Tampere University of Applied Sciences

Improving Time-to-Market and Customer satisfaction in the SoC Product Business

An approach to enhance productivity by “reusability strategy”.

Madhusudhan Gowda Mandya Channegowda

MASTER’S THESIS
June 2022

Master of Business Administration
International Business Management

ACKNOWLEDGEMENT

My sincere thanks to my teacher and coach for the suggestions, review, and feedback during the thesis.

Thanks to the management and the organization for their co-operation and support during this research process.

I am grateful to all the participants for their active response and for providing valuable input during the research. I want to thank everyone in the organization for their review, time, and patience during this research process.

Finally, I would like to thank my family for their love and support during this study.

Without all their support and input, this would not have been possible. I am grateful to all for making this research study successful.

Thanks a lot!

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Master's Degree/ Master of Business Administration
International Business Management
Tampere, Finland

MADHUSUDHAN GOWDA MANDYA CHANNEGOWDA:

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Master's thesis 70 pages, appendices 3 pages
June 2022

The objective of this study was to gather information about possible pain points and identify the areas to improve time-to-market (TTM) for "Company X" in the embedded / SoC product development business. In addition to TTM, the research study was also to identify areas to further improve customer satisfaction during the after-sales support stage in the product life cycle.

The Thesis is based on the pragmatic philosophy and mixed methods approach, including qualitative and quantitative methods. The qualitative study carried out a semi-structured interview, and data were collected from 18 selected individuals across the organization. The data were analysed using qualitative content analysis.

The good inputs from qualitative interviews and empirical findings arrived at the questionnaire for the quantitative study with a survey. The purpose of the survey was to gather deeper insights into those empirical findings of qualitative research and get input from a broad audience. The quantitative survey data were collected from 116 individuals across the organization.

The combined results from both qualitative interviews and quantitative surveys were analysed together.

A detailed report is shared with "Company X" to take further steps on the findings and recommendations. There is a lot of scope for an additional research study focusing on specific areas and discussing the suggestions briefly.

This thesis includes the confidential information collected in Appendix B and excluded from the public report.

Keywords: time-to-market, product, business, reuse, modular, agile, lean, soc, embedded, development, architecture, customer satisfaction, mixed-method leadership, people, process, practices

CONTENTS

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GLOSSARY

ASIC	**A**pplication **S**pecific **I**ntegrated **C**ircuit
API	**A**pplication **P**rogramming **I**nterface
CPU	**C**entral **P**rocessing **U**nit
CSR	**C**orporate **S**ocial **R**esponsibility
CSI	**C**ustomer **S**atisfaction **I**ndex
cr	**cr**edit
Firmware	is a type of software that is etched directly into a piece of hardware
HW	**H**ard**w**are
HAL	**H**ardware **A**bstraction **L**ayer
IP	**I**ntellectual **P**roperty
IC	**I**ntegrated **C**ircuit
KPI	**K**ey **P**erformance **I**ndicator
MBSE	**Model-Based S**ystems **E**ngineering
PCB	**P**rinted **C**ircuit **B**oard
ROI	**R**eturn **o**n **I**nvestment
SAFe	**S**caled **A**gile **F**ramework
SoC	**S**ystem **o**n **C**hip
SW	**S**oft**w**are
SPES	**S**oftware **P**latform **E**mbedded **S**ystems
SoS	**S**oftware Architecture **o**f a **S**ystem
SDLC	**S**oftware **D**evelopment **L**ife **C**ycle
TAMK	**T**ampere **U**niversity of **A**pplied **S**ciences
TTM	**T**ime-**T**o-**M**arket
XP	**E**xtreme **P**rogramming
WCED	**W**orld **C**ommission on **E**nvironment and **D**evelopment
3BL	**T**riple **B**ottom **L**ine

1 INTRODUCTION

The chapter briefly describes the research study's motivation, objective, purpose, and scope. It also provides the main research questions and the methodology used in this thesis. A brief description of the thesis structure is presented to the reader at the end of this chapter.

1.1 Product Business

“Company X” is a technology company which develops embedded and System on Chip (SoC) products. To achieve a competitive edge, improving the product's Time-to-Market is essential. The primary motivation of this thesis is to identify the pain points and the areas for further improvement in the product business.

Though the focus of this research is mainly on the embedded or SoC products business, the methodology, approach, topic, and the perspectives of this study can widely be applied to any electronic product business.

1.2 Scope of the thesis study

A system on a chip is an integrated circuit designed for a specific application. Typically, the personal computers will have one or more printed circuit boards which will use one or more SoC chips to perform a particular action. We can think that each SoC will have a miniature computer inside a single chip to complete a specific application.

Let us take an example of the Cell Phone, which is one of the end-user electronic consumer products. Inside the Printed Circuit Board (PCB) of a cell phone, more than one ASIC/SoC chip is implanted on the PCB with metallic wire to perform specific applications. The cell phone will have one or more SoC chips that interconnect with many other ASIC chips like Modem IC for cellular connectivity, display IC for touch and display usage, and power IC for battery usage and charging.

All these SoC and other ASIC ICs work together to fulfil the use case of an end-user.

The visible part of the product of the electronic product is called hardware components. The invisible program executed inside the processor of the SoC is called software or firmware in the embedded systems world. The software/firmware running in the SoC chip performs the needed operations for the designed application.

1.2.1 Software Terminology

Let us look into the detailed software terminology as described in the book,“ Reusable Firmware Development, A Practical Approach to APIs, HALs and Drivers”

“Configuration Layer refers to a software layer used to configure components within the layer.

Application Layer refers to a software layer used for the system- and application-specific purposes that are decoupled from the underlying hardware. The application code meets product-specific features and requirements.

Middleware refers to the software layer that contains software dependent upon the lower-lying hardware drivers but does not directly contain application code. Application code is usually dependent upon the software contained within this middle layer of software.

Driver Layer refers to the software layer that contains low-level, microcontroller-specific software. The driver layer forms the basis from which higher-level software interacts with and controls the microcontroller.

The hardware abstraction layer (HAL) refers to a firmware layer that replaces hardware-level accesses with higher-level function calls.

Application programming interface (API) *refers to functions, routines, and libraries that are used to accelerate application software development."* (Beningo, 2017.)

1.2.2 Typical Layered Architecture

Figure 1 illustrates the typical embedded / SoC products having the layered architecture. Broadly, embedded SW products are classified into "Application Software", "Operating System Software", and "Hardware". The design and development of the SoC HW are carried out with Hardware Description Language (VHDL) or Verilog etc. Hence, we can visualize similar layered architecture within the HW layer design itself.

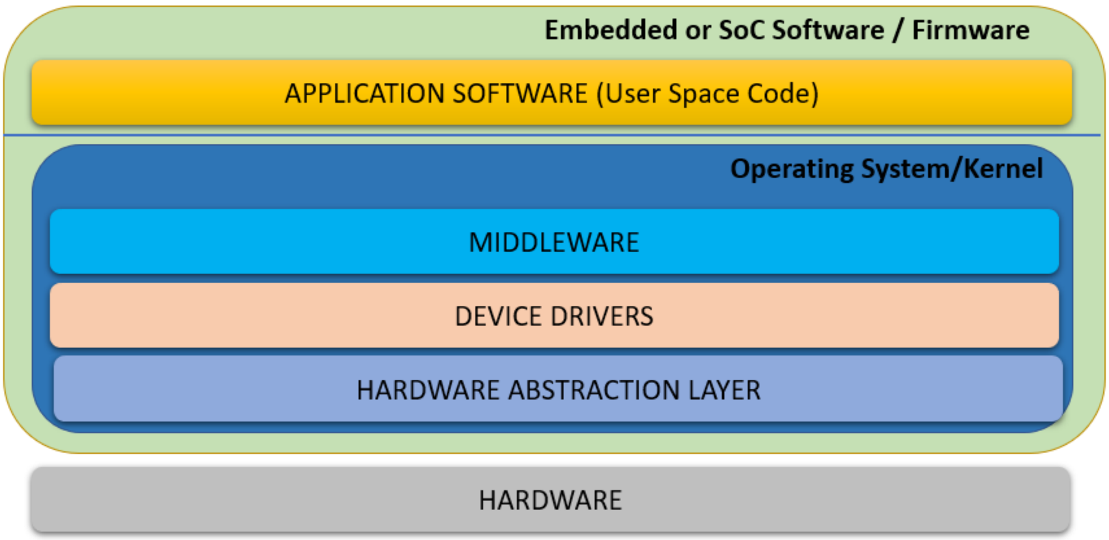

FIGURE 1. Typical Layered Software Architecture of SoC Software/firmware product.

The SoC chip will have CPUs, Memory, peripherals, Hardware IPs, power, clock circuitry, etc. and the Bus which connects them. Here is an example illustrated in figure 2 below, where one or more SoC and ASIC products have been embedded by any electronic product.

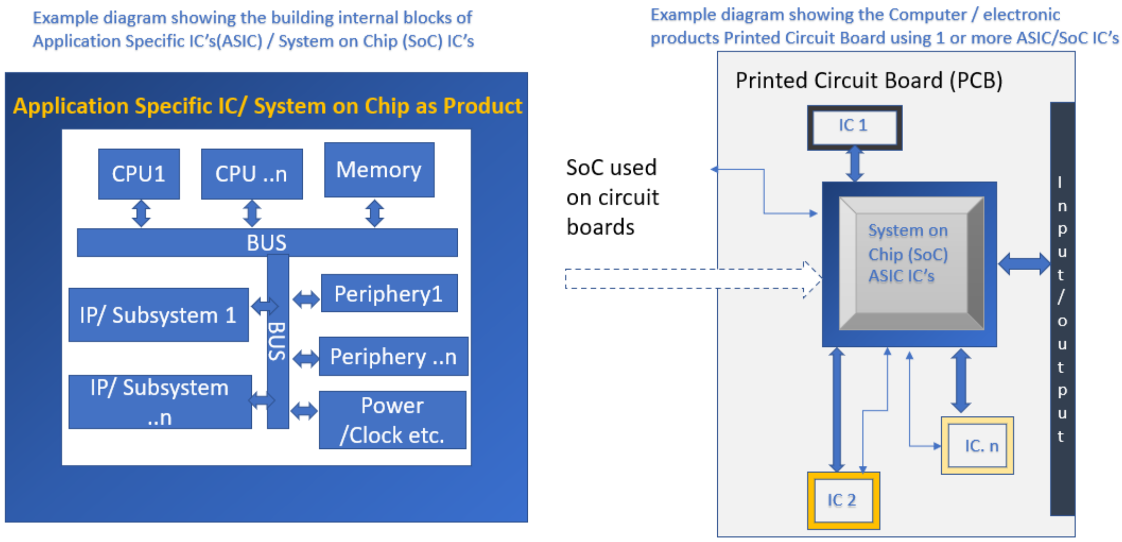

FIGURE 2. An example illustration of internal blocks of ASIC /SoC product.

On the other hand, the design and development of the SoC chipset itself is an independent sellable product. The main scope of the research study is the SoC chipset product development business.

A typical embedded product development life cycle involves,

1. Ideation / Exploration Phase – The innovative product idea is conceptualized and carried out with feasibility studies to ensure the concept can be realized into a product.

2. Planning Phase – The realized idea goes into the detailed planning process of the program, budget, resources, timeline, milestones etc., to execute the product development successfully.

3. Development Phase – The detailed requirements emerge from the collaboration of feasibility and product development teams. The concrete requirements are then input for hardware design and software design and development delivered in several milestones in an agile way.

4. Production and Deployment Phase – The final SoC design is frozen. The fabrication of the SoC chip as an ASIC product is mass-produced after final verification and shipped to the customer or deployed in electronic products.

Figure 3 illustrates the phases mentioned above during the product development overlapping on the timeline.

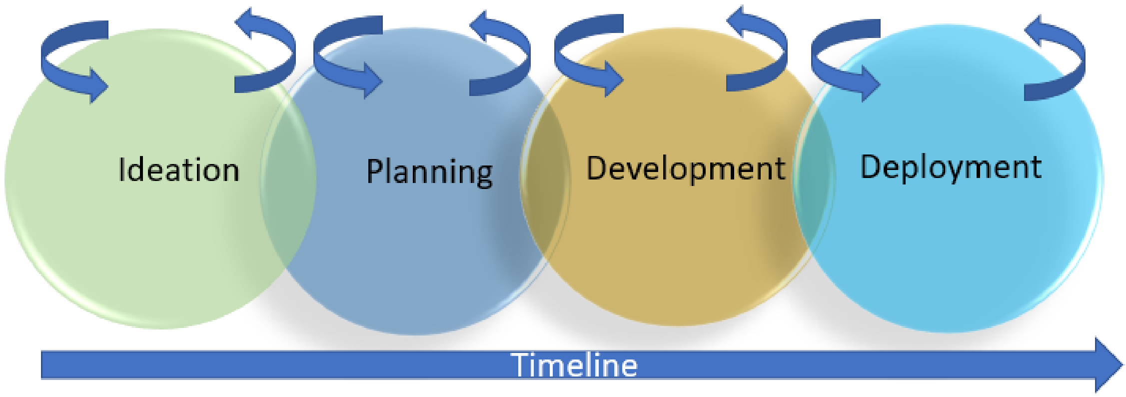

FIGURE 3. The typical product development process in embedded SoC products.

