy, release and learn together.

2.6 Resource allocation in product development projects

In project management, human resource management includes the processes that organize, manage and lead the project team (PMI, 2013). The project team is comprised of individuals with assigned roles and responsibilities for completing the project (PMI, 2013). Resource allocation to a project is seen as a key during project planning phase. The right expertise and the capacity of each team member must be critically evaluated to ensure that the team capacity is not over booked. It is believed that involvement of all team members in project planning and decision making can be beneficial. Early involvement and participation of the team members adds value during the planning phase and strengthens their commitment to the project.

For a project to obtain an effective human resource management plan, the following processes are recommended to be followed:

1. "Develop human resource plan – This involves the process of identifying and documenting project roles, responsibilities, and required skills, reporting relationships and creating a staffing management plan. This also includes identifying the training needs, strategies for team building, programs to recognize and rewards and other matters involving safety and compliance.
2. Acquire project team –This has to do with the process of confirming human resource availability and obtaining the team necessary to complete project assignments
3. Develop project team – This involves the process of improving the competences, team interaction and overall team environment to enhance project performance.
4. Manage project team – This includes the process of tracking team member performance, providing feedback, resolving issues and managing changes to optimize project performance" (PMI, 2013).

In R&D environment, human knowledge is the most important and most scarce resource. Assembling the right human resource to a project is vital. Hendriks et al. (1999) mentioned in their research that the more specific knowledge is required in every project, the more it is important but also the more difficult in the resource allocation process. In most research and development organization the matrix structure is commonly practiced and according to literature and in practice the methodology used in resource allocation varies. Furthermore, Hendriks et al. (1999) studies on how to optimize an existing resource allocation process in a large research and development organization, revealed that five elements are vital in setting up adequate resource allocation process. The five elements mentioned in their research are;

- Long-term resource allocation
- Medium-term resource allocation
- Short-term resource allocation
- Links

- Feedback

2.6.1 Long-term resource allocation plan

Most departments in research and development organization which are understaffed, it can take several months before the right competence is appropriately found. Hence, a long-term plan of the needed resource is required. A long-term plan is based on the organization vision and business strategy that specifies what the needs are for each discipline, for at least the coming year (Hendriks et al, 1999). This need should translate to the yearly budget for the organization. The sectors where efforts will decrease during the coming years must receive a decrease budget and disciplines where efforts are expected to increase must receive more resources hence an increasing budget.

2.6.2 Medium-term resource allocation plan

Planning a project portfolio for once a year can be effective but looking at the development organizations in practice this review time is too long because changes in the portfolio within a year is inevitable (Hendriks et al, 1999). This means a new model of resource allocation must be set up to determine the project portfolio. Typically, the long-term resource allocation is the main input to the medium-term resource planning and the output must synchronized with the short-term resource allocation.

2.6.3 Short-term resource allocation plan

According to Hendriks et al. (1999), the short-term resource allocation must be the key input for the day to day planning of resources for the coming weeks.

2.6.4 Links

The long, medium and short-term resource allocation process have their own goals and deliverable expectations but together they must be linked to provide the organization the needed results in doing business.

2.6.5 **Feedback**

The links give input to ensure the right decisions are executed. This input can be improved by reviewing the input versus the real efforts when the evaluation must be used for the medium and long-term resource allocation.

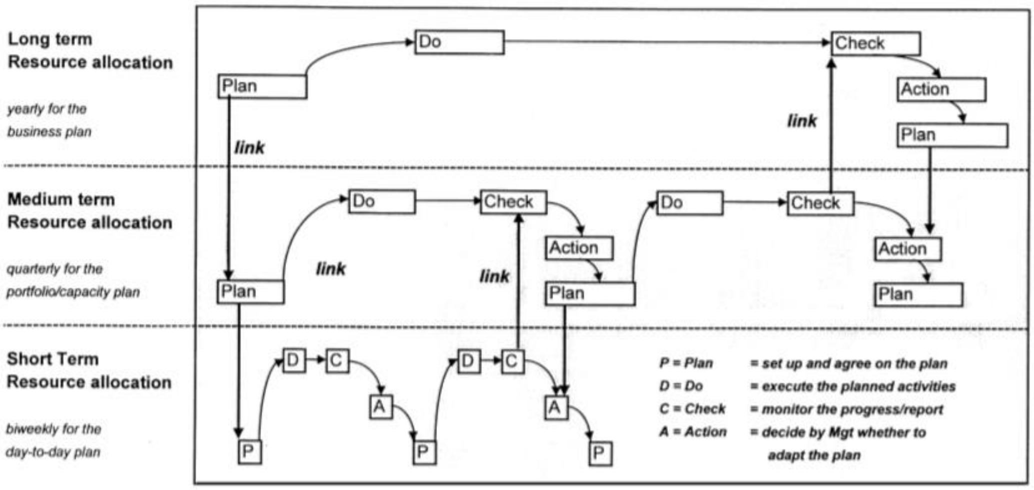

Figure 12. Links between the various resource allocation processes. Hendriks et al. (1999).

Table 4. Three resource allocation processes with their specific goals.

Resource allocation process	Purpose	Output	Frequency	Horizon
Long term	needed capabilities for accomplishing the Business Plan	• Department plan, budget per capability	yearly	5 years
Medium term	rough cut capacity planning for the project portfolio	• portfolio check, which projects must be executed • decision rules for group leaders • analyses of the effects on the milestones of the projects (changes in targets) • agreed rough allocation as input for the short term resource allocation	quarterly	±1 year
Short term	operational day-to-day assignment of people	• assignment of tasks to persons, within the medium term resource allocation assignment	bi-weekly	±6 weeks

2.6.6 **Effects of resource allocation on project effectiveness and success**

In the past, project has been managed as a technical system rather than behavioral system hence little attention has been paid to human resource factors in project delivery (Belout, 1998). Pinto and Prescott (1988) concluded in their research that human resource factor was the only factor that was not significant in all the four project life cycle stages. The four project life cycle stages mentioned were conceptualization, planning, execution and closing. Each project stage requires different intensity and effort, different type of tasks and actor hence variation of these cycles could have significant impact on project success (Belout, 1998).

Resource definition typically start in the beginning of every project but the question which normally come is, “what kind of resources are required to complete the project successfully”? Normally, the three elements in the iron triangle; scope, cost and schedule determine the overall needs of human resource for the project as seen in Figure 13.

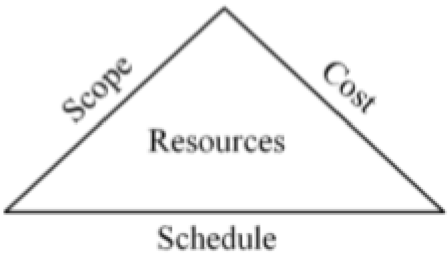

Figure 13. The three attributes defining resource needs.

In addition to the number of personnel required for the project, it is important for the project plan to include clearly defined roles, responsibilities, authorities and competences (PMI, 2013). Chin (2003) argued that without stating these clear definitions, project team members will tend to establish their own individual roles and responsibilities.

The first role to be allocated in mostly every project is the project manager. The project manager’s competence is quite significant to the project success. This assertion is supported by a research from Patanakul and Milosevic (2006) where they conceded that the project manager’s role is considered as one of the crucial steps in the resource allocation process. The project manager should have both technical and behavioral competences to be able to effectively relate to the project team. Integration of work breakdown structure (WBS) into the project plan is another important step in resource planning. This can make the project manager to have the general overview of the details of the tasks and the required skills needed to complete them.

Research has shown that firms that engage in new product development faces significant problem when allocating resources to an NPD portfolio management environment. Most firms typically have multiple projects running concurrently and same people are allocated in the same project. This can be a challenge when the risk involved in one of the projects is high. In a multi-project environments and projects where scope and schedules keep changing, scarce resource can render the resource allocation decision a critical factor for success. Scarcity may involve the overall budget for the project, testing equipment availability (Kavadias and Chao, 2008) or testing slot availability. Organization needs to access their employees and know the pool of competences available when assigning experts to a project.

2.7 Project performance

Both efficiency and effectiveness are key indicators in determining the success of a project (Jugdev and Muller, 2005). According to them, efficiency looks at maximizing output for a given level of input. Effectiveness on the other hand has been defined in different ways and mostly relate to the output. For instance, Ojanen and Tuominen (2002), defined effectiveness as the degree to which a predetermined objective is realized. Also, Neely et al. (2005) see effectiveness as when customer requirements are fulfilled. Efficiency has been attributed to be doing things right and effectiveness as doing the right things. For a project to thrive, both efficiency and effectiveness is required and management in project-based organizations need to consider this when taking actions to improve the success of a project. Profitability, cost and cycle time are some of the key metrics to measure efficiency. However, effectiveness measures are not that tangible or easy to understand and typically take longer time to determine and as a result, effectiveness has become a secondary area for focus for many project organizations (Jugdev and Muller, 2005).

Brown and Eisenhardt (1995) investigated factors affecting the success of product development and highlight the distinction between process performance and product effectiveness. They defined process performance as the speed and productivity of product development. Several other definitions have evolved from this description. For instance, de Weerd-Nederhof et al. (2008) propose that process performance or process effectiveness not only comprise speed and productivity, but also process flexibility, referring to the ability to gather and rapidly respond to new knowledge as a project evolves. Similarly, Kekäle et al. (2010) discussed process effectiveness as reflected in speed and productivity, but with the additional dimension of the need for a dynamic fit between the product development system and its context. The process should be capable of adjusting to new information as the project evolves to be considered effective.

The main target of every design project in most cases is to make a product on time and on budget. This can be achieved when we have a successful design process. Academic literature has shown that a successful process is the one that is built on experience. Hence, continuous design process improvement is required to make a process more effective and efficient to deliver quality product to the market (Eckert & Clarkson 2005). However, Eckert and Clarkson (2005), stated that, most hardware design processes are typically intertwined with other engineering processes. They believed these processes are also embedded in other business processes in the organization and linked to several supplier companies' processes hence it is difficult to define a successful process connected to processes in other projects or within supplier companies. For example, designing an embedded hardware component in most cases involves both hardware and software requirements. Both requirements are developed using different processes. These processes are also linked to the dedicated supplier processes who design these components. Design process improvement requires knowledge of how these processes works and what influence their behavior.

Research has also shown that early problem solving is directly linked to development performance. For instance, bringing conflict early in the development process is considered as a key factor for successful development projects. This means by resolving problems within teams or in the lower level in the organizational hierarchy, a clear project vision is accomplished and this subsequently could speed up the development process. In addition, effective external communications between suppliers and other key stakeholders also opens the project team up for new information. When this communication is task oriented, project team gain information from different perspectives beyond that of the team (Brown and Eisenhardt, 1995). Communication openness brings transparency and this is seen as a key step in early problem solving.

