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Assessing the connection between the size of product portfolio and required product sustaining efforts

A case study in a manufacturing company in the technology industry

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ABSTRACT:
Product portfolio management involves a lot of decisions regarding which products to keep in the portfolio and which products might be worth terminating. To make such decisions efficiently and objectively, it is good to be aware of what it takes for the organisation to keep products in the portfolio. Consequently, it is useful to examine the amount of resources required to maintain the active status of products, as this will provide a useful insight into the costs involved in maintaining a portfolio. This is particularly important in the case of a large portfolio, which is known to be more challenging both to manage and maintain. In addition to simply looking at the maintenance requirements, it is worth investigating which product variations appear to be increasing the workload redundantly. In this way, when optimising the portfolio, the focus will be on the right products and the desired results will be achieved.

This study sought to understand what kind of product sustaining activities are undertaken annually within the case company and how much of the existing human resources are devoted to these activities. In addition, the study aimed to understand how the size of the portfolio affects the implementation of the activities, and what types of products in the portfolio are perceived to increase the time spent on product sustaining activities redundantly and identify these products from the case company's portfolio. To achieve these objectives, the study was conducted as mixed methods research, through eighteen qualitative interviews and supporting quantitative data analysis with methods such as of time-driven activity-based costing.

The findings of the study revealed that in the case company, products' active status is maintained through several activities. These activities and the time spent on them varied greatly depending on the responsibilities of the department. Few departments in the company were directly involved in product maintenance, whereas most were more indirectly related to maintaining the active position of the products. The study also found that the size of the portfolio has a clear impact on the effort required. This effect is mainly related to the fact that a large portfolio is strongly associated with higher complexity. As complexity increases, more time must be spent on maintenance and thus more resources must be committed. These findings provided important and useful insights, enabling actionable suggestions to be proposed to the case company. Besides being able to provide valuable information to the case company, the study also brought new knowledge to the field. This study contributed to filling a clear gap in the literature, as the costs of resource use, the size of the product portfolio and the effort required to sustain products have rarely been discussed in the same context.

KEYWORDS: product portfolio, assessment of resource use, time-driven activity-based costing, product maintenance, product sustaining activities

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TIIVISTELMÄ:
Tuoteportfolion hallintaan liittyy paljon päätöksiä koskien sitä, mitkä tuotteet kannattaisi säilyttää portfoliossa ja minkä tuotteiden lakkauttamista kannattaisi harkita. Jotta tällaiset päätökset voidaan tehdä tehokkaasti ja objektiivisesti, on hyvä olla tietoinen mitä tuotteen säilyttäminen portfoliossa vaatii organisaatiolta. Tästä syystä on hyödyllistä tarkastella tuotteiden aktiivisen aseman ylläpitämiseen tarvittavien resurssien määrää, sillä se tarjoaa myös käsityksen portfolion ylläpitoon liittyvistä kustannuksista. Tämä on erityisen tärkeää suuren portfolion kohdalla, sillä sen hallinnointi ja ylläpito on tunnetusti haastavampaa. Pelkkien ylläpitovaatimusten tarkastelun lisäksi on kannattavaa myös tutkia, mitkä tuotevariaatiot koetaan lisäävän työmäärää tarpeettomasti. Näin portfolion optimoinnissa pystytään keskittymään oikeisiin tuotteisiin ja saavuttamat toivotut tulokset.

Tässä tutkimuksessa pyrittiin ymmärtämään, millaisia tuotteita ylläpitäviä toimia tapausyrityksessä toteutetaan vuosittain ja miten paljon henkilöresursseja näihin toimiin käytetään. Lisäksi tutkimuksessa pyrittiin ymmärtämään, miten tuotevalikoiman koko vaikuttaa toimien toteuttamiseen, minkä tyyppisten tuotevalikoimaan sisältyvien tuotteiden koetaan lisäävään tarpeettomasti tuotteiden ylläpitotoimiin käytettävää aikaa, ja tunnistamaan nämä tuotteet tapausyrityksen tuotevalikoimasta. Näiden tavoitteiden saavuttamiseksi, tutkimus toteutettiin sekamenetelmätutkimuksena, jossa yhdistettiin 18 kvalitatiivista haastattelua sekä kvantitatiivinen data-analyysi hyödyntäen työkaluja kuten aikaperusteista toimintolaskentaa.