Figure 4 below captures the typical embedded electronic product development lifecycle on the Swimlane map. The embedded / consumer electronic product development involves hardware (HW) and software (SW) designs that are carried out in several stages during the Product Development Life Cycle. The HW design and development phase are smaller compared to SoC product development.

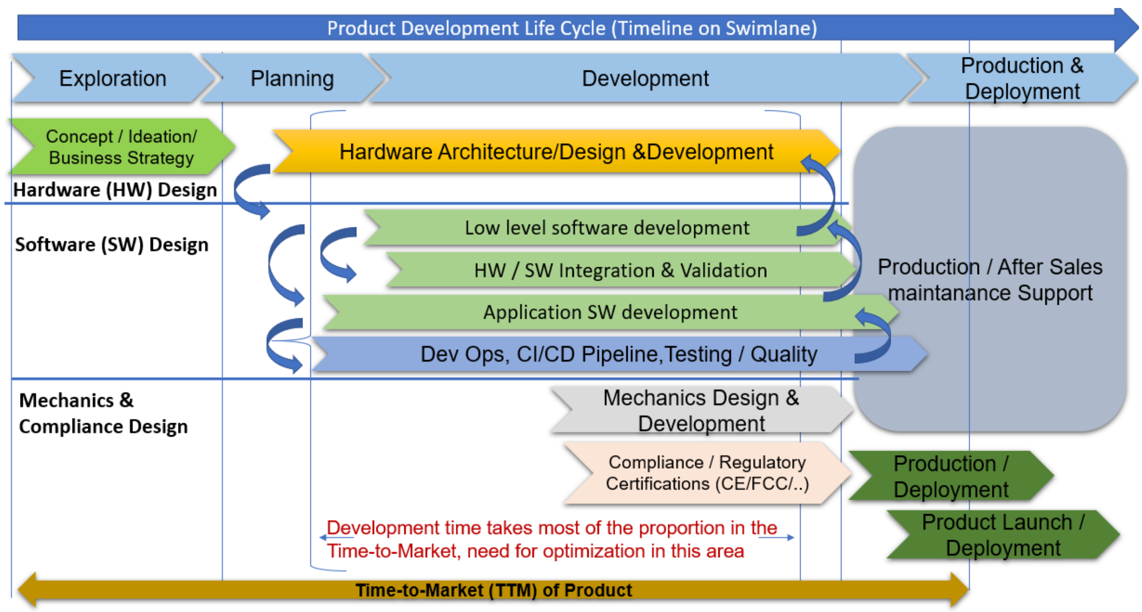

FIGURE 4. Typical embedded electronic products development lifecycle.

On the other hand, the SoC product development involves both HW and SW designs carried out in several stages. Still, the difference is that hardware design and development take many more complex steps in SoC development than electronic products such as cell phones or laptops etc.

The SoC HW design involves “Modeling” designs, “Physical Signal Design and RTL Design”, “Synthesis”, and “Physical Design and Verification” stages. The SW design involves designing the “device drivers / low-level software / operating system software”, “Integration and Verification SW”, and “Application Software”. The following figure 5 tries to plot the making of the SoC product on the Swimlane map as described before.

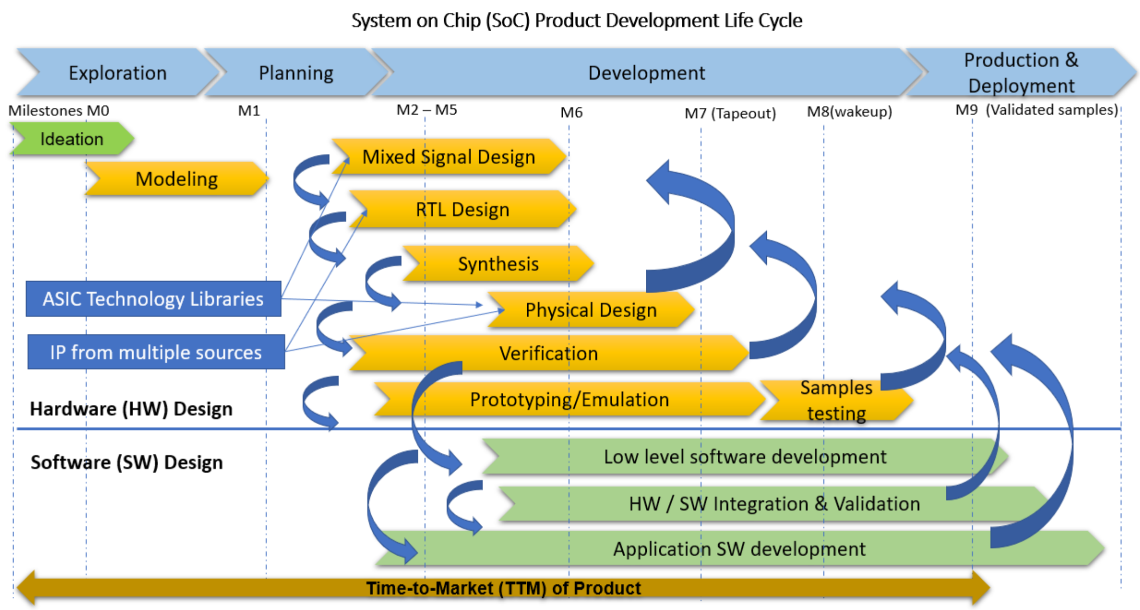

FIGURE 5. SoC Product life cycle. Adapted from sochub.fi (2021).

The duration of product design, development and verification/testing takes most of the time in the entire value stream of the product. Even the variants created from the already existing product lines can take almost the same development effort. Reducing the product development time by a reusable, modular, configurable strategy can reduce the time-to-market (TTM) of the product and increase the productivity of the product development. A collective improvement of the product lines can improve the agility and sustainability of the whole business.

1.3 The purpose of the research and the research questions

The main purpose of the research study is to identify the pain points in the product development and come up with a list of recommendations for the SoC product development business to help improve the Time to Market (TTM) of SoC products.

The thesis mainly addresses the following important questions:

1. How can a technology company optimize the product development time / improve the Time to Market (TTM) of the products with improved Quality?

2. How can a technology product company improve customer satisfaction in the entire product development life cycle/ after-sales support?

3. Can a technology product company improve the Time-to-Market of the product by increasing "reusability" in the product development cycle?

Customer satisfaction is crucial for the success of any business. The primary idea behind including customer satisfaction is to bring in the customer-centricity approach as one of the critical points. An example to mention is customer satisfaction during the product's after-sales / maintenance support. Hence the idea of customer satisfaction is very well thought out and has to be applied in the architecture and design of the product from the initial ideation phase itself.

Customer satisfaction and quality were emphasized in the topic of the thesis mainly to bring in more constructive ideas to improve the Time-to-Market of the product without compromising on the quality, capacity, reliability, resource, cost, safety etc., from the existing product development process and guidelines. The thesis considers the Time-to-Market as the main topic of the study, and customer satisfaction is embedded by default during the product development process. Hence it is not necessary to discuss further in detail in this thesis.

Though the main topic of the research study is to improve "Time-to-Market", during the qualitative interviews, many subtopics emerged which are connected to the main topic of study in the product business. They are,

Main research topic:

1. Improve Time-to-Market
2. Improve Customer satisfaction

Subtopics emerged during the qualitative study:

3. Agility – Changing market conditions and the requirements
4. Ease of development – Reusable, Modular, Scalable, and configurable approaches during product development
5. Ease of maintenance – Faster after-sales support and ease of troubleshooting/diagnosis.
6. Sustainability /Climate Change - Energy saving in products
7. Faster Innovation – Ease of developing innovative products with the approaches mentioned above.
8. People and Wellbeing in the product business
9. Finally, the Prosperity or profitability to innovate more products and business sustainability.

Here is figure 6, in which the author of the thesis captures all the perspectives that emerged during qualitative discussions pictorially. They are all connected to the product business and time-to-market, which are vital to achieving the overall enterprise agility & sustainability.

FIGURE 6. Perspectives around product business emerged to the author during the qualitative study.

1.4 Research Methodology

The research is based on the pragmatic philosophy and is based on the mixed-method approach, which includes both qualitative and quantitative studies in one research study (Tashakkori and Teddlie, 2003; Berman, 2017). “Chapter 4 RESEARCH METHODOLOGY” describes further in more detail.

1.5 Research Process of the Thesis

Here are the high-level steps followed during the research study illustrated in the following figure 7,

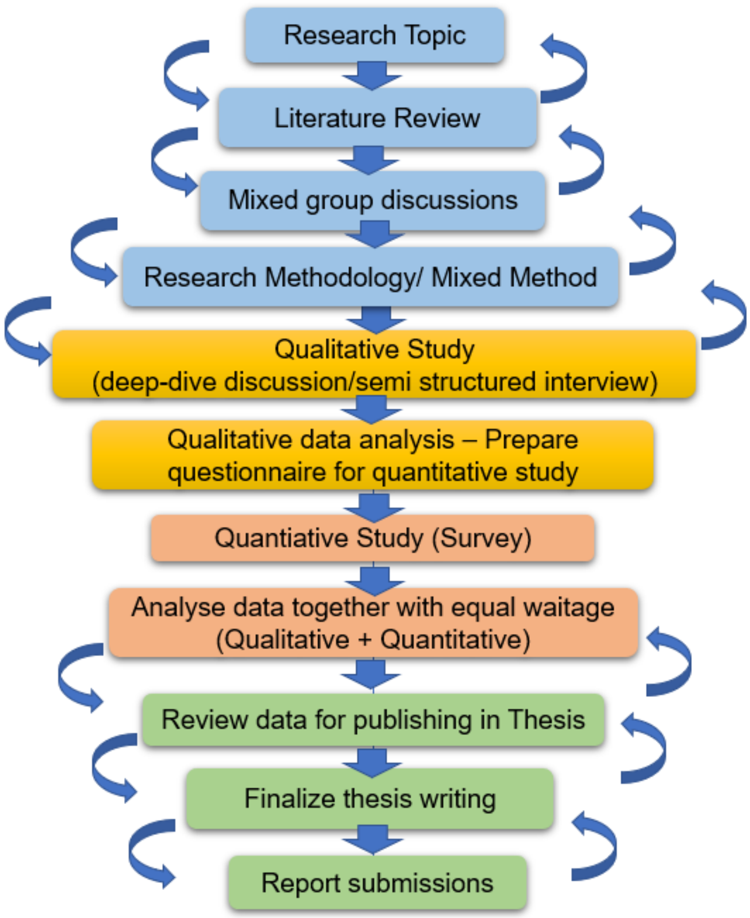

FIGURE 7. The research process of this thesis. Adapted from ‘The research process’ (Saunders, Lewis and Thornhill, 2007).

1.6 Structure of the Thesis

The Thesis contains eight chapters and two appendices. Here is the list of chapters and a brief description of them,

Chapter 1: Introduction – This chapter

Chapter 2: Concepts for successful product business – which provides the background of the literature and the knowledge base relevant to the topic of the study. The chapter captures and builds the theory around the topic of the thesis. It captures the important concepts which are vital for a product business, both the technology domain and business leadership and management domains.

Chapter 3: Analytical Framework – This chapter provides insights into the relevant frameworks and can be taken into use to address the research problems of the thesis. The recommendations are based on the standard methods that could potentially yield a concrete solution.

Chapter 4: Research Methodology – This chapter provides a detailed step followed in the research design and the methodological approach used in the thesis.

Chapter 5: Data Collection – This chapter captures how the data were collected during the research studies.

Chapter 6: Data Analysis – This chapter captures the analysis of the data collected during the research study.

Chapter 7: Recommendations – This chapter provides the list of findings and recommendations for further improvement.

Chapter 8: Conclusion and Discussions – This chapter goes through the whole research process, provides conclusions and limitations, and discusses suggestions for a further research study.

Appendix A: Provides the list of “Qualitative semi-structured interview questions”

2 CONCEPTS FOR SUCCESSFUL SOC PRODUCT BUSINESS

The chapter briefly describes essential concepts of the product business both in the technology domain as well as in the business domain.

2.1 Enterprise Agility

Enterprise agility is both sensing and responding to the market (Overby, Bharadwaj and Sambamurthy, 2006). Organizations need to be “agile” and develop their adaptive capability or agility if they are to survive and thrive. An agile organization can intelligently and proactively seize opportunities and react to threats and make timely, effective, sustainable changes that generate competitive advantage and give them some leverage in the marketplace or their ecosystem. (Holbeche, 2019.)

2.2 Time-to-Market (TTM)

In today’s business world, customer behaviour, demands, and needs are changing rapidly. Technology companies are under constant pressure to bring innovative products and services to meet the growing demands.

On the other hand, disruptive technological innovations pose new threats and have a significant impact on every enterprise (Forrester, 2003). The firms face pressures to reduce costs, enhance productivity, and maintain quality in new product development (Sun *et al.*, 2017). Among many threats, the competition with price, product quality, and customer satisfaction are decisive factors to stay in business. The product development time or Time-to-Market (TTM) is remarkable in the success of an enterprise.