2.8 Improving project performance

Many studies have been conducted to investigate the factors associated with changes in new product development cycle times and very few companies have published their project lead time (Griffin, 2002). This has led to a lack of information on just how NPD takes (Griffin, 2002). This data is highly useful to organizations managing portfolios of product development projects (Cooper et al, 1998) and try to develop aggregate project plans for current and future projects (Clark & Wheelwright, 1993). Without proper understanding of how long various kinds of product development projects take to complete, it becomes difficult to estimate the required resources necessary to complete the project plans (Griffin, 2002). In addition, the schedule dates for product release for customers and other key stakeholders may be based on wishful thinking than reality (Griffin, 2002).

Several researchers (Griffin 1997, Lynn et al, 1999, Kessler & Chakrabarti 1996) have all conducted studies on the composition of factors that influence the performance of product development projects. The empirical findings from their research suggest that project strategy, development process characteristics and organizational factors are associated with product development cycle time.

Figure 14 summarizes the findings from their empirical studies. These factors are key indicators for improving NPD cycle time.

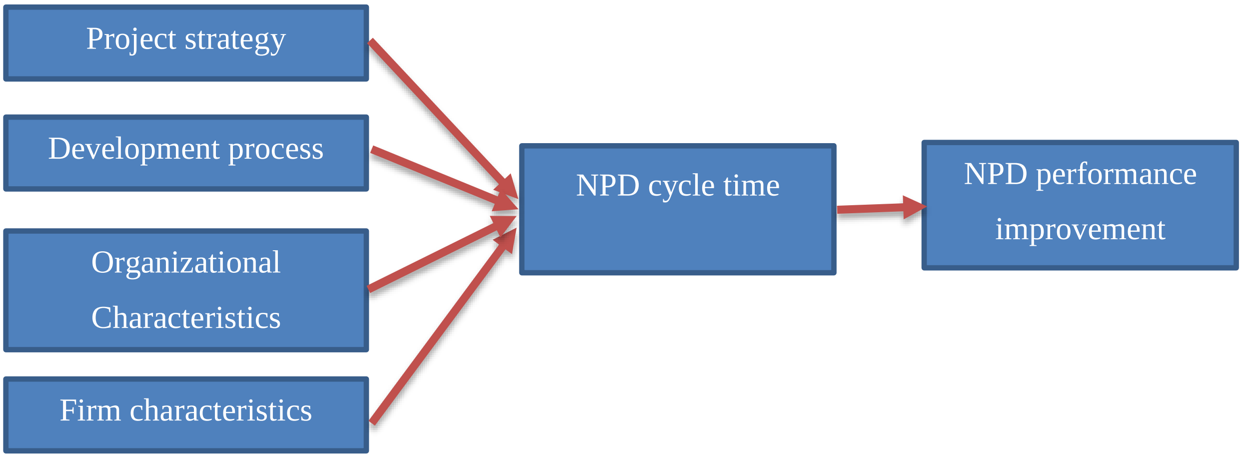

Figure 14. General factors investigated in relation to product development cycle time (Griffin, 2002).

Project strategy is related to issues such as the level of product complexity, level of innovativeness, technical difficulty and strategic intent. More complex, technically challenging and innovative projects are usually associated with long development times. This depicts that to depend on a strategy to shorten the average development time, an organization will need to develop a less complex, simpler, less innovative and less technically challenged projects. Though, the strategy could reduce development cycle time, the long-term benefits to the organization could be jeopardized. Product functionality improvement and regulation requirements are consistently pushing firms to rethink their product development strategy thus it will be difficult for a firm to continuously design same level of product complexity and innovativeness if they want to be competitive and dominate the market share.

Development process characteristics on the other hand, produce a more complex picture. During the past two decades, many changes have been implemented to improve the processes for development projects (Griffin, 2002). Most of the changes have been undertaken to improve the effectiveness of product development. This means, more faster products are developed to the market. Other changes such as concurrent engineering have also been undertaken to improve the efficiency of products moving to the market. Research has shown that the ideal situation would be to have a process changes that will simultaneously influence both efficiency and effectiveness. Research has also proved that involvement of customers will significantly lead to an improvement in product development processes. Griffin, (2002) outlined some of the key factors that can influence the cycle time of NPD projects and the summary of her findings are outlined below.

Factors associated with increases in product development cycle time

- For project strategy;
    - Increased product complexity
    - Increase number of assembly processes
    - Increase technical difficulties
    - Increase product innovativeness
    - Increase performance requirements
    - Increase product quality
    - Increase newness (amount of changes from the previous generation)
- Development process characteristics;
    - Higher supplier involvement in product development process
    - Design with frequent product testing
    - Increased numbers of customers involved with the process or prototypes
    - Increased nontechnical outside assistance

Factors associated with decreased in product development cycle time

- Development process characteristics;
    - Clear project goals
    - Process use
    - Process concurrency
    - Taking a long-term view
- Organizational factors;
    - Increased dedication of team members

- Cross-functional teams
- Integrating across sales and R&D
- Teams with members with long term tenure
- The ability of teams to record, file and review information
- Utilizing lessons learned from past projects into new projects
- More participation of management for complex projects

- Firm characteristics;
    - Characteristics associated with the firm's industry have an equivalent impact to firm characteristics in their relationship to average cycle times.

It is still unclear if there is a direct correlation between increased product quality and new product development cycle time. Ittner & Larcker (1997) in their research found that higher product quality was related to decrease in development cycle time while Boer & Logendran (1999) found it to be associated with increased in time. Many practitioners perceived that a decrease in product development cycle time can lead to NPD success. However, there is a little empirical data to support this perception (Griffin, 2002).

3 SUMMARY OF THE THEORETICAL FRAMEWORK

The design and development of a new product is a focal point of competition and due to the rapid technology and strong global competition, companies are compelled to design better products efficiently and shorten the development lifecycle. However, the development of new product is a complex process which usually involves many contributions from different stakeholders. Studies have shown that the performance of a project can be attributed to how the organization is structured. Organizations that have well established strong project management governance and effective development process tend to achieve project success.

Another thing, that was found from the literature review for this study involved the impact of resource allocation to projects. Belout, (1998) mentioned in his research that project has been managed as a technical system rather than behavioral system in the past. Hence, little attention has been paid to human resource factors in project delivery. In addition, cross functional team is recognized to be an effective way of collaborating in project teams.

Another interesting finding was also the factors leading to long duty cycles of development project. Griffin (2002) outlined project strategy, organizational characteristics and development characteristics as the key indices to determine the duty cycle of development project. The duty cycle has impact on the performance of the project.

An agile project model differs from the traditional product development project model in many ways. The difference between the traditional and agile project model is summarized in Table 5. The agile model was originally developed for software development projects. However, from the literature, it shows that it has proven to be effective to embedded systems development as well. Studies made about the introduction of agile methods in physical product development projects point out significant advantages over traditional methods. The benefits are increased productivity and faster results, a visualized picture of the project to the whole team, improved communication and less redundant work. The rest include improved team collaboration (Punkka, 2012) and product quality.

Table 5. Comparison of traditional and agile project models.

Project phase	**Waterfall project model**	**Agile project model**
Requirement	Detailed requirement specification at the beginning of the project.	Rough initial specification during the beginning of the project. Detailed specification only for the future.
Planning	Long term, everything is planned at once and documented in the project plan.	Mainly short term, continuous throughout the project.
Development	Completed all at once, after everything has been planned.	Incremental and iterative, learning from each iteration.
Testing	Started after the development of the product is ready	Done simultaneously with development.
Product delivery	One-time delivery after the product is completely done	Many versions delivered during the project
Customer involvement	Low during the project, feedback after the project.	High during the project. Constant feedback is provided throughout the project
Communication style	Mainly formal through meetings	Mainly informal, through daily interactions
Responding to changes	Slow, changes are handled in a separate process.	Quick, frequent changes are expected
Documentation	Vast and detailed	Only important documentation is created.
Lesson learned	At the end of the project	Several times during the project, after every iteration.

Ceschi et al. (2005) exposed good experiences of project managers with agile planning (agile managers were more satisfied with the project plan than "plan-based" traditional managers), while agile companies were also more satisfied with their client relationships than plan-based companies. It was very interesting to find that agile without a structure can cause chaos, particularly in large complex distributed projects where planning, control, and coordination are critical (Batra et al. 2010). Structure without agility can lead to rigidity, particularly when a project involves a great deal of learning, discovery, and changes.

Lee & Xia, (2010) made an empirical deduction from their study on a narrow area of the agile approach – the relationships among team response extensiveness, team response efficiency, team autonomy, team diversity on the performance of development projects. Their survey showed that response extensiveness and response efficiency impacts development performance differently. Team response efficiency positively affects the time, budget, quality and the schedule whiles the response extensiveness impacts positively only to the quality of the product under development. Moreover, they argued that team autonomy has a positive effect on response efficiency and a negative effect on response extensiveness whiles team diversity creates a positive effect on response extensiveness. The authors also discovered that standardized processes, methodologies, and tools help manage changes, time, and cost.

Shields & Young (1989) introduced the "Seven Cs" behavioural model for implementing cost management systems. The model focuses on human behaviour and incentivizing the employees to commit to the goals and strategy of the organization to achieve continuous improvement. The seven C's are clearly highlighted below:

1. **Culture**: The authors encouraged organizations to strive for a corporate culture which includes the employee's mind-set, shared beliefs, values and goals together with openness, honesty and collaboration. The three types of corporate culture are functional, dysfunctional and ill-defined.
    - A functional culture is supported by high worker involvement and participation, goal congruence between employees and management and

teamwork. This type supports a healthy organization and is most appropriate for promoting continuous improvement.

- A dysfunctional culture is run by overbearing management causing employees to have poor attitudes and low commitment to the organization, which leads to high turnover of employees.
- An ill-defined culture is practically a collection of employees with no similarity in values, beliefs and/or goals.

2. **Champions:** The champion is the person bringing positive change and innovation to the company. Top decision makers should support these champions and provide them the required resources to develop their ideas.
3. **Change process**: The change process is implemented by the champion, using controls, compensation, and continuous education, which are described later in the list. Enough time must be allocated for completing the change process.
4. **Commitment:** The organization and the employees should be committed to strive for continuous improvement. Different measures of performance and new compensation systems might be a threat to employees. Organizations should have counselling and education programs to describe the changes and its benefits to their employment.
5. **Controls:** There are three types of control mechanism typically used; Just in time (JIT) or Total quality control (TQC), Organizational structure and teams. The JIT/TQC controls are based on visualization rather than papers. Information is posted in a public place to display current performance to accelerate continuous improvement. Visual control is more timely, less expensive, more effective, and efficient.
6. **Compensation:** compensation can be used to motivate employees to focus on continuous improvement. The compensation should be based on team performance and individual development skills. Also, organizations should encourage innovation by allowing employees to take some risk. Non-financial compensation should be used to create an atmosphere of positive reinforcement.
7. **Continuous education:** Employees are the most important assets of the company and improving their skills increases the value of the company. Separate training

sessions should be augmented by employees constantly learning from each other. The employees should also be educated on the compensation system by explaining how they benefit from improving product quality.