Tutkimuksen tuloksista kävi ilmi, että tapausyrityksessä tuotteiden aktiivista asemaa ylläpidetään useilla eri toimilla. Nämä toimet ja niihin käytetty aika vaihtelivat huomattavasti osaston vastuualueista riippuen. Vain muutama yrityksen osastoista osallitui suoraan tuotteiden ylläpitoon, kun taas useimmat liittyivät enemmänkin välillisesti tuotteiden aktiivisen aseman ylläpitoon. Tutkimuksessa havaittiin myös, että portfolion koolla on selvä yhteys vaadittavaan työpanokseen. Tämä vaikutus liittyi pääasiassa siihen, että suuri portfolio on vahvasti yhteydessä korkeampaan kompleksisuuteen. Kun kompleksisuus kasvaa, ylläpitoon on käytettävä enemmän aikaa ja siten myös enemmän resursseja. Nämä havainnot tarjosivat tärkeitä ja hyödyllisiä näkemyksiä, joiden pohjalta tapausyritykselle voitiin esittää konkreettisia ehdotuksia. Sen lisäksi, että tutkimuksesta saatiin arvokasta tietoa tapausyritykselle, se toi myös uutta tietoa alalle. Tämä tutkimus täyttää osaltaan kirjallisuudessa olevan selkeän aukon, sillä resurssien käytön kustannuksia, tuoteportfolion kokoa ja tuotteiden ylläpitämiseen vaadittavaa panostusta on harvoin käsitelty samassa yhteydessä.

AVAINSANAT: product portfolio, assessment of resource use, time-driven activity-based costing, product maintenance, product sustaining activities

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Abbreviations

PPM – Product portfolio management

ABC – Activity-Based Costing

TDABC – Time-Driven Activity-Based Costing

RBV – Resource-based view

LCC – Life cycle costing

TCO – Total costs of ownership

CBA – Cost-benefit analysis

ERP – Enterprise resource planning

1 Introduction

The knowledge and holistic understanding of the products cost-structure is essential for making informed product portfolio related decisions (Sievänen et al., 2004, p. 393). The management of product portfolio contains decision-making related to actions such as what products do develop, sell, maintain and retire (Mustonen et al., 2020, p. 5). The given actions must be aligned with the broader business strategy of the organisation. This thesis examines the measures that must be taken to maintain the products' active status within the case company's product portfolio, and the costs associated with the use of the required human resources. This is done through identifying certain activities and processes involved in the act of product sustainment while estimating the required human resources necessary to complete the activities based on time use.

To estimate the associated costs, the principles and ideology of time-driven activity-based costing (TDABC) will be applied, together with semi-structured qualitative interviews, which will provide the basis for the TDABC analysis. TDABC is chosen, because it is well-established cost estimation framework focusing on assessing cost of performing certain activities based on how much capacity is required to perform them in terms of time (Demeere et al., 2009, p. 298; Hoozée & Bruggeman, 2010, pp. 185 – 186). Furthermore, the thesis aims to gain an understanding of the challenges associated with maintaining a wide product portfolio, focusing in particular on identifying product characteristics that make product maintenance more demanding and burdensome. At the same time, products that may not necessarily be profitable to maintain in relation to their demand can be identified. Hence, the aim of this thesis is to provide useful information on how much human resources are spent each year to keeping products active in the portfolio and which products may not be worth maintaining and thus provide useful insights for the case company when making portfolio related decisions. The scope of the thesis is determined in association with the case company's needs.

It is notable that having right resources within the organisation may not be enough for successful operation, but the resources must also be utilised in an optimal way to maximise the available competitive advantage (Heimonen & Takala, 2019, p. 192). This makes it crucial, that there is enough knowledge and awareness about how the given resources are used in the different activities to know if the company operates in an optimal manner (Kapur, 2024). The optimisation of available resources is also important in the context of weather it is worth it to sustain a product within the portfolio. According to Sievänen et al. (2004, pp. 398 – 399), the cost structure of the products changes and depend on which life cycle phase the product currently occupies. This is reflected in the fact that products often have higher maintenance costs in the decline phase of their life cycle than in other phases. According to Karakaya (2004) in Bengü and Kara (2010, p. 327), to enhance the evaluation process of life cycle costs, the cost occurrences during the life cycle can be divided into pre-manufacturing costs, manufacturing costs and post manufacturing costs, where different characteristics and aspects can be detected. To further gain understanding of the cost structure, tools like total cost of ownership (TCO) can be utilised. The given tool is a calculating method which takes into consideration, not only the acquisition costs but also other ones like maintenance and other related indirect costs (Carnicero et al., 2023, p. 7). The holistic evaluation of the cost of product or process is vastly important for organisations as it enables for better financial estimation of all related costs, helps to compare different alternatives and in the creation of long-term cost structures (Carnicero et al., 2023, p. 7). Additional information on processes such as resource and cost management, can be considered very useful in decision-making on which products to sustain in the portfolio. Removing low performing and redundant products from the portfolio enables certain benefits such as freeing certain inefficiently utilised resources (Leiter, 2011, p. 3). The thesis proceeds to study this aspect of resource use from this perspective and to further understand the influencing factors around the subject.