In this dynamic global environment getting a new product to market faster rewards companies for staying competitive. The faster the company’s product gets to the market, the higher the market share and the smaller the revenue loss. (Belay, Kekäle and Helo, 2011.)

2.3 Sustainability Concerns and Challenges

Due to increased pressure to meet the frequently changing market demands, it is challenging for the technology companies to maintain profitability and, at the same time, keep up the well-being of the people as well as the environment. It is essential to embed the sustainability aspect and the product business into the organization for long term success.

The term “Sustainability” was first developed by the World Commission on Environment and Development (WCED), also known as the Brundtland Commission -in an UN-sponsored study entitled “*Our Common Future”* (Brockett, 2012). where WCED described sustainability as an approach that “meets the need of the present without compromising the ability of future generations to meet their needs.”. (*Our common future*, 1987.)

At the organizational level, the Corporate Social Responsibility (CSR) is still evolving, and some research studies point to the pitfalls, others point to “a paradox of corporate social responsibility” (Weber and Wasieleski, 2018). CSR is more attractive due to global warming and environmental challenges. The pressure is moulding on all the corporates to adapt their business quickly to excel in the organization’s economic growth and take good care of the well-being of people and the environment.

The topic of sustainability is increasingly more prominent, and the study shows that currently, software product lines face many social, economic and environmental concerns to achieve it (Chitchyan, Groher and Noppen, 2017).

As per the Triple Bottom Line (3BL) framework, the sustainability of the organization lies in the balanced well-being of people, the planet and profit (Elkington, 1994) or prosperity of the organization (Kraaijenbrink, 2019).

Figure 8 illustrates the concept of 3P Tripple Bottom Line,

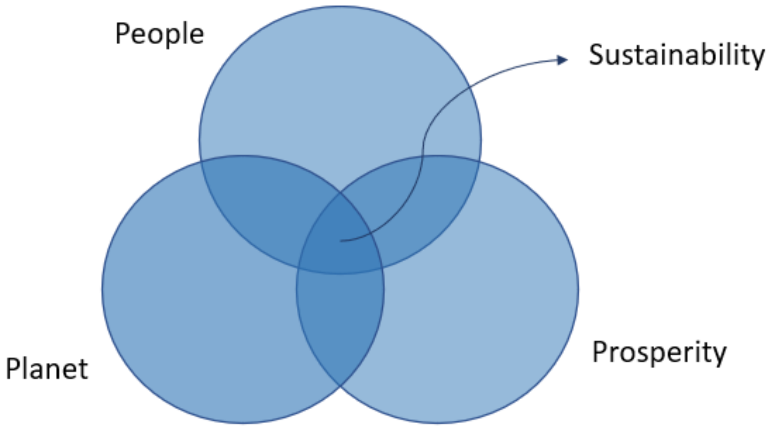

FIGURE 8. 3P Triple Bottomline People, Planet, Prosperity. Adapted from Kraaijenbrink (2019).

2.4 Current growing complexities in Software Development

As the software products evolve, the increased hierarchical dependency with other software components increases structural complexity. Software needs to be refactored to keep the structural complexity at a lower level. The excessive structural complexity is problematic for the ongoing development, testing, maintenance, and software reuse. If the complexity is at a higher level in the design hierarchy, it requires design restructuring and architecture reengineering. (Sangwan, Vercellone-Smith and Laplante, 2008.)

The repeated refactoring and architecture reengineering would increase product development time and cost and negatively impact the Return on Investment (ROI).

According to the ISO/IEC/IEEE 42010 standard, the software architecture of a system (or SoS) expresses what is essential about that system concerning its environment; components or constituent systems (in the case of SoS), how they interact, design rules, specific concerns, etc. (IEEE Standard, 2011). The complexity of the SoC product concerning the system and environment is increasing continuously. Hence the development of SoC product (Hardware and Software) architecture and design must be scalable and agile to meet the frequent changing system requirements.

Empirical studies (Tomer *et al.*, 2004s; Agresti, 2011) have shown that systematic software reuse can increase productivity and reduce product development time. The reusability approach can be applied to the SoC Products in Software/firmware design and development and always maintain business agility irrespective of market conditions.

2.5 Modularity in software increases reusability

Modularity in software is the functional separation of programs into more interchangeable modules. Each module contains a header and sources to execute a specific system function through the interfaces of the exposed modules (APIs). The primary benefit of modularity is that the program is broken down into smaller pieces and organized based on purpose and function. (Beningo et al., 2017.)

Modular architectures enable flexibility for multi-purpose use. Cost efficiency can be achieved by enhancing the product platform or family of products with modular structures. (Meyer and Utterback, 1993.)

2.6 Configurability and Re-configurability in Product Development

In product development, “reconfiguring the software modules in a codebase to add or delete a feature typically requires substantial effort. This lack of flexibility increases the costs of building variants or versions of a system, and delays the time-to-market of the products, amongst other problems”. (Murphy *et al.*, 2001.)

To quickly respond to changing customer requirements, the reconfigurability allows flexibility for changing feature/ function sets with minimal rework and cost. (Diaz, 1998.)

An empirical study on embedded processor systems shows that with reconfigurable fabric with both design-time configuration and run-time configuration, the performance can be improved by up to 1.41 times and, at the same time, reduce energy by up to 60% when compared to a configurable processor at the cost of additional area. (Souza *et al.*, 2018.)

2.7 Scalability - Architecture and Agility

Agile Scrum (Schwaber and Sutherland, 2015), Agile Manifesto (https://agilemanifesto.org), and Extreme Programming (XP) came to solve the complex issues in software product development in the early 1990s. They emphasise that actual architecture emerges with time.

As stated by Satoshi Bas in the following lines, “It seems that many agile method users misunderstand what agile methods are, just ignore architecture, and jump into refactoring”. Systems thinking would be necessary if the drive is to deliver value to stakeholders. Further, Abrahamsson, Babar and Kruchten (2010) try to discover the real issues and the semantics and illustrate in figure 9 below,

“If the yellow circle in Figure (a) represents all decisions made for a software system, design decisions (purple) will be a subset, leaving many decisions at the programming level. In turn, a small subset of these design decisions will be architecturally significant (red). Some decisions are made “upstream” in the form of requirements constraints (green). Unfortunately, the decision landscape is beginning to look more like Figure (b), where not much distinction is left between design and architecture (purple equals red).”

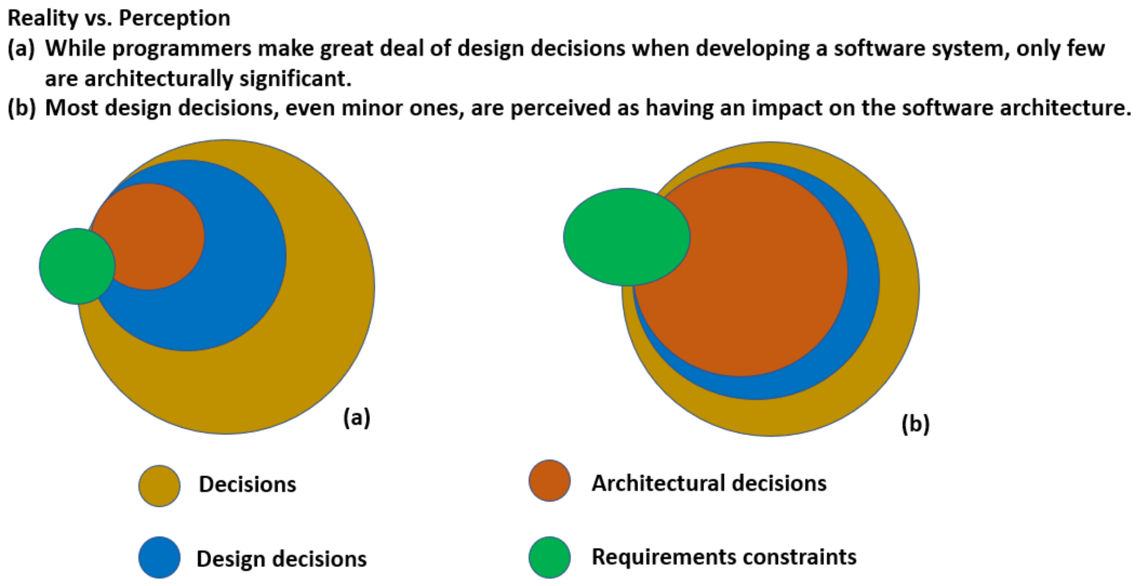

FIGURE 9. Agility and Architecture. Adapted from Abrahamsson, Babar and Kruchten (2010).

The importance of Architecture and Design decisions plays a vital role in achieving scalability in the product lines for variants for the future generation and, at the same time, supporting backwards compatibility for the previous generation of products.

The backwards compatibility of the platform can improve the competitive advantage (Kretschmer and Claussen, 2016).

2.8 Model-Based Systems Engineering methodology

Systems engineering is the framework that *"combines diverse engineering specialities to develop a complex product"*. The traditional approach of systems engineering is document-based, where many documents get exchanged between the stakeholders to arrive at the design to make the decision. The International Council on Systems Engineering (INCOSE) (Mirantes, 2017) defined MBSE as,

"the formalized application of modelling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases".

The Modeling is defined based on how the various stakeholders intend to use the models across the systems life cycle. The modelling languages are used to encode the design information in a model. (Fernández Pérez, 2019.)

The MBSE is widely used in the design and development of complex systems in the industries such as avionics, automotive, defence etc. The MBSE enables the systems thinking and approach while designing complex systems.

In the embedded product / SoC Products, the Model-Based Systems Engineering (MBSE) is getting more popular in the Hardware design. Recently “Software Platform Embedded Systems (SPES) 2020 “targeted making the production of embedded software across industry domains professional utilizing an integrated and powerful methodology. (Broy, 2010s; Pohl et al., 2012.)

The SPES modelling framework proposes the approach of “abstraction layers” and “viewpoints” in two-dimensional space, which focuses on the “requirements viewpoint”, “functional viewpoint”, “logical viewpoint”, and “technical viewpoint”. (Pohl et al., 2012.)

The MBSE approach and the methodology could help improve the time to market the products.

2.9 Product Business Domain - People, Process & Practices

2.9.1 People

People or the organisation's employees, Process the sequence or series of steps followed, and Practices govern the actions and methods applied to achieve the organisation's overall goal.

The success of any business lies in the effective utilization of 3P’s People, Process and Practices, as illustrated in figure 10,

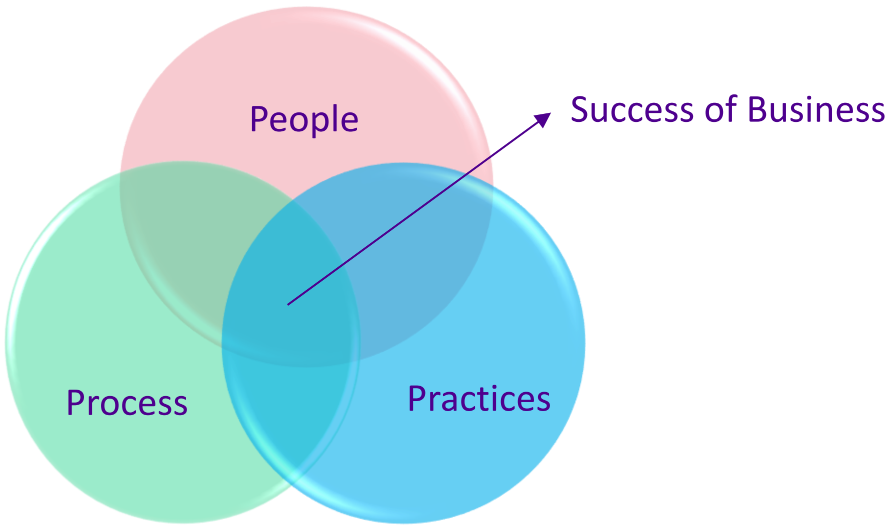

FIGURE 10. 3P's People, Process and Practices for Successful Business.

To uncover the better ways of developing and engaging people in the workplace the Manifesto for Agile HR Development (https://www.agilehrmanifesto.org) the following guidelines are proposed,

"Collaborative networks over hierarchical structures
Transparency over secrecy
Adaptability over prescriptiveness
Inspiration and engagement over management and retention
Intrinsic motivation over extrinsic rewards
Ambition over obligation."

The Disciplined Agile® Mindset for People Management, together with Pia Maia (Rittmaster, 2020), provides principles, promises, and guidelines for the effective people management as,

1. *People aren't resources*
2. *Enable team agility*
3. *Energize people*
4. *Enable people*
5. *Inspire leadership*

6. *The reward for agile behaviours*
7. *Enable cultural and structural fit*
8. *Be flexible*
9. *Reduce cycle time*
10. *Govern lightly* (Rittmaster, 2020)

2.9.2 Process

There are many processes involved in the whole product life cycle, which could impact directly or indirectly for time-to-market of the product business. As illustrated in figure 4, there are broadly Ideation, Planning, Development & Deployment phases in the product development process. Further, there are HW design process, SW design process, Project management process, collaboration and communication process and so on, to describe some

Communication & Collaboration

The global project management framework specifies practices that can increase communication and collaboration over distance, helping the management of virtual and multicultural teams

1. *Stakeholders and communication channels*
2. *Rules and templates*
3. *Global communication strategy*
4. *Global communication techniques*
5. *Global creativity* (Binder, 2016)

Knowledge sharing

Knowledge implies purposeless communion with reality and with other agents or teams (Silva and AgustíiCullell, 2008). Knowledge sharing across the teams and collaborative learning have a major impact on the overall productivity of the organization.