The Seven Cs model can provide guidance when an agile project model is being implemented in an organization. The framework can be utilized in order to reduce the resistance to change and make the transition smoother.

4 RESEARCH METHODOLGY

Methodology is a systematic technique or strategy applied to a field of study to outline how a research project should be conducted whiles identifying the methods to be used (Igwenagu, 2016). This means it is a set of guidelines used to enable a good research approach. A methodology does not set out to provide solutions, hence not the same thing as a method. Instead, it offers the theoretical underpinning for understanding which method, set of methods or best practices which can be applied to specific case, for example, to calculate a specific result (Igwenagu, 2016).

Research, on the other hand, is built on scientific reasoning; which could be inductive and deductive or both. Research is a blend of both experience and reasoning and can be said to be the most suitable way of discovering the truth, precisely in the natural Sciences. (Igwenagu, 2016). This chapter will investigate the research methods use in collecting and analyzing data in research projects.

4.1 Research methods

Qualitative and quantitative research methods are the two main common methods used for collecting and analyzing data when undertaken a research project. Quantitative research tends to answer the question "why"? and the result is deduced statistically. In contrast, qualitative research, seeks to answer the questions "how"? or "what"? Moreover, qualitative research can further be broadly defined as any kind of research that produces findings not based on statistical procedures (Strauss and Corbin, 1990). Unlike the quantitative research method which seek to be causal determinative, predictive and generalization of findings, qualitative research instead seeks for understanding and extrapolation to similar studies (Hoepfl, 1997).

4.2 Research types

There are several criteria for the classification of research types, these include method of research and goal of research. Research can also be classified by the research method used. However, many research projects use methods from more than one class. The following are some of the mostly used methods in research project.

4.2.1 Case study

A case study is a qualitative research analysis that aims to uncover concepts and relationships in rich descriptions to develop existing theories or create new theories. So primarily case studies are conducted to develop theories. The main steps in conducting a case study include: identifying the problem, reviewing relevant literatures, research design, data collection and data analysis. The rest include evaluation of concepts and theories and reporting of the findings.

A case study approach is used to collect and analyze data for this study. A qualitative approach was chosen as the preferred methodology since the data required to be processed is coming from a single department in the target organization. In addition, the sampling size is very small hence face to face interview is preferred. Also, the data to be processed does not need any quantitative interpretation. The different kinds of case study research are presented below:

- **Exploration**: This is used to develop research ideas and theory development. The research structure tends to be an in-depth case studies or longitudinal field study.
- **Theory building**: This method is used to identify key variables and identify the linkages between those variables. This is used for multi-site case studies or in-depth field studies.
- **Theory testing**: Test theories developed in the previous stages and predict future. The research structure is typically a multiple case study and large-scale sample of population.
- **Theory refinement**: This is a type of case study which is used as a follow-up to a survey-based research to examine more deeply and validate previous empirical results.

In a case study research, a field data collection is done by using a combination of different methods to study the same phenomenon. Interviews, questionnaires, direct observations, content analysis of documents and archival research are some of the means to collect data for case study research.

4.2.2 **Survey research**

The main goal of conducting a survey research is to contribute to theory development. In addition, it can also be used to explain or predict a future phenomenon. Typical characteristics of a survey research include collection of information by asking people for the desired information in a structured format. Usually a survey requires a quantitative research approach with a standardized information to define or describe a variable or to study relationships between variables. The information obtained are through a sample size which is a fraction of the population with the need to be able to generalize findings from the sample to the population. The key steps in a survey research include the following;

- *Define the problem*
- *Develop research questions*
- *Backgrounding (acquire knowledge about research issues)*
- *Defining and operationalizing concepts*
- *Formulating hypotheses*
- *Deciding on a survey approach, example, telephone, mail or face-to-face*
- *Designing and pretesting questionnaire*
- *Sampling*
- *Collecting data (interviewing or mailing out questionnaires)*
- *Analysing, interpreting results and verifying or falsifying hypotheses*

There are several techniques which can be used to collect information in a survey research. In-person interviews, telephone interviews, online and mailed questionnaires are some of the most common data collection techniques used in a survey.

There are two major kinds of survey research. The first type is classified as exploratory and the objective is to become more familiar with a topic. There is typically no model in exploratory research and the concept of interest need to be better understood and measured. The other type of survey is the explanatory research and considered the most important. This research is devoted to finding causal relationships among variables.

4.2.3 Action research

Krathwohl (1998) developed the argument that the main aim of action research (AR) is to find solutions or improvements to practical problems. The AR process begins with a notion in the researcher's mind that a change in work practice is desirable. The four key characteristics of AR are Plan, Act, Observe and Reflect. Action literature suggests that it is critical to develop a plan of informed action to improve current practices (French, 2009). French (2009) argued that the plan must be flexible to allow adaptation to allow any unanticipated constraints. The plan must be prospective to action; meaning looking forward whiles taken into consideration a retrospective action to correct past actions. After developing the plan, it is necessary to act to implement it. After implementation, the action is observed. The observation process includes collecting data and documenting the effect of the actions. Finally, the whole prospective action is reflected through a critical self-retrospective where the AR action plan is continuously refined according to the whole AR action cycle in case there are still some issues to solve the target problem.

4.3 Collecting and analyzing data

Interviews are the most common means of collecting data for a qualitative research. Interviews can be structured, semi-structured or unstructured. Structured interviews use predefined questions, which are asked in the same order from every interviewee. Semi-structured interviews allow the interviewer to ask follow-up questions if the interviewee seems to have additional input to the topic. Unstructured interviews enable maximum flexibility, but the analyzing of the responses can be difficult. Semi-structured interviews are usually preferred when conducting case studies as the interviewees can express themselves better when they are not restricted to the researcher's perspective. (Hancock & Algozzine, 2006 and Kothari, 2004).

This case study will utilize both interviews, desktop research, observations and internal documents from the target organization related to the case study. The desktop research involved reading and analyzing academic literature associated with new product development projects. The case study consists of a face to face interview with mostly personnel with hardware expertise. The interviews are semi-structured and is tailored based on the interviewee knowledge and experience in the organization.

4.4 Validity and reliability

Golafshani (2003) mentioned that although the term ‘Reliability’ is a concept used for testing or evaluating quantitative research, the idea is most often used in all kinds of research. Reliability and validity are conceptualized as trustworthiness, rigor and quality in qualitative paradigm. However, Stenbacka (2001) suggested that the concept of reliability is irrelevant and misleading in qualitative research because there is no measurement method. She concluded that a thorough description of the whole process, enabling conditional inter subjectivity is what indicates good quality when using a qualitative method.

This study intends to interview eight experts from 2 different departments. The experts are carefully selected from Hardware and Testing & Validation teams. The composition of the experts selected for interview is to seek for a balanced information on the perspective of hardware development projects. Also, these experts have been involved in several hardware development projects and is believed to have diverse and good understanding about the automation hardware development processes used in Wärtsilä. The interviewer does not speak Finnish. The target organization uses English as its official language, hence the interviews were carried out in English language and the researcher does not think conducting the interview in English could lead to any misunderstanding. All the questions were sent to the interviewees a week to clarify any misunderstanding before the interview day. The interviews were conducted face-to-face in a private meeting room. The interviews were recorded and transcribed to ensure every bit of information is included. The transcribed message is sent back to the interviewee to validate the content of the interview message before they were used in this study. The researcher is an employee of the target department and tried to stay objective.

5 AUTOMATION HW DEVELOPMENT PROJECT IN A&C

Automation and Control department in MPS have the core competence to develop and maintain automation hardware components for the 4-stroke engines. This means continuous hardware development products are inevitable. The components are developed in close collaboration with suppliers and other internal stakeholders. The final product must meet Wärtsilä's technical requirement specification before the component is fully released for use on production engines. In most situations, the automation hardware components on the engines are designed through projects to secure quality. The projects are managed by project managers and have team members from different functional organizations with diverse responsibilities thus careful coordination and collaboration is needed to have an effective cross-functional team. Development of a new automation hardware components such as sensors, actuators, electronic modules and so forth for use in a harsh environment is typically complex and a lot of collaboration and coordination between the supplier and Wärtsilä is required to ensure a smooth development process.

However, we typically, underestimate to understand the big picture in the development process. From the beginning of developing a new component, we need to have the full kitting in place. Understanding the component functionality and how it will be integrated into UNIC automation system is necessary to have system thinking approach in the development process.

This chapter will highlight the case study project and present the development process currently used for hardware development projects in the target department.

5.1 Description of "WCD-20 project" as a case study project

The WCD project was initiated in 2015 to bring the needed ignition spark technology for Sparked ignition gas engines. The new ignition module is required to extract all the potentials offered by the Wärtsilä UNIC 2.0 automation system. The motivation behind this development is to have better control of the ignition event (spark duration and selection of energy levels), diagnostics, reliability and prediction of spark plug lifetime.

The main driver for WCD-20 project was to develop an ignition module that will replace the current spark plug ignition system WCD-10 based on the desired technical specifications created by the target organization. The key deliverables were to test and validate;

- Alpha sample
- Beta sample
- C sample and
- D sample which is intended to be used in production.

Testing and validation of each samples were to take place in the different phases of the project lifecycle. Testing of the Beta and C sample were to be carried out both on the rig and on lab engines (W31 SG and W34 SG). Testing of the D samples were intended to be carried out in the field. This means the samples would be installed in a Wärtsilä customer site to accumulate a specific amount of engine running hours to test the functionality, robustness and ruggedness of the module before they are released for production use. The component was to be developed in a closed collaboration with a selected supplier. The project is dependent on a single vendor. The vendor has previous experience with Wärtsilä and the main supplier of the current WCD-10 ignition system.

5.1.1 Challenges in WCD-20 project

The WCD project started very well in late 2015. The requirement collection begun even before the project was started. The project was started without any customer pool so to get a high priority initially from a RDE management was not easy. Lack of focus and priority from Wärtsilä affected the resource allocations for the project. One of the key issues for the project was the loose definition of roles for the project team. Though the project plan emphasized on a pool of experts required from different departments, only hardware expert was fully involved in the project from the beginning. This certainly impacted quite much the requirement collection stage causing a huge time for the project

According to the project plan, the project was planned to close in the end of second quarter of 2019. Delivery of Alpha samples were done as scheduled. However, the rest of the samples delivery schedules were not regular. In addition, there was quite a big number of changes that were not in the original plan for this project. Wärtsilä 46TS engines were not in scope but later it was realized that this ignition system to be used for this new engine portfolio. In addition, the supplier was not given the big picture of what they were expected to deliver. This caused delays and cost due to rework.

5.2 Product development project processes in Wärtsilä

In Wärtsilä, all projects are divided into three categories. These are Customer Delivery (CD) Projects, Product and Solution Development (PSD) Projects and Operation Development (OD) Projects. Each of these projects have a set of project model guidelines to realize the success of the project. Automation hardware development projects fall under PSD projects; hence this study will focus on PSD project processes. The company utilizes the PMI project management principles and ISO 2500 standard to enhance project management best practices.