1.1 Background and study gap

This study is a case study of a specific case company that desires to gain insight into the activities performed by the various departments that enable products to have an active status in the product portfolio, and also the costs associated with the labour required to perform these activities. The large size of the product portfolio is an acknowledged concern in the case company, which is why the company wants to gain a better understanding how the size of the product portfolio impacts on the required product maintenance efforts. There is particular interest to investigate whether there are some activities that must be performed for each active product regardless of the produced or sold quantity. The aim of this study is to provide validated insights into these activities and give the company valuable information that can be utilised when making product and portfolio related decisions. Thus, this study can be seen as part of a broader objective of the case company.

Companies must make continuously different kind of decisions on where and how they want to allocate their resources in order to achieve sustainable competitive advantage (Heimonen & Takala, 2019, p. 192). Due to scarcity of resources such as financial capital, human talent and technological assets, resource allocation decisions have crucial role to ensure that the organisation is capable of achieving its objectives (Ahsun & Elly, 2024). The efficient allocation of resources requires an awareness of the actual resource requirements in order to avoid resource shortages or over-allocation and thus optimise operations (Ahsun & Elly, 2024). According to Cooper et al. (2001, p. 3) portfolio management can be seen as a complex and constantly evolving decision-making process where multiple aspects must be taken into consideration. The decision-making process results in a choice of which products to either include or maintain as part of the portfolio, or which products to retire and remove from the portfolio (Cooper et al., 2001, p. 3; Mustonen et al., 2020, p. 5). In other words, portfolio management is the allocation of a company's resources in a way that enables the organisation's overall business strategy to be realised (Cooper et al., 2001, p. 3). Common challenge in portfolio management is that too many projects are included in the portfolio resulting that these projects must compete for resources as there is mismatch between demand and supply (Cooper et al., 2001, pp. 12 – 13). In other words, the size of the product portfolio and the resources required to maintain it are not in line.

Products costs depend on the life cycle phase product is in (Bengü & Kara, 2010, pp. 327 – 328). Sievänen et al. (2004, p. 393) state that knowledge of product profitability is vital for cost-conscious product-related decision-making. They noticed that also products profitability is influenced by the life cycle phase. Especially, they noticed that products in the decline phase have clearly higher product sustaining costs compared to products in other phases. Thus, at this point unnecessary extension of product life cycle and post-poning retirement often raise product sustaining costs as sales volume is decreased. Product sustaining costs refers to costs resulted from activities that enable that production of individual products is possible (Kaplan & Cooper, 1998, pp. 90 – 91). According to Kaplan and Cooper (1998, pp. 90 – 91) typical examples of product sustaining activities are maintaining and updating product specifications, special testing and tooling, services and technical support provided for individual products. They continue that it is relatively easy to identify which activities are related to which products, however, it is more challenging to quantify the resources needed for these activities, as they are not related to the number of units or batches produced or sold.

Cost estimation can be defined as process that utilises historical data in order to forecast cost required to perform tasks and activities (Mislick & Nussbaum, 2015, p. 11; Owens (2007) as cited in Fanny, 2019, p. 59; Li et al. (2008) as cited in Fanny, 2019, p. 59). Activity-based costing (ABC) allows the calculation of costs associated with the use of resources to perform activities (Niazi et al., 2006, p. 569; Andrade et al., 1999, p. 177). However, the ABC system has several weaknesses, such as limited scalability and laborious maintenance, which means that the ABC is probably not the most appropriate method for most companies to allocate costs (Kaplan and Anderson, 2003, p. 3; Siguenza-Guzman et al., 2013, p. 38). In order to solve these problems associated with ABC, in the early 2000s Kaplan and Anderson developed time-driven activity-based costing (TDABC) (Kaplan and Anderson, 2007, p. 8). According to them this more efficient, simpler and cheaper alternative to assign resource costs to cost objects as it only utilizes two parameters: the cost of providing resource capacity per unit of time and an estimate of the units of time required to carry out certain activity (Siguenza-Guzman et al., 2013, p. 39; Kaplan & Anderson, 2007, p. 8).