In the organizational hierarchy, the flow of knowledge vertically between top and bottom and horizontally between the teams could help to improve productivity. The teams share the learning through workshops, social learning, etc., which can positively impact.

Periodic process innovation could significantly improve the productivity and hence time-to-market of the products.

2.9.3 Practices

The empirical Agile Scrum/ Scaled Agile Framework (SAFe) has the potential to empower the team and deliver innovative outcomes (Malik, Sarwar and Orr, 2021). Agile thinking attempts to simplify things by reducing the complexity of planning, focusing on customer value, and shaping a fruitful climate of participation and collaboration. (Stober and Hansmann, 2009.)

The Agile methods and practices are further described in “Chapter 3, ANALYTICAL FRAMEWORK”.

2.10 Leadership

The term *leadership* has many definitions (Gibson and Weber, 2015). Leadership is defined by one set of authors as the art of mobilizing other people to want to struggle for shared aspirations (Kouzes and Posner, 2007). In contrast, others define leadership as the ability to influence a group toward achieving a vision or set of goals (Robbins and Judge, 2015).

Leadership is the foundation of the success of an organization. The leadership journey starts from the self when driven with the proper purpose and leads the team and the whole organization towards success.

As per Reiss (2004), the leadership starts with self-motivation, which can be an empirically testable theory of 16 basic desires to move on to a purpose-driven journey.

The guide to the Project Management Body of Knowledge (PMBOK) (Project Management Institute, 2021; Boral, 2016) states that the leadership and project management are based on the four values of ethics

- *Responsibility,*
- *Respect,*
- *Fairness, and*
- *Honesty* (Project Management Institute, 2021).

As per Goleman (1999) Emotional intelligence skill of a leader is very important for the success and is listed below as it is and the author of the thesis tried to illustrate the same with the figure 11,

"Self-awareness—knowing one's strengths, weaknesses, drives, values, and impact on others
Self-regulation—controlling or redirecting disruptive impulses and moods
Motivation—relishing achievement for its own sake
Empathy—understanding other people's emotional makeup
Social skill—building rapport with others to move them in desired directions." (Goleman, 1999.)

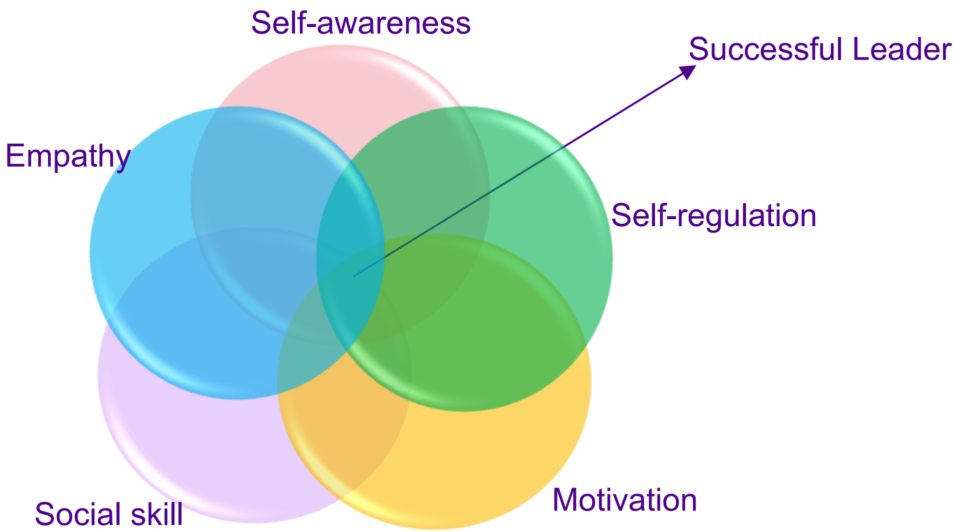

FIGURE 11. What makes a Leader? (Adapted from Goleman, 1999)

The Lean-Agile (SAFe) mindset embraces the openness to change and proposes the foundation for Lean-Agile leadership with four pillars.

1. *Respect for People and Culture – Respect for people and culture is a basic need. When treated with respect, people are empowered to evolve their practices and improve.*

2. *Flow – establish a continuous flow of work that supports incremental delivery based on constant feedback and adjustment.*

3. *Innovation – Coach and mentor innovation and entrepreneurship in the organizational workforce. Provide time and space for people to be creative to enable purposeful innovation.*

4. *Relentless Improvement – encourages learning and growth through continuous reflection and process enhancements.*

5. *Foundation Leadership - The foundation for Lean is leadership, a key enabler for team success.* (Leffingwell, 2018.)

Empathy, visionary thinking, and transformational leadership qualities of an individual lead the team and the organization to great success. The collective success of individual teams is remarkable in the organisation's success. In contrast, the collective success of every individual in the organisation as a leader could lead the organization to the greatest success path.

3 ANALYTICAL FRAMEWORK

The chapter describes the frameworks used in the SoC product development life cycle. Here is the list of analytical frameworks discussed briefly in this chapter,

1. Scientific empirical Agile Scrum
2. Scaled Agile Framework (SAFe) method.
3. Lean Thinking & Lean Flow-efficiency
4. Model-Based Systems Engineering method.

3.1 Scientific empirical Agile Scrum framework

The agile Scrum framework came into use in the 1990s to address complex problem-solving in software products. The successful use of Scrum depends on people becoming more proficient in living five values:

“Commitment, Focus, Openness, Respect, and Courage”

Scrum is founded on empiricism and lean thinking. The empiricism is based on *“transparency, inspection and adaptation”.*

The Scrum Team is small enough to remain agile, nimble and large enough to complete significant work within a Sprint, typically ten or fewer people. The main strength of the Scrum team is cross-functional, meaning the members have all the skills necessary to create value for each Sprint. They are also self-managing, meaning they internally decide who does what, when, and how. (Schwaber and Sutherland, 2015.)

Here is the scrum framework, illustrated in figure 12, a self-organizing and cross-functional Scrum team planning, executing and incremental delivery in the Sprint.

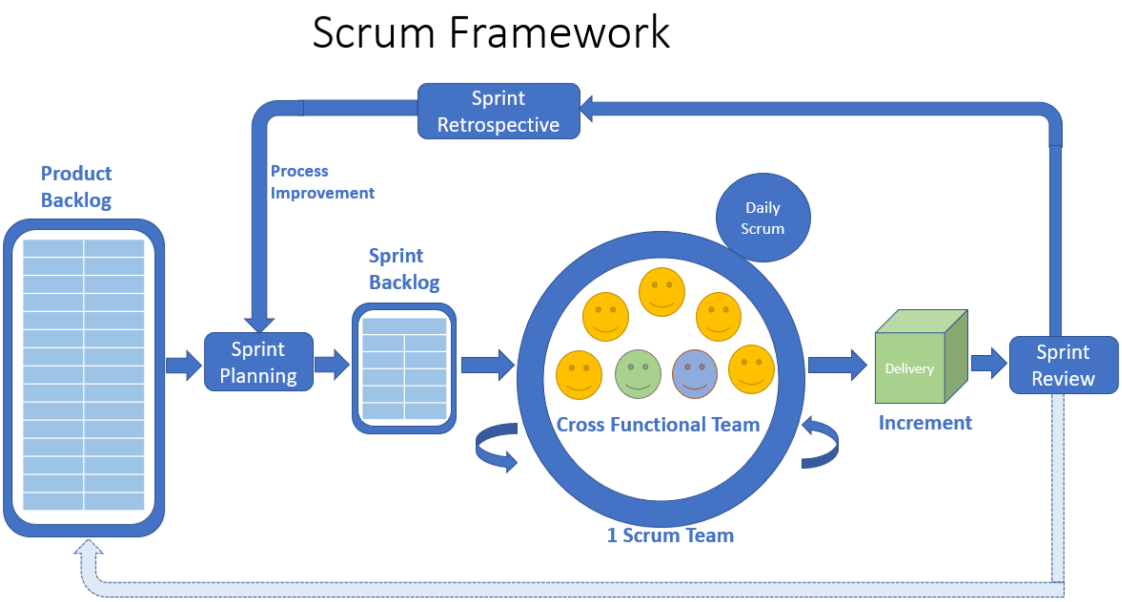

FIGURE 12. The Scrum Framework. Adapted from Schwaber and Sutherland (2015).

3.2 Lean Thinking and Principles for Product Development

Traditionally, the "Lean" concepts/approaches were developed for the manufacturing industry (Ohno, 1988; Womack, 1996), but the definition of lean is drifting out of manufacturing and is widely applied to other fields as the concept of new product development. (Baines *et al.*, 2006s; Salgado and Dekkers, 2018.)

"Lean Thinking" defines the five principles, which are,

1. *Define Value*
2. *Map the value stream*
3. *Create Flow,*
4. *Establish the pull and*
5. *The Pursuit for perfection (Womack, 1996.)*

The 13 principles of the Toyota product development system (Liker and Morgan, 2011) have created the baseline for widening the application of lean concepts to the entire value stream to eliminate waste and unwanted waiting time and improve the flow efficiency and productivity in the system which enhances business value.

Also, the seven lean principles defined for “software development”,

1. *Eliminate waste,*
2. *Create knowledge*
3. *Build Quality In*
4. *Defer commitment*
5. *Deliver fast*
6. *Respect for people*
7. *Optimize the Whole value stream (Shalloway, 2010.)*

3.3 Lean-Flow Efficiency

The “flow efficiency” is the amount of time it takes from identifying a need to satisfying that need. Resource efficiency focuses on efficiently utilizing the resource that adds value to the organization, whereas flow efficiency focuses on the unit that is processed in the organization. This moves the resource focus to customer focus. (Modig, 2013.)

The resource-efficient system could create more waiting time and reduce the flow of the intended work quickly in the value stream. Organizations practising to achieve high flow efficiency with higher resource efficiency will land in the perfect state to achieve enterprise agility. In the SoC Product development, to get the products quickly with good modular architecture, the whole development process should increase the flow efficiency to get the product faster to market. This could be the key to achieving enterprise agility.

In figure 13, the author tries to apply the lean efficiency matrix to the SoC or embedded product development life cycle. The mapping of higher “lean-efficiency” improvement can be achieved with a combination of high flow efficiency and high resource efficiency with the effective application of Lean and Agile methodologies for the entire value stream of product development.

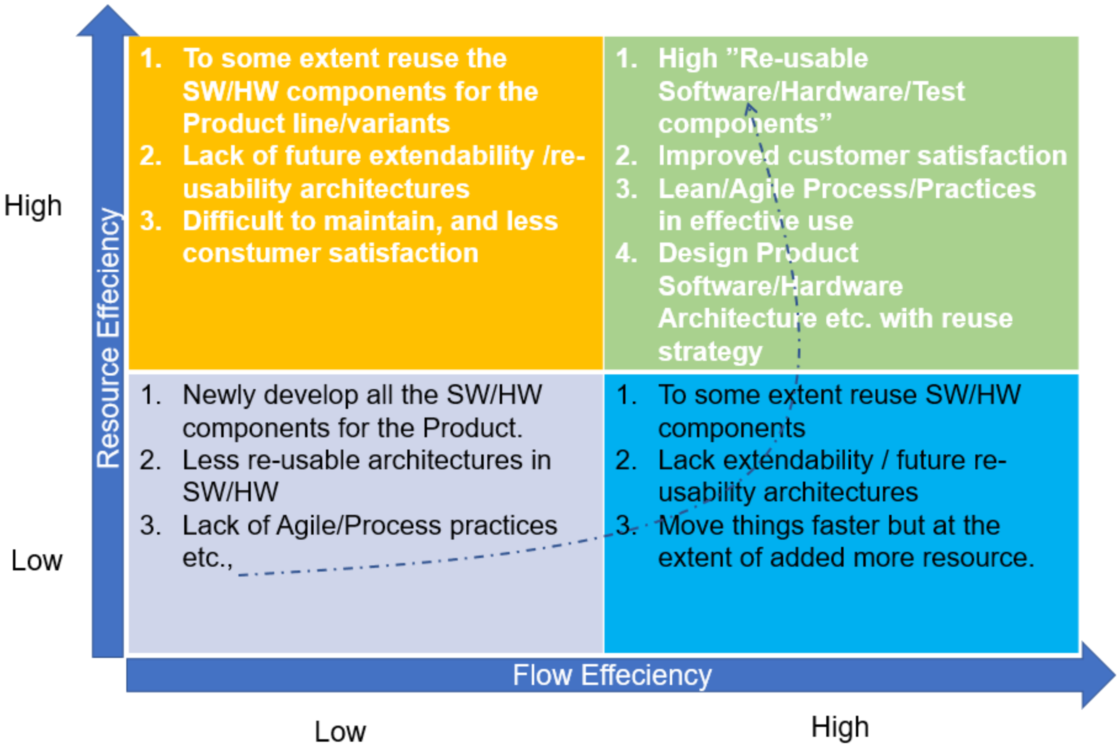

FIGURE 13. Custom application of Lean efficiency matrix onto the value stream of the product lifecycle. Adapted from Modig (2013).