Project phases and process groups steer project execution and support project implementation work in order to achieve the desired project result. The basic structure of Wärtsilä project model is described in Figure 15

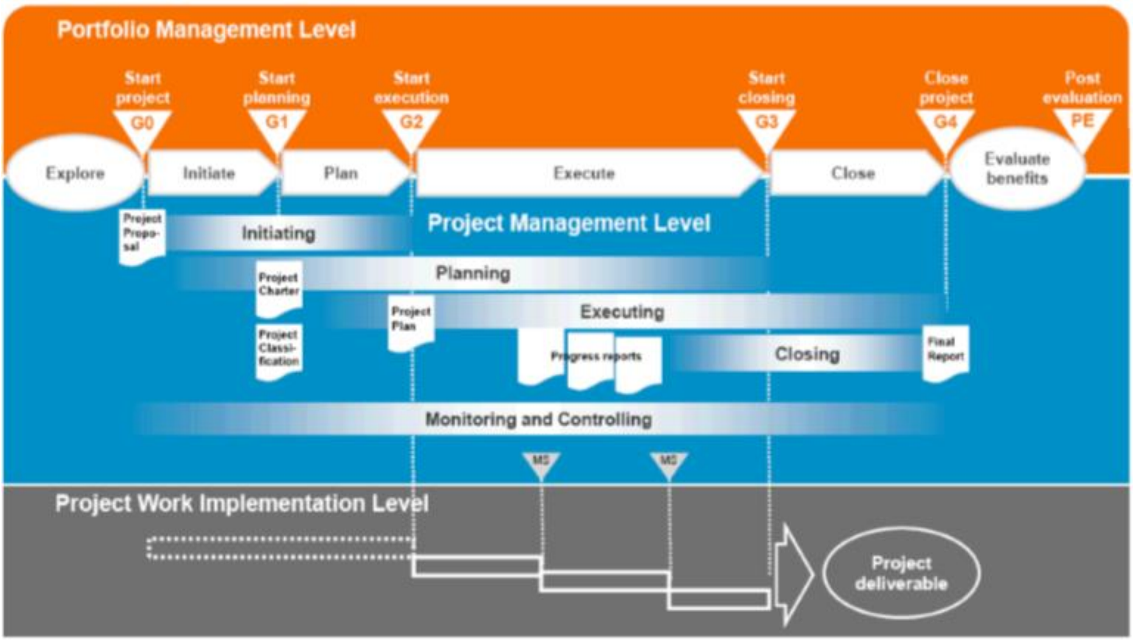

Figure 15. Wärtsliä Project Model framework.

5.2.1 **Project life cycle and decision point**

The project life cycle is divided into four main phases, namely; initiating, planning, executing and closing. In addition to these project lifecycle phases there are two subsequent project-related phases outside the project: explore and evaluate benefits. Each project lifecycle phase starts and ends with a mandatory decision-making point that in the Wärtsilä Project Model are called Gates, see Figure 15. Gates are obligatory project management decision points, where achieved results are evaluated from a business and strategic point of view by the project owner and/or project steering committee. At every gate the decision maker decides as to whether a project is continued (GO), terminated (NO GO), must be redefined and brought back for approval or is put on hold. The Wärtsilä Project Model includes five mandatory Gates that are common to all projects3;

- G0 “Start project”
- G1 “Start planning”
- G2 “Start execution”
- G3 “Start Closing”
- G4 “Close project”

If a project deviates so much from its objectives that the project owner’s or steering committee’s mandate is not enough, it must be brought back for decision-making at portfolio level. In small projects, gate decisions can sometimes be combined if agreed beforehand. In addition, the project model includes a “gate” for post-project evaluation (PE). Decision-making is supported by project documents e.g. project charter or project plan that include the essential project information. The five gate models are explained in detailed below.

Start project, G0: G0 is a decision to approve the project idea. In projects the G0 decision is made by the respective portfolio management board, which also nominates the project owner. G0 decision is based on a written Project proposal. Approval of the project proposal in G0, starts the Initiating phase.

In PSD projects, the project proposal is refined and necessary feasibility studies are implemented in the initiating phase (between G0 and G1). The project owner has the responsibility for the preparation work, which is often done as part of normal line, management and specialist work. The nomination of the project manager and the project team is done in the initiating phase.

Start planning, G1: G1 is a decision to start the project management planning. The project owner/steering committee suggest the G1 decision and the project portfolio management board makes the final G1 decision (go/no-go). The G1 decision is based on the written Project Charter. Approval of the Project Charter in G1 starts the planning phase.

The most important objective in the planning phase is to create a project plan. The Project Plan includes all the necessary information about what deliverables should be ready when the project is closed, how the project will be executed and what are the acceptance criteria and process. The project manager is responsible for ensuring that the project plan is done.

Start Execution, G2: G2 is a decision to start the project execution. The project steering committee makes the G2 decision. During the execution phase the project manager and the project team are responsible to ensure that all the tasks and activities described in the project plan are executed. Every deviation from the project objectives needs to be reported by the project manager to the steering committee, which will evaluate the risk levels of the deviation and propose actions to mitigate them. If significant deviations to the project schedule, budget or deliverables are needed, the project owner has the ultimate authority to accept the deviations / or the project must be taken to the portfolio management board for decision.

Start Closing, G3: G3 is a decision to approve project deliverables and start project closing. When the acceptance criteria for the project deliverables defined in the Project Plan have been fulfilled, the project manager makes a proposal to approve the project deliverables. The main purpose of project closing is to ensure that the project deliverables are handed over to the line organization. The result of the project is documented in the Final report Lesson leaned are collected and documented to assist future projects.

Close Project, G4: G4 is a decision to close the project. In PSD projects, the portfolio management board makes the G4 decision and decides when the project post evaluation should be done. Project closing means that all the activities related to finalizing the project deliverables and handing them over, as well as administrative tasks, have been completed.

5.3 A&C automation hardware development process

The A&C department used to be practicing the traditional project management model for embedded hardware development projects. Dedicated team are set up and a project manager is nominated to lead the development process. This way of managing projects have changed since spring, 2019, after the department adopted the SAFe agile framework for developing products for end-users. This means there is no dedicated hardware team within the department anymore, but rather cross-functional teams made of hardware, software and application developers. Due to the new way of working, the development process for developing embedded systems have also been updated to align with the SAFe model.

The whole order intake to the department is prioritized according to customer value and time critically of the request. The selected requests are planned in a two-day PI planning session. The whole department attend the PI planning, where work is distributed to various teams based on the need. Each team is committed to the PI objectives and promised to deliver value for the next ten weeks. The tasks are planned in iterations. Each iteration takes two weeks.

A cross functional team comprises of a development team, Product owner and Scrum master. The development teams are self-driven and self-organized who plan their work every iteration. The team uses daily stand up meetings where each team member explains what he has done a day before, what he is intended to do today and if there is any impediment.

The scrum master facilitates and coordinates the daily stand up meetings, teams backlog refinement, Demo and retrospective sessions. The scrum master is responsible to create good team spirit and remove any impediments that may hinder the team to achieve the sets goals.

The Product owner (PO) serves as the team lead or the project manager in the team. He is responsible to prioritize features (work) in the team backlog. The PO is responsible to accept or reject the acceptance criteria for each user stories or task in every iteration. In addition, the PO communicates the progress of the team to the management team and the project owners.

The process below describes the development process used to develop automation components for Wärtsilä engines with embedded automation systems. The goal of this process is to ensure high-quality and well-suited hardware components are developed. The whole project is divided into smaller iterations.

- **Feature:** A Feature is defined and placed in an Agile Lifecyle Management (ALM) backlog ready to be analyzed when a new development is required. The Feature should be any wok package that would deliver some value after completion.
- **Analyses and Planning:** The Feature is analyzed and prioritized based on the time criticality, business value and effort. After the analyses, the feature is selected to be included to the next PI planning.
- **Update Feature Analysis**: The feature is updated in the ALM system after the analysis.
- **Task Planning:** The Feature is split into stories during the PI planning. Tasks are made from the stories and are planned in detail in the ALM for an iteration. Each iteration last for two weeks. The detailed plan is accessed in the ALM Kanban Board.
- **Initiate Wärtsilä Supplier and Part Approval Process (WPAP):** The WPAP is initiated by contacting responsible Supply Management Category Manager and filling in the validation project request template. The WPAP case team lead agreed and nominated together with Category Manager.

The activities required in the initiation phase of the project highlighted above is visualized in **Figure 16**.

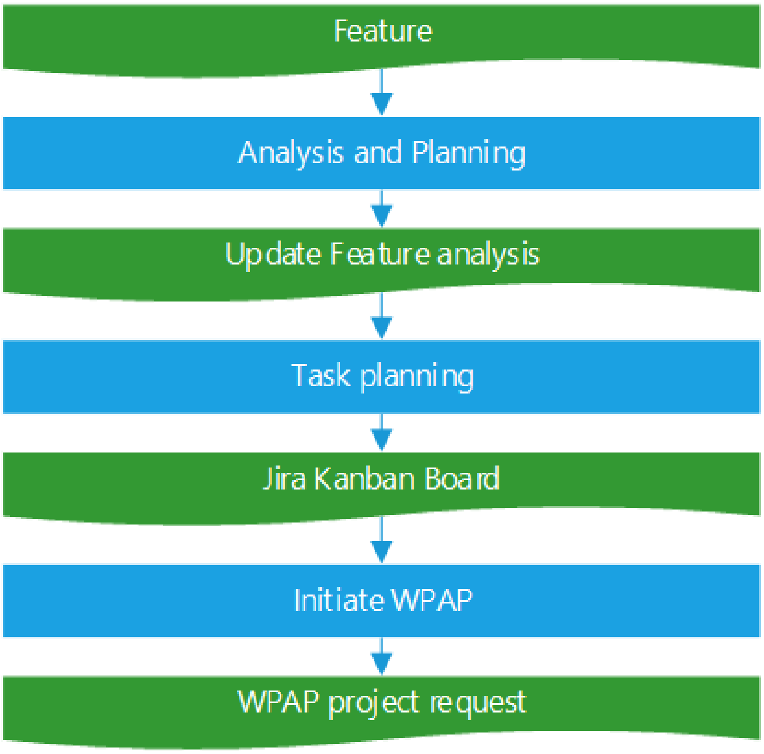

Figure 16. Initiation phase.

2. Requirements/Specifications

- **Define requirements:** The requirements are collected, defined and documented. Each requirement should be well defined and must have a known stakeholder or requester.
- **Requirement specification:** Once the requirement specification has been written, the technical requirements are reviewed with stakeholders and requesters to ensure all requirements are correctly understood. The minutes of meeting (MoM) from the review meeting is documented.

- **Supplier Selection:** A supplier is selected in cooperation with the Supply Management. Multiple Suppliers might be needed in case design party and manufacturing party are not the same. In case the component to be developed is a new generation of an existing component, the same suppliers are typically nominated.
- **Define product specification:** The requirements are reviewed with the supplier and the actual product specification is agreed and finalized. Once the specification is agreed, it is ensured that all requirements are fulfilled. In case a requirement cannot be fulfilled, the requirements are reviewed with the requester.