3.4 Scaled Agile Framework (SAFe)

The effectiveness of Scrum is achieved with a smaller team size from 3 to 10 persons. The Scaled Agile Framework (SAFe) came into popularity to address the larger size of the team. It combines the team of teams or the larger group in the whole product development process.

Integrating Agile principles with the Lean Principles and the Scaled Agile Framework (SAFe) defines the best product development process and practices to achieve enterprise agility (Leffingwell, 2018).

The "Lean Thinking and Principles" are one of the research methods of this thesis on eliminating waste, reducing the unwanted waiting time in the process, and improving flow efficiency. Eventually, this will reduce the overall Time-to-Market of the embedded / SoC Products.

4 RESEARCH METHODOLOGY

The chapter goes through the methodology used in the research and data collection. It also introduces the reasoning behind choosing the research method. The sequence of steps carried out during the research process is illustrated.

4.1 Mixed method research

The study is based on the pragmatic research philosophy. For the pragmatic research philosophy, the mixed-method is the closest approach (Tashakkori, A. & Teddlie, 1998). The mixed-method combines qualitative and quantitative data collection and data analysis in one study (Tashakkori and Teddlie, 2003; Hanson et al., 2005).

As mentioned by Ivankova and Wingo (2018), why researchers use mixed-method further as stated below,
"Researchers use mixed methods research when they collect, analyze, and integrate both quantitative and qualitative data within a study or program of inquiry to generate conclusions that are more credible or convincing (Creswell and Tashakkori, 2007)*. Using mixed methods allows researchers to address complex research questions, find answers to both exploratory and confirmatory questions within a single study, and reveal a fuller picture of a problem in practice* (Bliss, 2008)*".* (Ivankova and Wingo, 2018.)

The mixed-method is increasingly popular in management research in recent years as it has the potential to offset the drawbacks of the mono method (Mamabolo and Myres, 2019). One of the benefits of the mixed research method is the convergence of the data collected by all methods in a study to enhance the credibility of the research findings (Hesse-Biber, 2010).

The design topology used in this research study is *"Exploratory sequential design ("Exploratives Design")",* where the first phase of qualitative data collection and analysis is followed by the collection of quantitative data to test or generalize the initial qualitative results. (Schoonenboom and Johnson, 2017.)

In the three-dimensional typology of designs, the typology of mixed methods designs falls into the category of “Fully mixed sequential equal status design”, which involves conducting a study that mixes qualitative and quantitative research within one or more of, or across the stages of the research process. (Leech and Onwuegbuzie, 2007.)

4.2 Mapping on “The research ‘onion’”

Here is figure 14, which illustrates the overall research design and approach followed during this thesis, which the author of the thesis tried to map on the “The research ‘onion’ (Saunders, Lewis and Thornhill, 2007).”

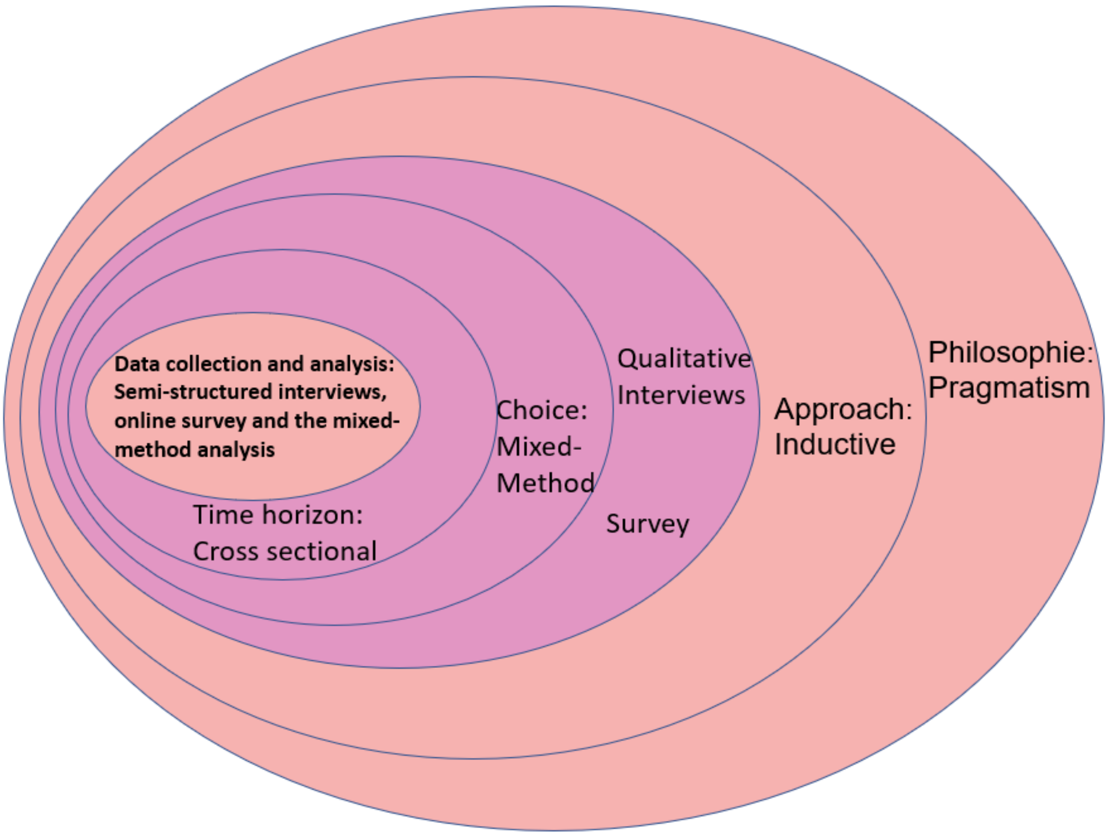

FIGURE 14. Mapping the study on research onion. Adapted from The research ‘onion’ (Saunders, Lewis and Thornhill, 2007).

4.3 Funnel of sequential steps

Below are the steps sequential steps followed during this research study, and the figure 15 illustrates the same,

1. Mixed Methods approach
   I). Qualitative data collection with semi-structured anonymous interviews with selected persons individually,
   II) Based on the input during the semi-structured interview, arrived at the questionnaire for the survey
   III). Quantitative data collection with a larger audience anonymously with the survey. Collect both quantitative and narrative data inputs from the participants.
2. Analyze both the qualitative and quantitative data together with equal weightage anonymously
3. The analyzed results are shared with the organization as a report.
4. The reviewed results are included in this thesis, and confidential information is collected in Appendix B and is excluded from the public report.

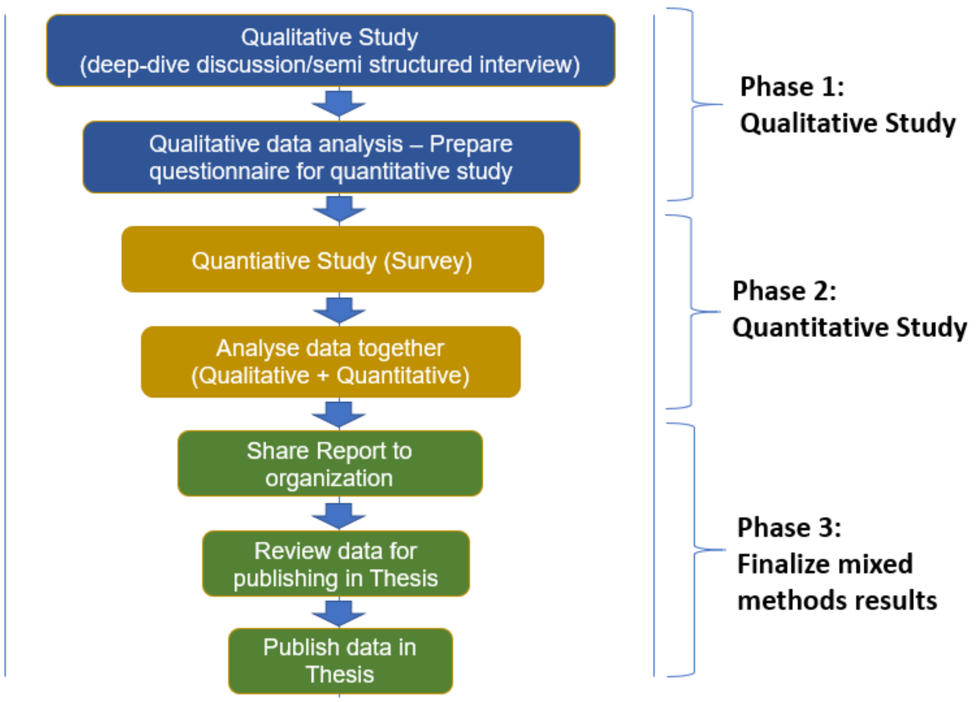

FIGURE 15. Mixed methodology – Funnel of sequential steps followed during this research study.

5 DATA COLLECTION

As a positive outcome of this research process, many perspectives emerged around the product business. The chapter explains the sampling method and process followed during the data collection during both qualitative interviews and quantitative surveys. The author has illustrated them with a diagram in this chapter.

5.1 Timeline of data collection

The qualitative data collection lasted for around 5 to 6 weeks which involved preparing the semi-structured questions for qualitative interviews and approaching the identified persons to agree on their suitable time for the semi-structured interview.

In the last phase of the qualitative study, the author started preparing for the quantitative survey with a questionnaire. The survey was active for a total of 2 weeks for participation. After the survey was closed, the data analysis and report finalization took around 3 to 4 weeks. Figure 16 illustrates the schedule and milestones achieved on the timeline.

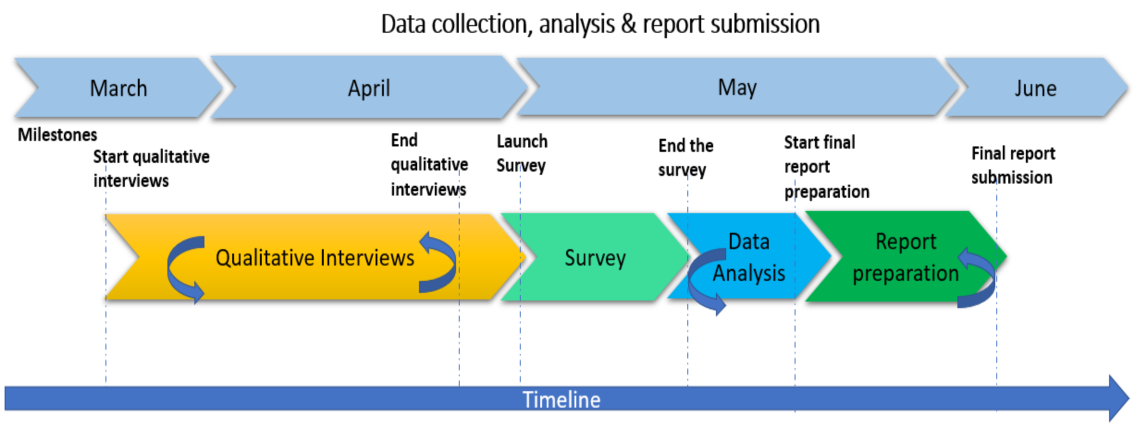

FIGURE 16. Schedule and milestones of thesis achieved on the timeline.

5.2 Data collection - Qualitative interviews

This section describes all the steps carried out during the qualitative research. The sampling method during the data collection, preparations carried out before the semi-structured interview, and the process followed during and after the semi-structured interviews.

5.2.1 Sampling method

The life cycle of the SoC product development involves many phases, and many teams are involved in developing the whole product. Individuals from multiple departments across the organisation were carefully selected for the interview to get more information and deep insights into the entire product life cycle. The sampling method used in choosing the individuals for qualitative discussion is purposeful sampling (Patton, 1990).

The individuals for the interview were selected based on the following criteria, such as

1. Role
2. Area of expertise
3. Experience working in multiple departments /sub-organizations
4. Duration of experience in the current organization

The qualitative study involved performing a semi-structured interview with selected 18 persons individually across the organization. Five persons were from business leadership and program management roles, three persons from architecture roles, six persons from technical leadership roles and four persons from design and development roles.

In figure 17, the author tried to map the careful selection of individuals for the interview across the organization who have expertise in different areas in the product development life cycle.

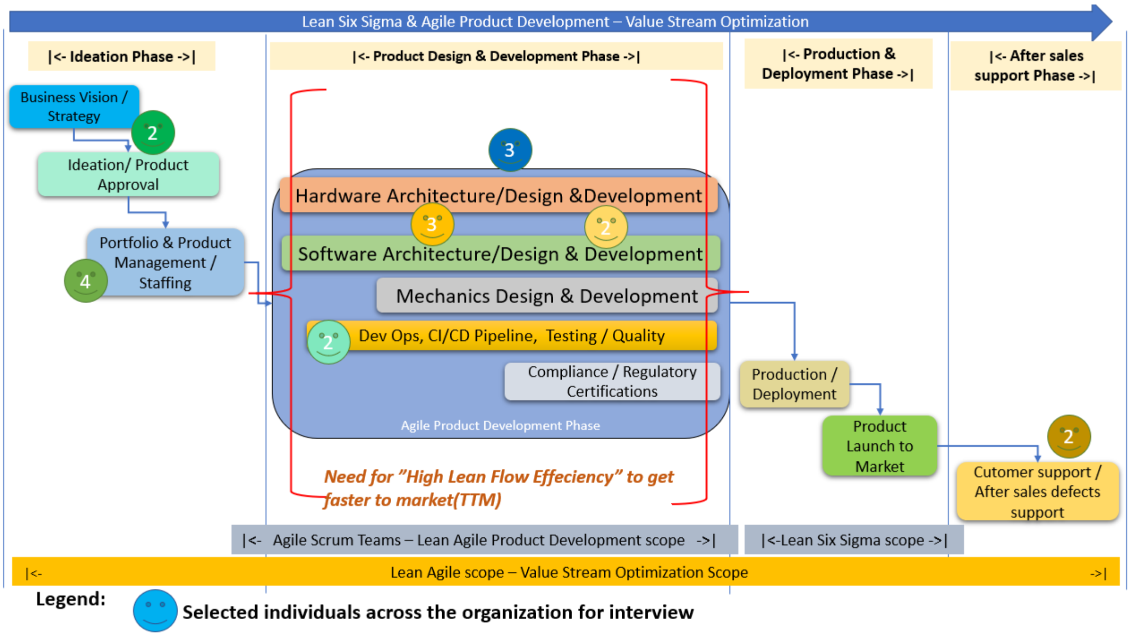

FIGURE 17. Sampling – Number of individuals selected across the organization for a qualitative study.

The author approached a few identified individuals working in the production and deployment phase of the product, but due to the busy working schedule on their side could not get an appointment from them for the interview within the timeline of the qualitative research study. Hence figure 17 captures the same.

All the 18 individuals are from 7 different departments/sub-organizations. Twelve persons had more than 20 years of total working experience, and most of them had long working experience in the same company. Three persons had more than 12 years of experience. Three persons had less than five years of total experience in the Information Technology (IT) product development business. Out of 18 persons, 12 of them had worked many years in multiple departments/sub-organizations across the organization.

5.2.2 Before the interview

All the participants were approached individually and found their interest in the topic of the research study. They were requested by email and agreed to the possible time for them to have a semi-structured interview. The formal invitation for an online interview was created with Microsoft Teams.

While creating the online teams meeting invitation, a one-page document providing an overview of the following topics mentioned below,

1. The topic of the research study
2. Research Objective & Purpose
3. Main research questions
4. Research Method and the process involved

A PowerPoint presentation was used for the semi-structured interview, which captured the above topics and additional information about the anonymous research study was attached to the invitation. Apart from the above two documents, for the individuals who would like to know more about the background of the research study before they appear for the discussion, an additional document which captures the initial background study of the literature review was also shared along with the interview invitation.

5.2.3 During the interview

All the participants were thanked for their interest and time for the discussion at the beginning. Everyone went through the topic of the research study and the process followed during the thesis. All the interviews were carried out in online meeting mode individually. The discussion/interview was audio recorded with the consent of the participants and transcribed verbatim for later analysis. The essential points were noted in the book during the interview to get a quick overview of the overall discussion.

The discussion was started with the question, *“What is your view on the topic of the thesis? Do you think it adds value to the SoC product business?”*.

Further, the following main research questions of the thesis were discussed deeply and openly

Research Questions:

1. How can a technology company optimize the product development time / improve the Time to Market (TTM) of the products with improved Quality?

2. How can a technology product company improve customer satisfaction in the entire product development life cycle/ after-sales support?

3. Can a technology product company improve the Time-to-Market of the product by increasing "reusability" in the product development cycle?

During the discussion, many open-ended and probing questions were asked depending on the circumstance to deeply understand if there are any pain points in those areas. During the interview, they were also asked how to address those pain points to improve further. With the continuous learning from the previous interviews arrived at additional topics and questions used with most of the participants. The interview questions are listed in "Appendix A. Qualitative semi-structured interview questions".

While doing the qualitative interview, many perspectives emerged around the main topic of the research study. Initially, the main research topics such as Time-to-Market, and Customer Satisfaction were used for discussion. While probing with open-ended questions, many more subtopics emerged that were very important not only to improve the time-to-market of the product but also to have a long-term sustainable growth of the product business, as described earlier in the "Chapter 1 INTRODUCTION".

The duration of the interviews ranged from a minimum of 1 hour to a maximum of 2 hours, depending upon the topic. The average time of all the 18 interviews lasted more than 1 hour and 30 minutes.

5.2.4 After the interview

After finishing the interview, on the same day, the empirical observations, findings and important narrations were captured in the text document mapping each person with an anonymous coded name. The audio recordings were transcribed in the default English language and stored with the code names.

It helped to analyse the transcriptions quickly, and at the same time real identity of the participant was protected. The data files were archived in the personal computer with the encrypted file format and password-protected to enhance the safety and security of the data collected and ensured that privacy and compliance with data protection (GDPR) were achieved successfully. After the final submission of the thesis, those encrypted coded data archive files were deleted permanently from the computer disk.

The initial analysis and findings from the qualitative interviews further proceeded to collect the quantitative data from a large audience within the organization with a survey.

5.3 Data collection - Quantitative survey

Quantitative research was used for collecting and analyzing numerical and qualitative text data. The survey intended to collect the data from the whole group of interest in the product life cycle.

5.3.1 Purpose of survey

After finishing the qualitative research, a quantitative research study with a survey questionnaire was created. The purpose of the quantitative survey was to get the inputs from a wider audience on the thesis topic and, at the same time, validate the major findings of the qualitative research data with a broader magnitude. The main aim of the survey was to get a concrete and convincing outcome overall in this research study.

5.3.2 Arriving at the questionnaire

It was challenging to arrive at a suitable questionnaire for the survey. The initial narrative analysis and empirical findings during the qualitative interviews helped arrive at the questionnaire for the survey. The questionnaire for the survey was created considering multiple perspectives around the main topic of the thesis, as illustrated in figure 6 in the "Chapter 1 INTRODUCTION".

5.3.3 Survey

Microsoft forms (https://forms.office.com) were used as a web-based tool for creating the survey. The anonymous survey was launched to the whole interest group within the organization. It was ensured in the Microsoft forms settings that it restricts the participants from outside the organization. Also, it was confirmed in the settings of the Microsoft survey forms that one person could participate only once during the period of the survey. Figure 18 illustrates the 5-point Liker's scale used for arriving at the survey questionnaire,

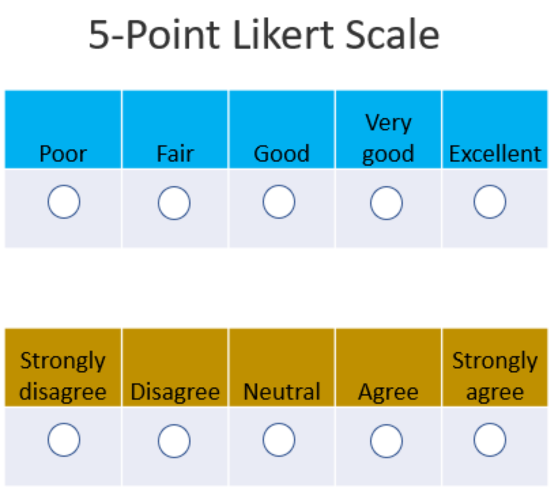

FIGURE 18. The 5-Point Likert scale type of questions was used in the survey. Adapted from (LIKERT, ROSLOW and MURPHY, 1993).

The whole survey questions were composed of "blue scale" & "blown scale", as illustrated in figure 18.

The “blue scale” in figure 18 was used only for a few questions to get simple, straightforward verbal answers, and the results were not averaged during the data analysis.

The “brown scale” in figure 18 was used for most of the questions in the survey. The average out of the 5-point scale was carried out during the data analysis. The 5-point scale percentages were converted into 3-point scale percentages for comparison. Further, a verbal summary was derived from the data analysis to suggest the recommendations.

The questionnaire was framed in such a way so that the majority of questions are “optional”, and participants can skip the questions/statements if they like to do so. This option not only to adds flexibility for the participant, but on the other hand, it boosts the confidence level of answered results in the survey.

The survey was communicated with an email request to all the interest groups related to the entire SoC product development phases. A couple of gentle reminders were sent to encourage the interested individuals to participate in the survey.

The final anonymous data results in the Microsoft Excel format file were downloaded from the Microsoft survey forms at the end of the survey duration. This file is further used for the analysis of the survey results.

The survey was posted to the whole SoC product business comprising 500+ employees. The survey was a great success and was answered by 116 active participants across the organization. The author considers this a good accomplishment in this research study and an excellent learning experience during both qualitative and quantitative research studies.

Since the quantitative questions and the results of the data are confidential, they are collected in Appendix B, which is excluded from the public report.

6 DATA ANALYSIS

The qualitative data and observation, and findings are narrated in detail. The chapter describes the data analysis methods used to analyse the data collected during qualitative interviews and quantitative surveys. Further, the chapter describes how the results with a common overlay of the data analysis are carried out.

Due to the quantitative questionnaire's confidentiality and results are listed in Appendix B and are excluded from the public report.

6.1 Qualitative data analysis

Thematic analysis is a poorly demarcated, rarely acknowledged, yet widely used qualitative analytic method within psychology (Braun and Clarke, 2006.). Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data. It minimally organizes and describes the data set in (rich) detail. However, frequently it goes further than this and interprets various aspects of the research topic. (Boyatzis, 1998.)

The qualitative data were analyzed with both narrative analysis and thematic analysis methods. The narrative analysis involves the stories and historical background around the topic of the question. The thematic analysis is the method of analyzing the themes which arrive during the deep dive discussion. The thematic analysis is an exploratory process and time-consuming. The questions also adapt during the research process based on the themes.

As stated by Flick (2017), "*Qualitative content analysis is a method for systematically describing the meaning of qualitative data (Mayring, 2000; Schreier, 2012). It requires the researcher to focus on selected aspects of meaning, namely those aspects that relate to the overall research question. There can be many* *such aspects – some coding frames contain well over 100 categories and sub-categories – but ultimately the number of aspects is limited by the number of categories a researcher can handle*". (Flick, 2017.)

Figure 19 illustrates the qualitative data in the inductive categories model with the inductive analysis.

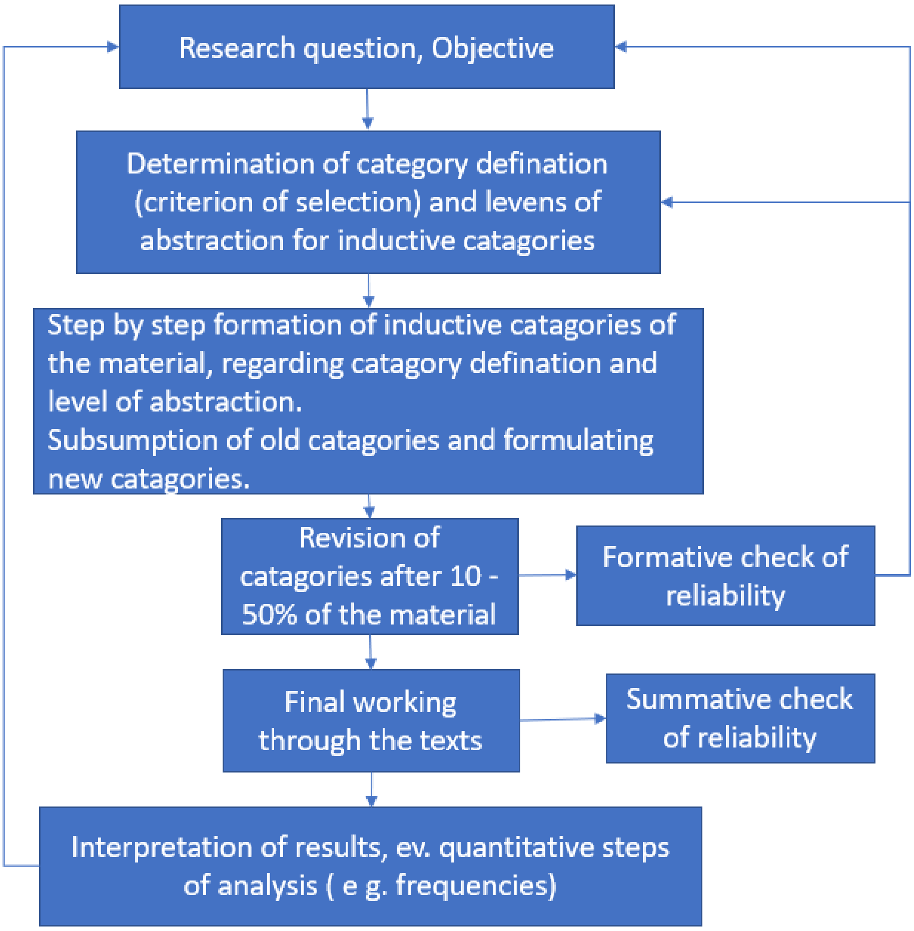

FIGURE 19. Step by step model of inductive category development. Adapted from Philipp Mayring (2000).