The requirement and specification process are shown in Figure 17.

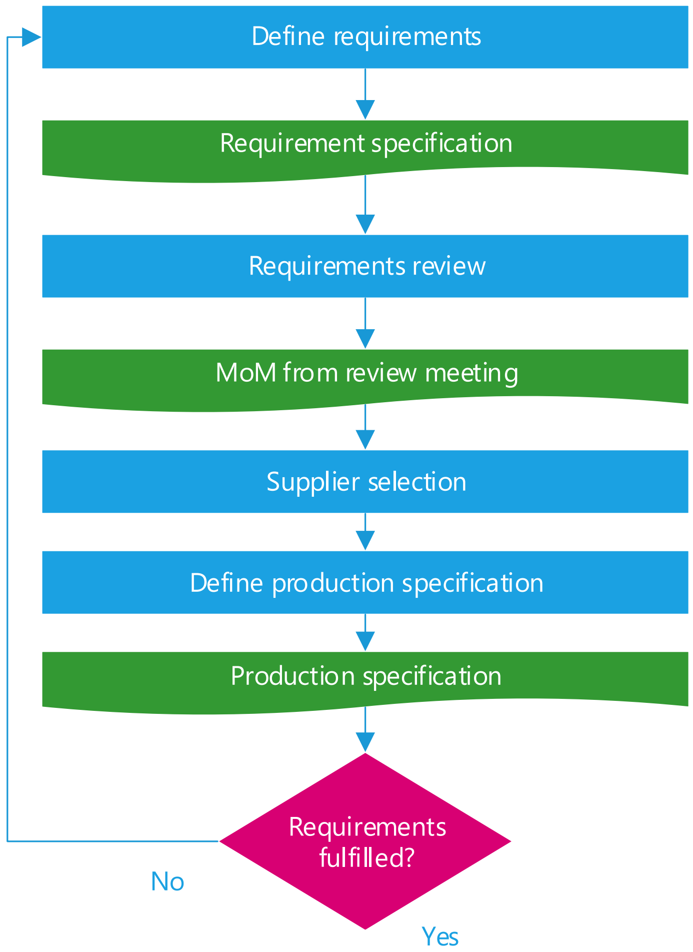

Figure 17. Requirement and specification process.

3. Design and development phase

The design and development phase of automation hardware development phase is characterized by the following process;

- **Design and development:** The design and development are performed internally and/or at the chosen supplier depending on the circumstances of the component. The design is documented, and documentation is stored in the organization document management system.
- **Testing and validation:** once the design is ready, the developed component is tested by the Supplier and by Wärtsilä. The Wärtsilä internal testing include the develop component installed on a laboratory engine for 500 running hours to check the functionality of the component. When the component passed this test, the component is required to be installed on a customer engine for 3000 running hours. The component is not allowed to fail during this period for the test to be considered successful. The test results are reported, reviewed and documented. When major defects are found from the testing, the supplier is informed, and the defect must be corrected and retested again. Below is the flow diagram for the design implementation phase.

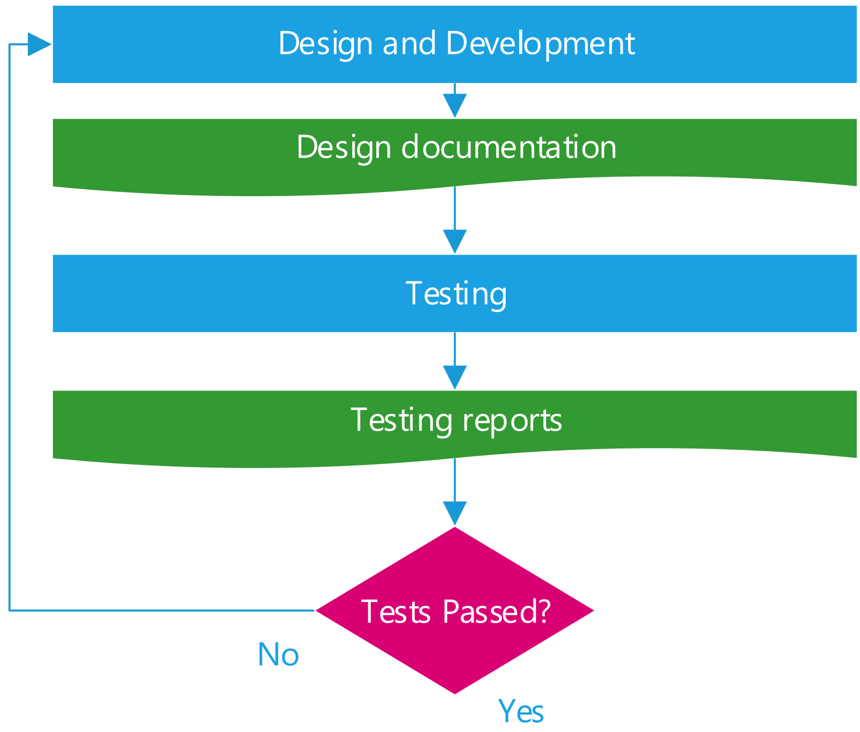

Figure 18. Design implementation process.

4. Production validation and component release phase

This section is done when component has passed all the required tests and zero-series production is ready to be commenced. The workflow for this process is defined in Figure 19.

- **PQAP support:** Once the tests are passed, a design review is conducted with the supplier. A design review is part of the Part Quality Assurance Plan, which in turn is one step in WPAP. The PQAP document is maintain by the supplier.
- **Initial sample inspection:** Initial samples are ordered and manufactured based on the process agreed in the PQAP. Prior to manufacturing it is agreed with the supplier how the initial samples shall be verified, and the plan is documented in the PQAP form. After manufacturing the initial samples are verified by both the Supplier and Wärtsilä according to the agreed verification plan.
- **Component release:** The component is released after all outstanding issues have been cleared. After the release process is approved, all required stakeholders are

informed about the release of the newly developed component. The component is ready to be used on a production engine.

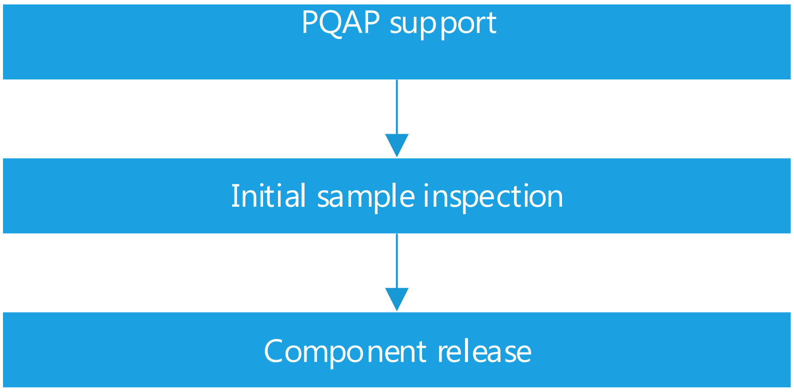

Figure 19. Production validation and component release process.

6 FINDINGS

This section is aimed to provide an overview of the interviews conducted with HW experts from A&C and the internal documents from the case study company. The findings are grouped into six sub-sections. Section 6.1 discusses in detail how embedded HW development projects are planned and scheduled. The interviews seek to find answers on how the project planning was done using waterfall approach and what benefits agile bring when planning for HW development projects. Requirements and specifications collection is broadly presented in section 6.2. Here, the interview was intended to explore who are involved in requirement collection for HW development projects and if it is required to gather all the requirements and specification before the product is developed.

Also, section 6.3 highlights the results from the project team resourcing and what is required to have a high performing team for project success. In addition, how the development and testing phase is done is outlined in section 6.4. Moreover, section 6.5 seeks to understand how supplier collaboration could be maximize to speed up the development process for HW development projects. Finally, section 6.6 seeks to find out the opportunities and challenges in implementing agile in embedded HW development projects.

6.1 Project planning and scheduling

Previously, all HW development projects in A&C department have been using the waterfall model for project delivery. This means detailed information of the project need to be documented in the project plan before the design is started. When the interviewees were asked how projects are planned and scheduled in the beginning, expert (C) had this to say;

"*Traditionally, what has been done in the past was to have the whole plan done from the start and you are expected to follow the plan from the beginning to the end. When you have changes you will have issues because you need to re-plan everything*".

Moreover, expert (B) mentioned that scheduling should be part of the project plan to be able to be followed. In addition, target for specific milestones should be planned. Major features and milestones are to be identified but not necessarily drilled down to the task level. In his opinion, project plan is not carefully well followed in Wärtsilä for HW development projects.

Interestingly, all the experts interviewed agreed that the planning should contain only what is needed first from the beginning. According to them, the details can come later and any attempt to go too deep in the beginning can prolong the project schedule time. When the interviewer asked the question;

What does good project planning involved?

The experts gave interesting answers to this question. For instance, expert (C) considered timeline estimates, major functionalities of the product and milestones to be included in the project plan. Also, risk management plan and how requirements will be collected should be clearly outlined in the planning phase. In addition, expert (D) believed a good project planning should involve a good stable project group and stakeholders with very clearly defined roles. In his opinion, the stakeholders group is typically quite stable but the roles are not well defined, for example, what is expected from them rather than just participating in meetings. In the Gate model, this somehow works but even there, they are or they should have a clear roles defined but in agile the roles are not defined, the interviewee stressed. Another interviewee (expert G) stressed that it is very important to know the scope and all the requirements or the functionalities on how the product will be integrated on the engine. Here is a quote from expert (G) interview;

"I will say good planning is to take the whole spectral of knowledge from mechanical design, electromechanical design, commercial and customer impacting ideas or something like that, so that at the end, we can solve some customer issue".

Furthermore, it was mentioned that lesson learned from previous projects could be a key input when planning for another project. Also, identifying all key stakeholders early and establishing good communication plan for the project is considered quite significant. Almost all the experts interviewed agreed to early involvement of suppliers in the planning phase. This means the selected suppliers must come to Wärtsilä for the kick-off meeting of the project where more clarification and brainstorming are done. One other thing that was mentioned related to good planning is to separate the roles of a Project. Manager and a technical lead. My understanding from expert (D) interview was that in most cases where they have smaller projects, the technical lead doubles as the project manager. In his opinion, it is typically the hardware lead who is communicating to stakeholders. It's difficult to run small project when technical lead is reporting and facilitating with the project. The technical lead should focus more on the designing of the product and mitigating technical issues. Lastly, it was mentioned that location and time difference should be considered when planning.

6.2 Requirement and specification

In the waterfall project method, it is expected to have a detailed requirement and specification in place before the implementation of the design is conducted. In view of this, the interviewer wanted to find out from the interviewee how requirement specifications are collected and who are typically involved in gathering these information.

Most of the interviewees emphasized that for HW development projects, it is important to have some relevant information at the initial stage to enable the sourcing department to start scouting for potential suppliers. This requirements must be baselined after it has been reviewed by all key stakeholders who are interested in the product to be developed including potential suppliers. It was mentioned that critical requirements which determines the functionality of the product must be collected first and the "Nice to have" requirements can come later on in other versions of the product. This is typically the case for embedded hardware development projects. However, in case the development involve some auxiliary automation components with just one basic functionality on the engine, it is then necessary to have all the agreed requirements before the component is fully released.

When asked from the interviewees who should be involved in writing the requirements, they confirmed that key stakeholders such as Technical Services, Product management team, the technical lead and all the departments that will somehow use the product should be involved in collecting the requirements. Another important revelation from the interviewees was that requirements often changes a lot throughout the project life-cycle and it is important to agree on each changes and document them for easy traceability. One of the key drivers mentioned for the requirement changes was due to changes in legislation. For example, changes in RoHs, Atex and marine requirements can have big impact to the project since suppliers are required to test the product under development against latest standards.

To find out how deep requirements should be available before design is implemented, the interviewees were asked the below question;

Do we need to gather all technical requirements in the planning phase before design is implemented?

Expert (D) had this to say concerning the above question;

"Typically we need to have some structure of the requirements and present it to stakeholders for review and comments. This could be iterated a couple of times before we have a baseline requirement which is reviewed together with the supplier"

The above assertion was also corroborated by the interviewees. For instance, expert (C) explained that iterative development of requirement is preferred if they are embedded systems. Also, expert (G) reiterated that it is important to obtain a draft version of the requirements and review them together with suppliers and internal key stakeholders. The feedback from the review is used to develop the requirements iteratively before we obtain a baseline and freeze the requirements for the development contract to be signed.

Moreover, almost, all the interviewee revealed that, agile method could be utilized to collect the requirements in embedded hardware development projects. Expert (D) explained that when developing an electronic module, it is important to understand how the software and hardware integration works, hence it is beneficial to have a cross functional team which will have firmware, hardware, software and sometimes control applications experts to understand if there are some requirements that need to be stated or known early in the development phase.

6.3 Project teamwork collaboration

For a project to succeed, it requires assembling a strong dedicated and highly motivated team. In research and technology organization, it is often difficult to find the enough resources due to multiple of projects undertaken in parallel. To ascertain how a project team are organized in the target department, the interviewees were asked the following key questions which pertain to resource allocation in a project organization. The first question asked was;

Is definition of roles for the team and key stakeholders clear enough before the project kick-off?

This question revealed very interesting answers. The experts who have participated in the WCD-20 project believed the definition of roles was not clear enough from the beginning of the project and they were quite confident that one of the reasons for the delay of the project could be attributed to that reason. This confirms the assertion made by PMI (2013) that it is important for a project plan to include clearly defined roles, responsibilities, authorities and competences. In addition, Chin (2003) also argued that without stating these clear definitions, project team members will tend to establish their own individual roles and responsibilities.

Furthermore, expert (D) had this to say;

"This however, depends a bit on each project but typically definition of roles is loosely defined. If you have project where you have different R&D teams; then you have something like Automation team, Turbocharging team and things like that. There should be clear roles for TRS creation, designing phase, integration of component on the system level".

However, a few of the experts confirmed that in most of the past projects, definition of roles was quite clear for the team. What is usually not clear is the expectations from the project key stakeholders. Typically, we are waiting for the requirements and needs from stakeholders and there should be a clear definition and expectations to know who to contact, explained by expert (F). One other important point which was further raised in the interview by expert (F) is when a member of the team is leaving the project. According to him, this creates a lot of issues especially, if the replacement is not found before the team member is left. This could bring a knowledge gap in the team if proper knowledge transfer is not conducted.

I went further to ask the question;

What is needed for a good teamwork in an embedded hardware development project?

A summary of the answers obtained from the interview is listed below;

- Good communication inside the team.
- Good team spirit and having the right competence in the project team.
- Team autonomy to be able to take own decision.
- Clearly defined roles.
- Cross functional team. Both software, firmware, hardware, mechanical and electromechanical designers' plays different roles in embedded HW development projects.
- Proximity of project team and having face to face meetings

In addition, during the interview, one of the experts mentioned that during project team formation;

"It is good to listen to people who don't want to change to new project. When people are happy the whole team is happy".

6.4 Design and development phase

This section is aimed to understand what challenges HW development projects encounter and what could be done to speed up the design and development cycle time. There was quite a significant revelation regarding the design of HW components within A&C department. Firstly, two key questions were asked by the researcher. The first question seeks to brainstorm the causes for long duty cycles for HW development project and the question was framed as seen below;

In your opinion what do you think are the causes for long duty cycle time for HW development projects?

A lot of factors that were discussed with the expert during the interview were attributed to long duty cycles in HW development. Heavily involvement of suppliers were seen to be the biggest issue concerning long development cycle. According to the experts, there are always some technical surprises during the design and development phase which prolong lead time of the project. Also, suppliers are using different processes and there seems to be less synchronization with their processes and the development process used in Wärtsilä. In addition, lack of focus and a lot of support work by the HW developers in the project team typically is the cause for long project lead times according to expert (C). According to him, if you are getting a lot of other work coming from outside the project at the same time that the project development is actively in progress, the multitasking can damp the spirit required to complete project activities.

Moreover, it was interested to know that in some situation there may be component under development already installed on production engines but still not released due to some bureaucracy in the department HW development process. For instance, expert (E) questioned the criteria for full release if the component is already installed on production engines. Another important factor influencing long duty cycle mentioned in the discussion were long testing of components on the engines, acquiring certification for components and external testing of the components. For the latter two factors raised; the organization can influence the lead time very little. However, most of the experts agree that field testing hours could be determined by case by case.

Other important concerns raised by almost all the experts were the lack of resource allocation to a project team, unclear project scope definition, not clearly defined roles and responsibilities and lack of clear project priority. In addition, it also came up that in most situations, the organization do not have a common schedule for HW development project. For instance, it was explained by expert (G) that if the organization want to develop new electronic module, there should be a commitment from all department that matters to actively get involve at the appropriate time. Finally, getting an engine testing slot for operational and functionality testing of the component under development has been a challenge and expert (A) had this to say;

“Engine availability is usually a challenge. Usually we don’t have the product samples to be tested when we have engine available and when we have samples, we don’t have engine availability due to some performance test ongoing. Operational tests are not easily able to get good slot due to this problem”.

However, based on the factors influencing the longer lead times mentioned above by the experts, the researcher was interested to understand from the expert how they could be improved by asking the below question;

What could be improved in the development process for hardware projects?

Most of the experts agreed that it is very significant to involve the suppliers in the early phase of the project. They explained that the selected supplier(s) should be part of the kick-off meeting to brainstorm most of the critical technical issues needed to be clarified in the early stage of the project. In addition, they mentioned that it is equally significant to visit the selected company to check the capability of the supplier and make a light audit. This, according to them, will give an early premise whether there may be some bigger issues during the production process of the component. However, the majority of the expert believed this is usually done when suppliers are selected for the first time, they stressed that same visit should be done to existing supplier partners when they are developing newer generation to obsolete their old generation products if, for example, the product is expensive and highly risky. Another suggestion for improvement that came up was to explain to the suppliers in a better context rather than just providing them with the technical requirement specifications. Moreover, it was also mentioned that effective communication is required between the development team from Wärtsilä and the supplier. According to some of the experts, open communication is very important from both sides for early problem solving and it also brings honesty and trust between the supplier and Wärtsilä.

Furthermore, partly automatization of Wärtsilä internal testing could speed up the testing process. Also, it was mentioned that some of the least important test cases could be outsourced to the supplier or other third parties and testing result shared between Wärtsilä and the supplier. For instance, expert (A) emphasized that joint testing between Wärtsilä and the supplier is required in some situation and besides Wärtsilä could also visit the supplier to check how they are testing the product. This, according to him, will enhance faster determination of the weakness of the product and also bring some transparency to how the testing is conducted. In addition, there were different opinion as to which test should be conducted early. For instance, expert (G) emphasized the importance of making HALT test during the early phase of the design. According to him, the outcome of the test at that stage will give a good overview and provides early information where the design needs to be improved. However, expert (A) thought differently; he believed this test is very expensive and it should be conducted when design is close to be ready.

6.5 Supplier Collaboration

Based on the literature reviewed for this study, supplier involvement was one of the causes for longer duty cycles for development projects. In view of this, I was interested to understand how effectively, the target organization can maximize their collaboration with their partnered suppliers during embedded hardware development. Interestingly, it was revealed by all the experts interviewed that indeed the heavily involvement of suppliers in their development project is the key factor for long lead time of project.

According to the experts interviewed, the supplier’s key role is to design and develop the component in accordance to the specification agreed in the beginning of the project. In some instances, the component is developed jointly by Wärtsilä and the supplier. However, one of the important factors hindering supplier and buyer collaboration is effective communication. This is a quote from expert (A) regarding how they could improve supplier involvement in product development.

“Open communication and quick problem solving from our side can give early feedback to suppliers for them to react in time. This also applies to Suppliers given quick decisions to Wärtsila”

Brown & Eisenhardt, (1995) stated in their studies that a strong buyer-supplier collaboration in the design and development of a product enables the buyer members and the supplier members on the project to openly share relevant information. Holding back of some technical information that affect each other's design and development processes can lead to unnecessary changes and reworks later (Loch & Terwiesch, 1998). This means that open information sharing is critical for coordinating of work schedules to ensure that the sequence of tasks avoids any unnecessary gaps or overlaps. However, previous studies have shown that the frequency of communication between the buyer and the supplier is not so critical but rather the quality of the communication is considered to have a positive impact on the project performance.

6.6 Opportunities and challenges of agile in HW development

The target department where this research was conducted has started implementing SAFe framework for developing embedded HW development projects and they have less than a year experience in this agile new way of working. Though agile was initially developed to suite embedded software development, the adoption of this model for HW development is an interest since not too much literature is available in this area. Therefore, the researcher was motivated to find out from the interviewees the contrast between HW development with agile and the waterfall model.

According to the experts, one key advantage of the agile methodology is the opportunity of meeting all key stakeholders during the program increment planning period. This gives a chance to get a quicker clarity of some key issues before the project is kicked start. Also, expert (D) emphasized that agile brings transparency in testing and validation and decision making as well. From his observation agile utilizes cross functional teams, hence both the HW developer, the testing engineer and the SW developer could be in the same team unlike having a separate team for testing and validation as it used to be previously. Another positive side of agile in HW development pointed out is the possibility to use agile to effectively develop and iterate requirements specifications. The requirement collection for embedded HW is seems to take a longer period in the project lifecycle and since the requirements are constantly changing, it is important to have a framework which support changes quite easily.

However, most of the experts believed that proper planning from the waterfall model can equally establish an effective cross functional team to serve the same purpose. From their understanding agile does not bring any value for embedded HW development projects but rather overheard. Punkka (2012) conceded in his research that agile brings value to embedded HW development projects when co-designing software and hardware together. Even though in HW development the end user benefit is only when the physical component is released and installed on an engine, agile provides quicker feedback between agile project team and suppliers. This fast feedback assists in fixing issues related to design or testing of the component to enhance the progress of the component under development.