The qualitative data were analyzed with the various categories on the themes separated from the rich data. Broadly based on the confidence level point of view, it is coded and divided into three categories under "high self-confidence", "middle self-confidence", and "low self-confidence".

Figure 20 illustrates an example table of coding the separation and analysis of the qualitative data.

Category	Definition	Coding Rules
C1: high self confidence	High subjective conviction to have successfully coped with the situational demands, which means - to be clear about the demands and their coping possibilities, to have a positive, hopeful feeling in handling the situation, - to be sure to have coped with the demands on ones own efforts.	All three aspects of thew definition have to point to "high" self confidence no aspect only "middle". Otherwise C2: middle self confidence
C2: middle self confidence	Only partly or fluctuating conviction to have successfully coped with the situational demands	If not all aspects of definition point to "High" or "low"
K3: low self concept	Conviction to have badly coped with the situational demands, which means not to know what the situation exactly demands, - to have a negative, pessimistic feeling in handling the situation, - to be sure that ones own efforts had no effect on improving the situation.	All three aspects of definition point to low self confidence, no fluctuations recognizable

FIGURE 20. An example of coding. Adapted from Philipp Mayring (2000).

The thematic separation of the data arrived at many topics, which are then separated into various categories based on the confidence levels in the SoC product business.

- Time-to-Market
- Reusability in product development
- Requirements and management
- Environment tools and automation
- After-sales support / Customer satisfaction
- Sustainability climate / Energy saving
- Many other topics

The following sub sections provide the data analysis based on the higher self-confidence level of topics during the qualitative research study.

6.1.1 Reusability strategy

The qualitative data analysis reveals that the reusability as the strategy in the product business is beneficial in the long run and could help reduce the time-to-market of the product and its variants. This concept applied effectively could help innovative products in a shorter time than the traditional method.

It was also found and emphasized that, at times where there is no possibility to reuse, it is good to ignore the reusability altogether, take dramatic steps and come up with innovative products. Further, the following variant products created out from them could be reused.

It was also found that reusability is good in product business currently compared to previous products. Also, there are still more opportunities for improvement in this area.

6.1.2 Product making process

SoC product development is complex and involves many stages before the product is shipped to the market. As illustrated previously in figure 5, the product development involves many smaller programs such as,

1. Feasibility Study & Product planning
2. Modeling
3. Mixed-Signal Design / RTL Design
4. Synthesis
5. Physical Design
6. Verification & Emulation
7. Software design and development
8. Validation & Product Release etc., (sochub.fi, 2021.)

They are all executed in parallel and coordinated with product and portfolio programs to achieve the organisation's strategic goal.

1. Product Requirements and Management

The product requirements are broken into subprograms, for example, hardware design, software design, etc. They are taken into development in an agile framework with incremental deliveries released to the product. The observation and finding are that the product requirements, details, and flow across the teams are critical in the whole program. Due to dependencies, coordination between the sub-programs plays a vital role in achieving the final product delivery goal.

It was also noted that requirement management areas had significantly evolved in comparison to the previous history of product development. Despite that, it was found that there are some pain points in those areas. It was also emphasized in the data analysis that there is room for further improvement.

2. Development Environments / Tools / Automation

Observation and findings in this area are that the product development environment, tools, testing, and validation are crucial for achieving the targeted milestones within the schedule. There have been many improvements done in this area since earlier products.

It was also noted that there were some glitches in this area due to many reasons, and hence there is further room for improvement in this area as well.

3. After-sales

The findings and observations in those areas show that customer satisfaction with after-sales support is doing well. Many priority improvements have been made already in this area to enhance the end-user experience.

It was also noted that rarely in some cases, the maintenance support of providing the solution for the problem might take additional time than expected. Improving further in this area would be good to achieve excellent customer satisfaction.

4. Model-Based system engineering in Product Business

As described in “Chapter 3, Model-Based system engineering” MBSE is one of the methodologies used in designing and developing the SoC products. It enables systems thinking and helps streamline the product development phases from requirement creation to product design.

It was observed and found that Model-Based system engineering is one of the key methodologies which is already applied to many product developments. Most of the participants also emphasized that the method could help streamline many other areas of product development and improve the overall time-to-market of the product.

5. Sustainability & Climate/ Energy Saving

This is one of the topics that emerged during the deep dive discussion as climate change, and energy-saving is picking up global attention. Embedding the environmental aspect in the product development and system will attract more attention due to the topic's importance.

During the discussion, it was observed that the current products are far better efficient from an energy-saving point of view than earlier legacy products. It was also emphasized during the discussion by many participants that all the products should be “power-aware” in the future. It was also learnt that the power saving topic is currently already taken as one of the priorities in the organization to achieve the best energy efficiency across the product lines.

6. Knowledge sharing across teams

The whole product development goes well in a coordinated way. Sometimes if the information is not shared with the dependent teams, it could introduce some delays in the final product delivery.

One of the findings from the data analysis was that, though there is a good process in place from the communication and collaboration point of view, there are some areas where knowledge sharing across the teams would be needed. This could help to improve the overall time-to-market of the product.

6.2 Quantitative data analysis

A quantitative research study collects numerical data that must be analysed to help draw the study's conclusions. Data analysis aims to reveal the underlying patterns, trends, and relationships of a study's contextual situation..(Albers, 2017.)

The data collected from the survey generated two types of data.

1. The data output on the 5-point Likert's scale and
2. The qualitative data is in text format.

The aim of having both the type of questions in the survey was to get the numerical statistics and receive qualitative inputs from a broad audience across the organization.

The qualitative text inputs received in the survey form are similarly separated into themes, occurrence, and severity point-of-view. These inputs are converted into verbal summaries and taken into final findings in verbal form.

The anonymous survey data were converted from the 5-point Likert scale data into 3-point scale groups as below,

1. Agree+ = (Agree + Strongly Agree)
2. Neutral = Neutral
3. Disagree- = (Disagree + Strongly disagree)

These 3-point scale data results percentages were used for comparison and analysis. Further, these percentages and findings were converted into verbal form. The summary of the verbal form of finding is included in APPENDIX_B, which is excluded from the public report due to confidentiality.

Here figure 21 illustrates the grouping shown on the 5-point Liker scale pictorially,

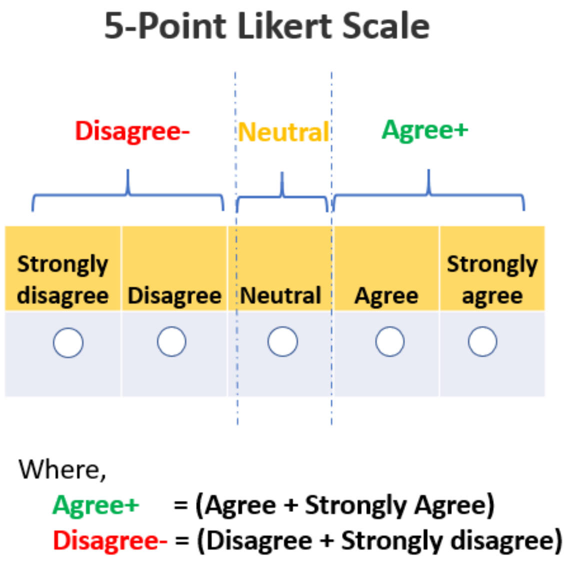

FIGURE 21. Survey data grouping from 5-Point Likers scale to 3-Point Scale. Adapted from (LIKERT et al., 1993).

The "Neutral" status result is left outside the conclusion in the analysis. If the share of "neutral" is high compared to Agree+ or Disagree- then it could reveal some interesting insights behind the question.

The survey results were analysed with a comparison of 3-point analysis in percentages and then converted into verbal form. The observation and findings in the survey are well aligned to a significant extent with the results from the qualitative study, which are described in the "Qualitative data analysis" section in this chapter before.

As mentioned previously in the thesis, since the quantitative questions and the data results are confidential, they are collected in Appendix B, which is excluded from the public report.

6.3 Mixed method data analysis

The data analysis method used in the Mixed method research is “exploratory design”, where the qualitative study was carried out at the beginning, followed by the quantitative research. Figure 22 captures the “exploratory design” method followed in the thesis pictorially,

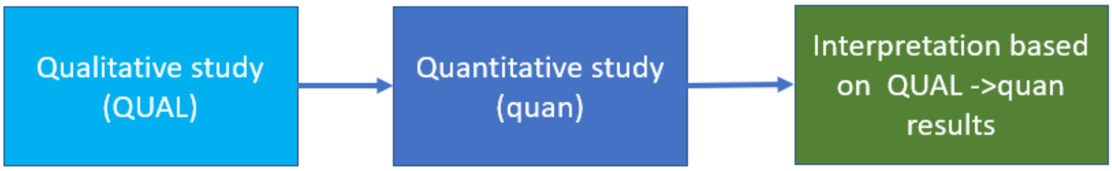

FIGURE 22. The Exploratory Design. Adapted from Creswell (2018).

The interpretation of the result is carried out with both the results of the studies having an equal weightage. The author thinks this would give the common overlay of both the results, which will be more concrete and convincing to take it forward to plan and make decisions based on the results. Figure 23 illustrates the overlay of the findings with a mixed-method,

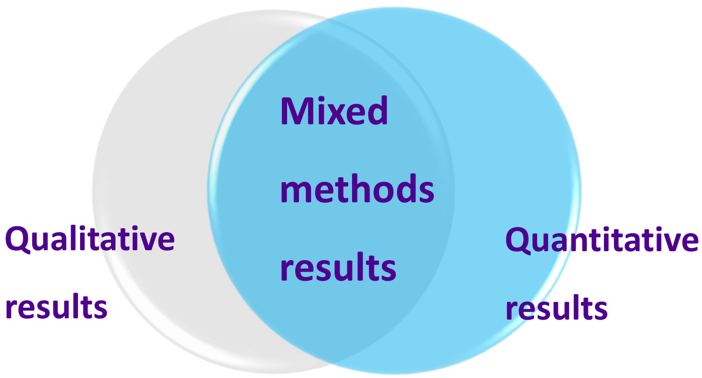

FIGURE 23. Data analysis and interpretation with equal weight in mixed method.

As mentioned before in this thesis, since the quantitative questions and the results and the verbal summary of overlay of the data results are confidential, they are collected in Appendix B, which is excluded from the public report.

Overlay of summary of both qualitative and quantitative results upholds all the findings of a qualitative study. The results, observations and conclusions are concrete and convincing, and the author sees this as a success in the research study. This overlay of results is used for arriving at the list of recommendations for the organization.

7 RECOMMENDATIONS

The chapter describes a list of recommendations for “Company X”, which will further help improve the overall time-to-market of the product. At the same time, this could help gain long-term sustainability and enterprise agility in the product business.

The chapter uses the combined results, findings and observations of mixed-method analysis described in “Chapter 6 DATA ANALYSIS” as the input for arriving at these recommendations and suggestions.

7.1 Increase the reusability across products & portfolios

As described in “Chapter 6”, the SoC product development involves a complex development process involving HW design in several stages, SW design in multiple layers, tools, verification and validation environments, Release and Delivery, automation, etc. For example, the reusability in the HW design process could be very different from the SW design process, which can be altogether different from the Tools and automation area and either so on etc.

The findings from the data analysis in this area reveal that though reusability seems to be overall good in the product development, there is scope for further improvement in certain areas.

To have better visibility on reusability across the products and portfolio, it is suggested to have it tracked in incremental milestone achievement checklists as part of the product making process. Having this visibility on the product development and portfolio level would enable a further increase in reuse and avoid spending time and effort reinventing something that other teams in the organization have already invented.

It could be good to arrive at common guidelines or suggestions on the reusability governing the whole products and portfolio management. The guidelines and checklists could help and stimulate the thought process further. Suggested to consider the essential concepts during the product development such as modular architecture and design (Broy, 2010s; Pohl et al., 2012; Meyer et al., 1993.), easily configurable (Murphy *et al.*, 2001), backwards compatible, scalable (Souza *et al.*, 2018.), and easily integrate with less effort to new product and portfolio.

The findings from the data analysis revealed that the analytical framework described in the "Chapter 3 Model-Based Engineering / Software Platform System" (Fernández Pérez, 2019; Broy, 2010s; Pohl et al., 2012) could be applied to all the product development in the future which would help greatly improve the reusability, improving the ease of development and ease of maintenance and more.

"Chapter 2 CONCEPTS FOR SUCCESSFUL PRODUCT BUSINESS" describes many essential concepts that could be considered for overall improvement in the product's time to market.

7.2 Improve the product requirements management area

Product requirements and management play a vital role in product development. The data analysis reveals that though compared with the past products it is getting better now, still there are more areas to improve further,

7.2.1 Increase the visibility

It was noted that the requirements in some areas are missing visibility across the product development teams. It was also observed that the timing of the information flow could also impact the time-to-market. It would be suggested to define the requirements at the early stage itself to a greater extent and further take it into the design and development stages.

With the findings from the analysis, it is suggested to gather all the needed information visible via a single tool or unify all the information in one place. It could improve the overall visibility and traceability of the requirements across the whole program and portfolio in the product life cycle.