7 DISCUSSION AND CONCLUSION

As described throughout the literature review in this study, there has been a lot of discussion related to improving project success. Project Organization characteristics, resource allocation and development process were some of the building blocks for project performance.

In a research and development environment, the organizational structure has greater influence on how a project is conducted. For instance, in a functional organization, the functional or line manager controls the budget and a team member acting as the “project manager” will be coordinating and expediting project activities rather than having project management responsibilities. It is often not advisable for this organization to execute complex or highly risky projects. However, in many technological environments the strong matrix model which was described in section 2.1.3 is more desirable, for instance, where highly important projects where better project performance is inevitable. The target project organization type seems to follow the strong matrix model. However, the absence of project managers in the agile framework currently being implemented by the target department might cause some issue. Even though the current set up have product owners who are responsible for features, it is still not clear who the owners of hardware product development roadmaps or EPICs are. In addition, not all the PO’s have more HW background or even some project management knowledge. It will be necessary to give some project management trainings to PO’s in case the role of a project manager will fade out in the department organizational chart.

Effective resource allocation in project management is seen as a tool for effective teamwork. Belout, (1998) mentioned in his research that project has been managed as a technical system rather than behavioural system in the past. Hence, little attention has been paid to human resource factors in project delivery. The research brought up ways for research and development organizations to optimize resource allocation. According to Hendriks et al. (1999), it is very significant for organizations using the matrix model to have both long term, medium and short term resource allocation in their strategy. In addition, cross functional team is recognized to be an effective way of collaborating in project teams. In addition, latest studies also show that project team technical capabilities is critical but behavioural features and traits have been focused on at an increasing extent (Amollo & Omwenga, 2017). It has also been stated that personality traits affect work performance and project delivery outcome (Strang, 2007). This assertion was corroborated from the empirical result from this study. The findings from this research revealed that a balance of both technical competence and behaviour competence is required to establish an effective project team. There is the need to have enough technical competence to speed up the design and the development by mitigating technical issues. Nonetheless, project teams are working with different cultures and people, hence it is equally important as well for each member of the team to have a strong behavioural skill. Being aware of your team dynamics and cultural dimensions create a self-motivated and self-organized team.

The reduction of project lead time from conception to the final release is seen in many industries as a competitive edge and this has been a prioritized challenge for many industries. Due to this, technology managements are reconsidering their traditional way of designing new products and are continuously looking for new ways of working and practices of improving the organization and execution their development processes to create outstanding products (Minguela-Rata, 2011). This assertion necessitated the Automation and Controls department in MPS to introduce SAFe framework for their project delivery including hardware development projects. This new way of working is intended to speed up HW development projects through iterative planning and development. The outcome from this research indicates that some improvement has been seen after the introduction of this framework in the case study project. However, many critics for agile introduction in physical products development, believe this cannot make HW development better.

7.1 **Summary of findings**

The goal of this research was to access automation hardware development projects and identify specific areas where advances could be made to improve the process. Additionally, the goal was to increase the knowledge of how the project performance in hardware development context can be improved. To obtain this, it was significant to investigate the factors affecting the performance of the various levels of the project. Some of the contributed factors that can easily influence the performance of HW development projects from the literature were greatly proven to be right. The case study interviews held with hardware personnel and the internal documentation reviewed, compared to the results from earlier studies undertaken in the literature were intended to find answers to the following research questions;

RQ1: What factors influence hardware development project performance?

According to this study there seems to be a lot of factors that impede the performance of hardware development projects. For instance, section 2.3 of this paper discussed how the organizational context can have greater influence to overall project delivery. In addition, lack of resource allocation and unclear project team roles and responsibilities were key to project success. These factors were clearly analysed in sections 2.6, 2.7 and 2.8. The empirical results obtained from the case study interviews confirms the theoretical findings from previous studies. Organizational factors, project strategy, developmental process and firms' characteristics were the major highlights contribution to long duty cycles for HW development project and these were clearly mentioned in Griffin studies in (1997) and (2002). For instance, since the department falls under marine, it is required for automation products developed to fulfil the marine type approval class requirement. This is one of the visible firm's characteristics where the department have little influence on the lead time for the release of marine type approval certificates.

Moreover, it was perceived from the interview that there is some bureaucracy in the development process which typically influence the final release of components. This is typically related to embedded electronic module design and development projects where they can have the physical component installed on a production engine but in theory the component is not yet fully released due to some requirements not yet implemented or clarified or release documentation not yet finalized. If the version of the component installed on the engine provides the required functionality for a customer engine and there is no major risk of it usage, it is better to agree early with stakeholders to have initial full release of the product in the system. Later, a new feature can be created to cater for the not-implemented requirements and when all the agreed requirements or technical issues have been resolved, the newer version of the products can be revised and released with the required documentation.

In addition, unavailability of lab engines slot for operational test and long field-testing period of component also contribute to the long duty cycle for hardware development. For instance, expert (A), explained that usually when there is engine available there is no samples available to be tested and when samples are available, engines are occupied with some performance tests. This could be improved with the current way of working where testing & validation managers are part of the PI planning. With this, testing and validation can already be agreed and prioritized when development teams knows when they are expecting samples of products from the supplier.

RQ2: How can hardware development project performance be improved?

According to Clarkson & Eckbert (2005), the design and development of a new product is a focal point of competition and due to rapid technological development and strong global competition, companies are compelled to design better products efficiently and shorten the development lifecycle. To achieve better results and performance in hardware development projects, the old way of doing projects needs to be improved and processes optimized. Project performance create business value to the company whiles meeting customer demands and expectations. This is possible when we increase the efficiency and effectiveness of the project.

The findings from this study revealed some useful information that can lead to improve the performance of hardware development projects. Firstly, it was discussed that requirement collection from key stakeholders usually takes the longer duration in the project life-cycle. It was mentioned from almost all the experts interviewed that, it is crucial to collect this requirement in the early stage and close in time. In addition, these requirements need to be reviewed with key stakeholders and agreed on the deliverables expected from the supplier. Moreover, it is equally important to involve the suppliers in the early stage of the project and communicate to them the clear project expectation, high level forecast and project plan. Clark and Fujimoto, (1989) concluded in their research that the early involvement of suppliers in product development was instrumental in reducing lead time and avoiding design problems that could prove costly. So, since the target organization is relying heavily on the technical capabilities of their suppliers, it is therefore important to have good relationship and court suppliers with the best product development design skills for their business. However, having the best suppliers may help but is not enough to ensure the best overall performance. It is therefore, important to have the big picture plan where clear ramp-up plan is actively communicated to suppliers so they can prepare and deliver on time. Also, when new suppliers are being screened, it is important for the target organization not to look at the technical capabilities alone but rather the project management skills of the supplier should be considered as well.

In addition, another factor raised to effectively contribute to the performance was the possibility to visit the selected supplier and conduct a pre-audit before the design is commenced. Even though, this seems to be captured in the development process for hardware projects in A&C, the findings from the interview showed that this was not done to the WCD-20 project. This should be enforced to all projects especially, where product cost and risk is high. In addition, definition of a clear project scope, roles and responsibilities of project teams were a means to improve the efficiency of delivering a project.

Moreover, the internal testing and validation of the products could be improved. This can be achieved when some of the least critical test is outsourced to the supplier or a third party. Also, a critical test like HALT, should be done early in the design phase. This according to the results from the interview will determine the weakness of the product in the early phase and there will be enough time to react in case there are some design effects to be corrected. Though this test is expensive, the cost of delay will far be more when the test is conducted when the product is ready and major weakness is found. Also, in the long team, automatization of some of the testing should be considered. This will reduce the testing duration for the products by the testing and validation team. In addition, it is important to improve the communication and tools strategy to effectively improve the supplier collaboration. One of the ways to do this is for Wärtsilä to put up an infrastructure in place to share the test sequences and data remotely with suppliers for troubleshooting.

The agile framework being implemented by the target department, could certainly improve communication with key stakeholders and obtain quicker feedbacks from them to enhance the iterative development of the product. However, the seven Cs model proposed by Shield &Young (1989) and mentioned in section 3 when an organization is transitioning from plan-driven project methodology to agile model should be implemented and sustained.

7.2 Applying Agile values to hardware product development

The agile values described in the agile manifesto as stated in section 2.5 were created for software development projects. However, there is no doubt that agile methodology can be applied to hardware development to some extent. Before we check how to apply agile values to hardware product development, we need to understand the basic difference between software and hardware development. The component procurement lead time, component cost and the variety of skills required to execute hardware development projects are greater and these are some of the reasons why hardware new product development is different from software. This section will discuss how these differences impact the agile values for hardware development.

- **Individuals and interaction** over tools and processes: communication is very critical to both hardware and software development. This makes agile method to be a great opportunity where developers can communicate frequently via daily stand-up meetings. Also, it provides a great avenue during PI planning for more clarification to be obtained from key stakeholders who might know more information about some topics related to the project which could assist the design and development of the product. However, the number of interactions in a complex hardware development product increases exponentially and communication could breakdown. In order to combat this, a good framework of processes and tools to keep everyone on the same page, in synchronism, using good practices and communicating well is even more essential. Thus individuals and interaction cannot necessarily replace tools and processes. In hardware development environment, both are required for a development team to achieve its goals.

- **Working software** over comprehensive documentation: in hardware development, a working product create more value. However, delivering a working product or changing requirements in hardware takes longer and has a higher cost than in software. Changes in hardware typically impact multiple components and processes. The delivery of documentation is required in hardware development. In the target department, design drawings, datasheets, test reports, product certification and purchase specification are still required to be delivered. These documents are required for both internal and external users. While it is often difficult to look at some software code and understand what the person who built it was thinking, it is often more difficult to look at a mechanical or electrical design and gain much comprehension and knowledge. Hence knowledge is better transferred through documentation when face to face transfer is not possible. Since the intention is to consider how this value fit hardware product development, the “working software” can be replaced with “working product”. However, documentation also create value too in hardware product development though it is recommended to deliver the most important documentation and minimize the effort to get those documentation.
- **Customer collaboration** over contract negotiation: hardware development in the target department involves a lot of collaboration with both internal and external customers. In addition, there is a close collaboration with suppliers. Getting early feedback from these stakeholders is considerably significant hence this value can directly be compared and translated to hardware development.
- **Responding to change** over following a plan: changes in hardware usually create more cost than effecting changes in software. The cost and the procurement lead time to obtain new parts or prototypes usually causes delays and involves some rework cost. Due to this, changing plans in hardware development is costly and is important to identify and agreed in the project plan how many prototypes will be built and tested. Late major changes in hardware product development especially, during zero series manufacturing can cause a huge impact to the project and it is very significant to reduce changes in hardware development. As such some part

of the plans, at least the later phase of the project, needs to be sufficiently accurate to be able to be followed without an extensive cost.

The “hardware effect” described in the above paragraphs affects the build, measure and learn cycle, the cycle at the heart of agile. The hardware effect changes everything and makes some agile values and principles more applicable than others in hardware development projects. In both hardware and software, requirement vary in value. From the information obtained from this study, it can be concluded that the value obtained from agile values can be summarized in Figure 20 and Figure 21 for software and hardware product development respectively. The aim to deliver a value from both hardware and software development is supported by the set of the requirements from the agile values. The requirements are supported by the strength of a spring which also support the goal. The greater the value of the requirement the stronger the spring and the more weight or value of the goal the requirement support. With software development, the values or requirements in the left create more value than those in the right.

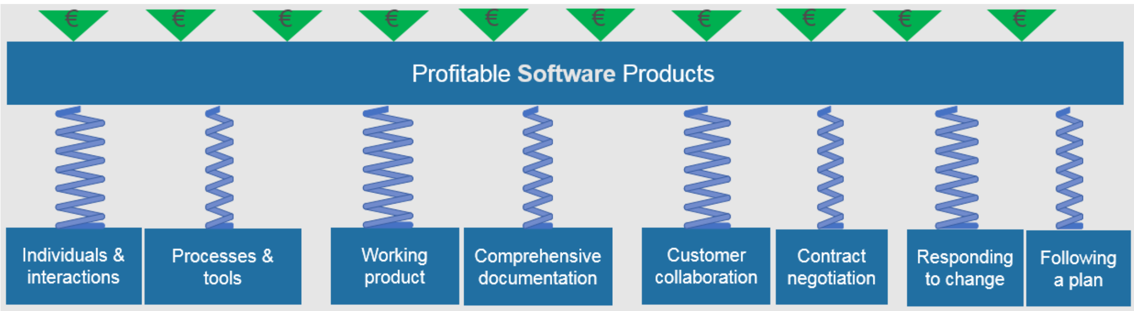

Figure 20. Benefits of Agile Values in SW development.

However, as depicted in Figure 21, the values or requirements in the right; Processes & tools, comprehensive documentation, contract negotiation and following a plan support more value profitably in hardware product development than in software development. This is attributed to the fact that the conditions for hardware products creates different cost and risk.

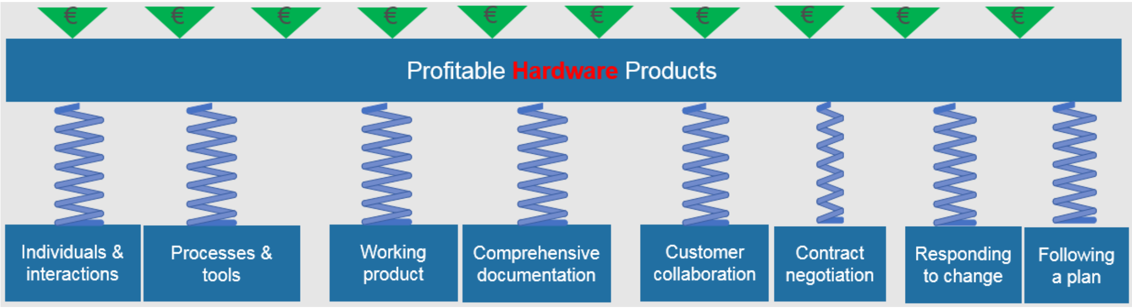

Figure 21. Benefits of Agile Values to hardware development.

7.3 Agile-Stage Gate Model Hybrid framework

Based on the findings from this thesis, the researcher proposes the Agile-Stage Gate Model combination for embedded HW product development in the target organization. This framework, shown in Figure 22 is divided into three hierarchical planning levels. The Strategic Project Management level is the planning level for the product portfolio management and steering committee. At this level, the stage gate model is used to define the roadmap of the product.

Also, the Value Chain or Project Portfolio Coordination is the tactical planning level between key stakeholders interested in the development of the product. This level is managed using visual methods whereby stakeholders from different departments periodically meet at a physical board to coordinate resources. The project execution is the planning level of the development team. This is managed by agile methods and supported by Product owner. The Product owner is thus responsible for communicating the progress of the project to the key stakeholders. The hybrid model also includes feasibility studies where the work required is conducted iteratively using the agile method before the project is started. Sommer et al. (2015) mentioned in their research that a combination of Agile and Stage Gate model generates a healthy tension between a plan driven and iterative problem solving. According to them, the Agile Stage-Gate hybrid framework provides organizations a promising alternative to the traditional Stage-Gate systems.

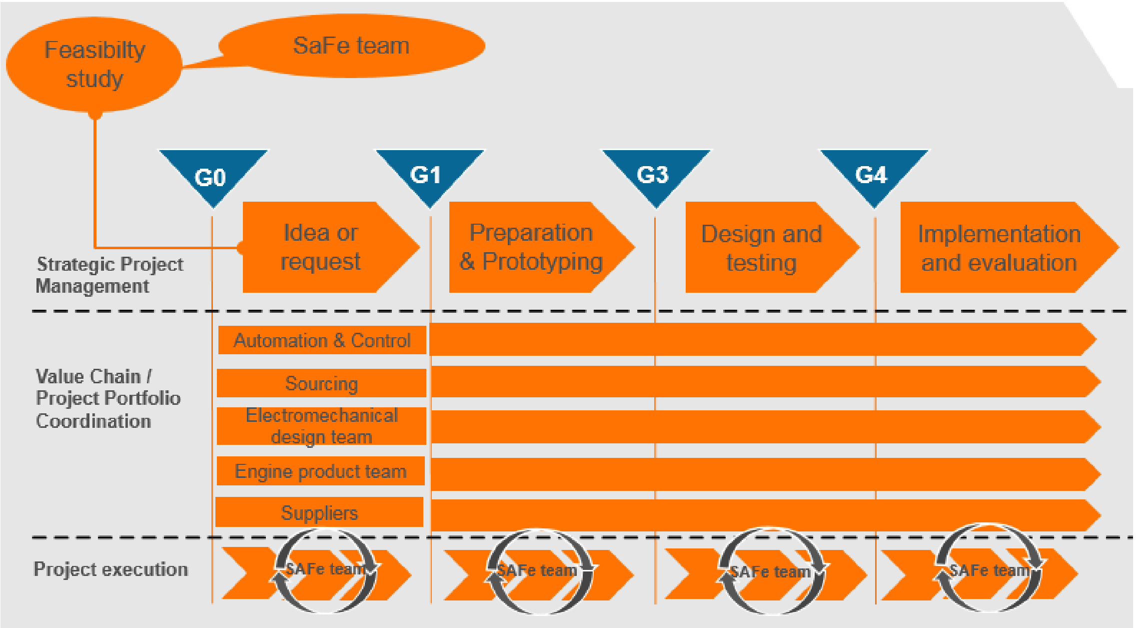

Figure 22. Agile Stage-Gate Model Hybrid Framework.

7.4 Theoretical contribution

The theoretical implication of this study is to provide more information regarding how hardware development projects could be improved. Adoption of agile frameworks including SAFe for larger organizations were covered in this thesis. The scientific contribution of this study lies in the increased understanding of project performance, factors influencing project performance and how project performance can be improved in hardware development. In addition, the study also seeks to highlight how the opportunities and challenges agile can offer to hardware development. Since there are few scientific research studies about agile application to hardware development, this research is also considered to contribute to the previous studies on agile hardware development.

7.5 Practical contribution

The research problem was inspired by the practical problem in the case study company. The research has contributed to the understanding of how automation hardware development is conducted in Wärtsilä. The findings obtained from interviewing experts provided ideas and experiences which could be useful for the company to improve their hardware development processes. For instance, removing some bureaucracies from the development process and addition of automation testing should be considered. Furthermore, the practicing of the seven Cs model should be encouraged and sustained to make the SAFe agile model being currently implemented in the organization to be less resistive for hardware development projects. The target department could consider the Agile Stage-Gate framework proposed by the researcher. Finally, other organizations looking for an improvement in their physical product development process could have this study very useful as well.

7.6 Limitations and future research

This study used only one case study from the target department as a base for this study. Besides, the interviewees were mostly from hardware and testing experts. Though, majority of these experts have gained some experience from hardware product development projects, few of the interviewees have less experience in developing hardware products by projects in the department. As a result, the findings from this study cannot be generalized. However, it could have been interesting to interview other personnel from sourcing department, strategic suppliers, and so forth to understand from their side how they see the performance of automation hardware development projects in Wärtsilä. In addition, the department just begun to develop their products using the SAFe agile Framework and thus it was too early to understand what was working and not working using agile for hardware development in the department.

Therefore, further research could be done later to ascertain the impact of the introduction of the SAFe model for hardware development. In addition, the target audience to be interviewed could be extended to suppliers and Wärtsilä sourcing department to understand how the supplier integration could be maximized to benefit the current way of working in A&C department in MPS, Wärtsilä. Finally, testing is the most significant cost factor in hardware product development therefore an alternative testing and validation model to reduce component testing on engine could be an interesting topic for future research.

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APPENNDIX I

List of interviews

Number	Interviewee	Duration	Date
1	Expert A	1 h 15 mins	11.11.2019
2	Expert B	1h 15 mins	20.11.2019
3	Expert C	1h 30 mins	20.11.2019
4	Expert D	1h 15 mins	21.11.2019
5	Expert E	1 h	30.11.2019
6	Expert F	1 h	02.12.2019
7	Expert G	3 h 30 mins	19-20.12.2019

APPENDIX II

Examples of questions for the case study interviews

Project planning and scheduling

- What do you know about the WCD-20 project?
- How is the project scheduled at the beginning?
- What does good project planning involves?

Requirements/specifications

- Who are involved when preparing the Technical Requirement Specification?
- Do we need to gather all technical requirements in the planning phase before design is implemented?
- How often is requirement changing during the project life-cycle and how are these changes managed? Is there mitigation plan for these uncertainties in the project plan?
- Are the changes communicated to all stakeholders in time?
- How could we have done the requirements and specifications differently with agile project management approach?

Role of the team and teamwork

- Is definition of roles clear enough before the project kick start?
- Are other key stakeholders outside A&C responsibilities clearly defined?
- What is needed for a good teamwork in embedded hardware projects?
- Do you think that teamwork affects the success of a projects?
- How will you rate the technical and behavioural competences to a project success? From a scale of 0 to 5, where 0 is not significant, 5 very significant
- Do you think agile create a better teamwork for HW development projects?

Design and development phase

- In your opinion what do you think are the causes for long duty cycle time for HW development projects?
- What could be improved in the development process for hardware projects?
- How could the design and development phase done differently with an agile way of working.
- What aspect should be considered when transitioning from plan driven project model to agile project model for HW development projects?
- Do you think agile style is suitable for hardware development projects?
- Which of the following has more value for you: A project that delivers everything all at once but may be delayed until is totally ready, or, a project that delivers a partial product quite early and then extra items can be added later?

Supplier(s) Collaboration

- What are the roles of suppliers in embedded hardware development projects?
- How can supplier collaboration be maximized to improve the development process?