7.2.2 Split the product use cases into details

The data analysis also reveals that the product requirements and use cases defined at the initial stages were at a high level. The different stages of product development involve HW design and development, SW design and development, testing, automation etc. would need separate details derived from the main product requirements.

Findings reveal that, though currently, this area seems to be doing well, there are still areas for further improvement. Hence it is recommended that breaking the high level-use cases into detailed product requirements would help.

7.2.3 Increase the collaboration & brainstorming

The product requirements are finalized at the early stages during ideation and involve several rounds of a feasibility study before the product requirements are frozen and further taken into development. The data analysis reveals that sometimes this process takes more iterations as there could be missing information between the “concepts to practicality”.

With the findings from the analysis, it is recommended to increase the brainstorming between the development and feasibility study teams. At the same time, there are opportunities to improve further collaboration (Binder, 2016) between all the groups involved in the product development.

7.3 Improve the development environment tools and automation

The product development environment, tools, frameworks, automation, etc., are vital factors to getting the product early to market.

The data analysis reveals a good amount of progress done already in this area. On the other hand, due to some reasons, there were random service breakdowns, hence it was also emphasised by the participants that there is room for further improvement.

Though there are many tools and automation environments involved in the whole product development, the author does not want to emphasise specific tools here as the process involves many tools and automation and generally suggests further improving this area.

7.4 Improve the after-sales maintenance support area

The after-sales support area is one of the crucial factors for the business's success. Sometimes this is very challenging and rewarding too.

As mentioned previously in “Chapter 6, DATA ANALYSIS”, this area needs further improvement and here are some of the recommendations drawn out from the findings from the analysis,

1. Improve the current after-sales support process

The handling of support requests takes time as product development involves many teams in the entire product life cycle. Also, the support request could go to the wrong team, which is not intended for and could cause some waste of time in handling them. The after-sales support process involves a lot of coordination to arrive at the solution.

Regarding the data analysis, it is suggested to have a dedicated after-sales team perform the initial assessment and analysis of the problem area and further hand it over to the right team to provide the solution.

2. Customer support - Improve the knowledge sharing across the teams

Many teams are involved in the investigation of the problem. There are many technical logs and guides involved during this analysis.

The findings from the data analysis are that it is recommended to improve the knowledge sharing (Silva et al., 2008) related to the customer support areas across the teams.

3. Improve the diagnostics and troubleshooting areas

The product troubleshooting involves analysing many logs from multiple systems and subsystems. As always in all the embedded systems products, identifying the problem would take considerable time and could vary.

The data analysis findings reveal that new ways of brainstorming with the teams can improve the troubleshooting and diagnostics area.

Overall, the whole after-sales and maintenance support area can be thought to be further improved in a Lean and Agile way. “Chapter 3 Lean flow efficiency” (Modig, 2013) describes the analytical framework for achieving the best results. Improvement in this area can further enhance the product business's overall “Customer satisfaction index (CSI)”.

7.5 Product Business - Increase the knowledge sharing across the teams

In the whole product development life cycle, many teams are involved horizontally and vertically. The flow of knowledge and information across the groups horizontally and vertically is essential.

Findings from the mixed-method data analysis are necessary to improve further communication and collaboration (Binder, 2016) and knowledge sharing (Silva et al., 2008) in this area. It may not be possible to have one method for all situations, and the teams could further brainstorm this topic. The thesis captures some of the standard methods in the “Chapter 2 People, Process & Practices” section, which can be thought to be taken into use.

7.6 Relook into Agile team size

In the product business, the teams work in many groups, for example, horizontal, vertical, diagonal, mixed interest groups, etc., in the whole product development life cycle. The success of every team will have a more significant impact on getting the product quickly to market.

One of the recommendations from the Scrum framework (Schwaber et al., 2015) is having a lighter team size of up to 10, as previously mentioned in the “Chapter 3 Scientific empirical Agile Scrum framework”. The effective application of the Scrum framework to the teams would help realise improvements in multiple areas that were already discussed before in this chapter. “Chapter 3 ANALYTICAL FRAMEWORK” captures more details that can be taken into use.

8 CONCLUSION AND DISCUSSION

The chapter discusses and evaluates the research process and its findings. The validity and reliability are assessed along with the limitations. The conclusion is presented in reflection of the whole study along with the suggestions for future study.

8.1 Research evaluation

The Time-to-Market of the product in a business is very important for the organisation's success. Due to the complex development process in the SoC products, the products often take more than the estimated schedule.

The main objective of the research was to identify the pain points in the product development life cycle which could harm the time-to-market of the product. The scope of the study was not only the SoC product but the whole development cycle. Though the scope of the research for the master’s thesis was a bit wide, the author thinks it was necessary to understand the problem with a big picture as there can be many other connected problems behind the main problem.

The mixed-method was chosen to better understand the problem and arrive at concrete and convincing results from the research study. The qualitative interview followed by the quantitative survey was carried out sequentially.

The qualitative study was very intensive, and within six weeks, this was completed successfully. The qualitative semi-structured interviews were planned, and the author successfully interviewed 18 individuals across the organization from many departments. The author thinks that it was a great learning experience discussing with each one of them. The interviews yielded vital information and analysis that found many areas which would need improvement.

To further get the concrete findings and to get more input from a wider audience, the survey was carried out. The survey was answered by 116 participants across the organization from multiple departments. The author of the thesis thinks it was a great success getting a good response to the survey. The analysis of the survey data emphasised many findings previously analysed in the qualitative research. The mixed-method analysis results were convincing and promising to take necessary steps based on them.

The recommendations were proposed based on the results of the mixed-method data analysis. The recommendations are based on the analytical framework and the essential concepts which are necessary for a product business both from the technology domain and management and leadership domain.

The author believes the solutions provided as recommendations in the thesis are concrete and convincing to take necessary actions in the product business based on them.

Though the research took a lot of effort and the author had to sacrifice most of his time during this thesis, the author feels satisfied and thinks it was an outstanding achievement in completing the research and proposing recommendations confidently.

8.2 Validity and reliability of the thesis

In the product development life cycle, many changes will happen with time. The results analysed in this research may not be valid or reliable after several months or a year. The circumstances will be changing in many teams. Hence the consistency of data collected in both qualitative and quantitative studies could vary. Also, the number of participants answering the survey could alter the results. Therefore, the proposed recommendations based on the findings could differ and may not be valid over a period.

8.3 Validity and reliability of qualitative research

The qualitative interviews were conducted online with carefully selected individuals. To get the bigger picture, more individuals were selected across the organization to increase the reliability of the data collected.

If the samples were chosen without prior planning, there could be deviations in the results. There are many aspects such as the roles, areas of expertise, working experience in multiple areas of product development, and overall experience in this domain. There can be changes in the results and findings.

As with online interviews, the non-verbal information and observation are missing and could slightly change the results and emphasise specific topics.

The observations and findings of the qualitative research may not be valid with the time if there are changes in the people, process, and practices in the product development. The same interview after a year could yield a different result.

8.4 Validity and reliability of quantitative research

The quantitative online survey was carried out with the whole organization. There could be some deviation in the results with the number of participants in the survey. The number of participants in this survey was 116. If the count of participants decreases, then there can be deviations in the data collected and hence the results.

Since there will be continuous changes in the organization, the survey results may not be valid over a few months or years. There can be a deviation in the results if participants change in the following survey as their views, thoughts, and experience can be different.

8.5 Limitations

The section describes the limitations of the qualitative interview and the quantitative survey in more detail.

8.5.1 Survey limitations

Online surveys commonly suffer from two serious methodological limitations, the population to which they are distributed cannot be described, and respondents with biases may select themselves into the sample (Andrade, 2020).

It is always challenging to arrive at a suitable questionnaire that fits all the group's targeted audience. The survey was designed in such a way that,

1. Binary statistical inputs comprise many of the findings and observations from the qualitative data analysis.
2. Participants can share thoughts and ideas as text input related to the question.
3. The whole organization should be included in the survey but should not keep the questions mandatory, which could negatively impact the final data collection and hence the results.
4. Though many questions are lengthy, it should be possible to complete the questions in a short time. If the participant didn’t like to continue, flexibility was provided to the participant.
5. All the questions except input text boxes are created with a 5-point Likert scale for ease of use and be able to answer the survey just by clicking relevant option buttons.

Even though the questions were created thinking multiple aspects to increase the accuracy of the data collected, there can be limitations in the survey questionnaire.

The short description of the background information may not be sufficient in the survey questions, and they could expect more background information before the question. On the other hand, if the questionnaire is lengthy, some participants could lose attention and interest, and arriving at the best fit is always challenging.

To boost the accuracy of data collected from every participant, most of the questions were created as “optional”. If participants do not like to answer them for some reason, they are allowed to do so. Though the questionnaire was designed and emphasised as “optional and can be skipped” at the beginning of every question, it could be possible that some participants might have answered them without much information about them. Due to this, the results collected could differ.

8.5.2 Interview limitations

There can be limitations in the interview. The interviews were carried out online, compared to face-to-face interviews, such as lack of spontaneity. Lack of information about nonverbal communication and its observation during the interview could be one limitation in this area.

As the deep dive discussions are time-consuming, it was challenging to cover all the topics of interest for the research study. The author had to sacrifice a few questions from the list mentioned in Appendix A to the couple of individuals.

8.6 Conclusion

The main objective of the research study was to identify the pain points in the SoC product development life cycle. The design and execution of the research study was performed systematically with an unbiased mindset and with careful attention as much as possible to avoid any errors.

Although mixed-method research was time-consuming and took a lot of effort from both the researcher and the participants, this method was emphasized to yield confident results. The common pain points identified in qualitative and quantitative methods emphasize the real problem area that needs improvement.

The recommendations drawn out in the thesis are based on the standard frameworks or concepts which have the potential to yield excellent results when applied systematically.

8.7 Suggestions for further study

Once the recommendations proposed are taken into action, it is good to get the visibility and progress as a health check in those areas. Hence the author suggests to

1. Perform a similar research study with the same target group and with similar research questions after a year of application of proposed recommendations. It can be only a survey or interview, or both.

2. Identify the smaller group which can be of interest to understand the progress of that area with a similar research study after a year from the application of recommendations.

3. Out of the six recommendations suggested in the thesis, the first five seem very important. The author suggests carrying out further research studies individually to get additional vital information in understanding the root cause of the pain point. Other research studies on the selected area can be carried out immediately or after a few months or a year.

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APPENDICES

Appendix A. Qualitative semi-structured interview questions

These are the questions used for semi-structured interviews during the qualitative study. Following are the main questions at the high level asked to go deep into the topic for discussion.

1. Time to Market (TTM) optimization
   A. What do you think about the topic of the thesis? Does it add value to the business?
   B. What is your thought about optimizing the Time to Market of the Product?
   C. How can we improve the Time to Market TTM / optimize product development time of the Product?

2. Changing Requirements in Product Development– Agility
   A. How often do we get the changes in the requirement during development?
   B. Have we prepared to accept the changing requirements easily?
   C. Does the Architecture or Design of the Product & development is such that it can adapt quickly to the changing requirements?
   D. How can we improve the agility in product development?

3. Reusability in Product development
   A. Does the Time-to-Market be improved by increasing reusability in product development?
   B. What are the areas we have good reusability?
   C. How can we improve the reusability during product development?

4. Planet/Climate Change - Energy Saving / Power Optimization
   A. Where are we with the energy saving in the product? Would it benefit the organization and the customers with energy optimization?
   B. How can we reduce the energy consumption of our products?

5. Plug & Play – Ease of development & reuse
   A. Does the HW & SW support the plug-and-play type of ease of development/reuse/easy integration?
   B. Does it help if product development takes this approach?

6. Modularity in Product Development
   A. Do you think the Modular architecture improves reusability in product development?
   B. What other benefits do you see with this approach for product development?
   C. Are there any drawbacks or limitations with this approach?
   D. Any thoughts on how can we tackle them?

7. Configurability & Re-Configurability in Product Development
   A. Does configurability help to develop product variants faster?
   B. How can we improve in this area?

8. Backwards Compatibility & Scalability
   A. How can we maintain the backwards compatibility in products?
   B. Would it improve the TTM to support scalability in HW & SWs? How?

9. Agile process & Practices/ Lean /SAFe
   A. What process or practice is in use?
   B. Do you see any gaps in the process that would need to fix to improve TTM?
   C. Any thoughts on how can we improve it?

10. Product development Process
    A. Do we have any gaps in product development Processes or the Definition of Done (DoD)?
    B. Would it help speed up the TTM if "Reusability" is addressed at the product development process level?
    C. How do you see is there any room to improve in this area? How?

11. CI/CD – Tools (Quality)

A. Are there any pain points in CI/CD pipelines and other tools for the product development environment?
B. How can we improve it?

12. Testing /Verification /Quality – Automation etc.
   A. How is the Testing and Release/Delivery system doing?
   B. Are there any known issues with Testing /Delivery areas?
   C. Do we have any areas which would need improvement to help development?

13. Customer Satisfaction – Product Maintenance/ after-sales support
   A. How can we improve customer satisfaction during the product maintenance phase?
   B. What are the current issues we do have in the maintenance process?
   C. Any thoughts on how can we improve them?

14. Any other topics from your perspective that could help improve the Time-to-Market of the Product & also improve customer satisfaction in the product life cycle?

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