Existing studies often address only some of the following issues: estimation of the costs associated with the use of resources, the size of a product portfolio and its impact, or the effort required to maintain a product 's active status in the portfolio. However, it is rare to find studies that combine all these aspects, which is the basis of the research gap in this thesis. This study aims to address this gap by providing information on how the size of the product portfolio affects the required product sustaining efforts and how costs of required sustaining efforts can be estimated by applying TDABC principles. This research gap is illustrated in the figure 1 below to help understand this multi-level gap. In the figure 1, these three aspects are shown as separate circles, and the intersection of these three circles represents the study gap in this thesis, where the views from these three different issues are combined.

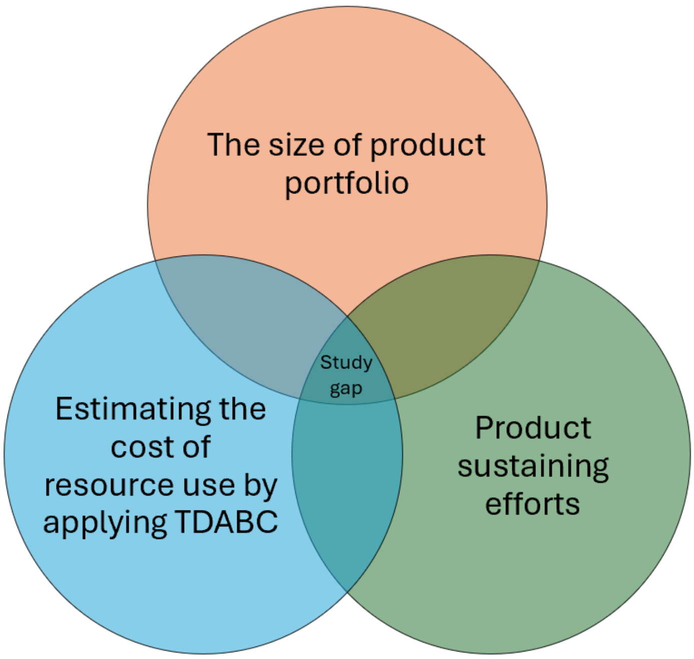

Figure 1. Study gaps (source: author)

1.2 Research scope and limitations

This sub-chapter contains definitions of the research scope and limitations, and also the case-specific constraints of the research are being set. The aim of this sub-chapter is to provide clear understanding of the scope of this research and also acknowledge its limitations. The study focuses on estimating the costs of product sustaining activities based on the labour involved, and on assessing the impact of the size of the product portfolio on the workload of these activities. The thesis' scope is narrowed to examine only the labour used by white-collar workers. The scope of including only white-collar personnel and excluding others was made, due the available resources and the scale of the research. Although the inclusion of blue-collar workers could potentially provide more comprehensive results, it would also require more resources than are available, as the scope of the study would be much wider. Interview participants are chosen to portray the relevant teams and functions to the studied matter. Thus, the study focuses on the departments represented by the chosen interviewees and not the entirety of the case company. This research also excludes cost related to resources and areas such as materials and machine use. It is important to acknowledge that the exclusion does not mean that the given aspects are irrelevant, but it is done to enable a less obstructed view and more discrete consideration of the core problem.

The literature review is limited to literature published in either Finnish or English, which may result in language bias. Several different academic databases such as Wiley, EBSCO, ScienceDirect, ProQuest, ResearchGate, Emerald, Taylor & Francis, SAGE Publications, and Springer are used to retrieve the literature. Google Scholar is also used for including not peer reviewed grey literature such as consultancy report and theses, that are published outside general academic databases as part of the literature review to ensure that a wide and appropriate range of sources is included. The literature review therefore highlights the findings of various journal articles, research reports, books, consultancy reports and theses. The aim of the literature review is to provide a comprehensive overview of the relevant theoretical frameworks and to ensure that sufficient knowledge has been gathered to proceed with the empirical part of the study.

The research focuses on a specific case company, which means that the results are not directly generalisable to all companies due to differences between companies. Within the case company's product portfolio, analysis of quantitative primary data is limited to three product families as the product portfolio of the case company is quite large and resources for this study are limited. The study is designed to include product families that are different in terms of their characteristics, in order to provide as comprehensive a picture as possible of the entire portfolio of the case company, despite the limited scope of the study. These three product families selected for this study's quantitative analysis are defined as follows: product family 1, product family 2 and product family 3.

The first product family is relatively new in the case company's portfolio and includes electronics that make the products more complex to maintain. This product family is also under continuous development, as it is at a relatively early stage of its life cycle. The second product family includes the case company's standard products, which have been part of the company's product portfolio for a long time, so their stable status means that they do not require extensive measures from the case company to keep them active in the portfolio. The last product family covers accessories sold alongside the main products and the case company mainly distributes these as a reseller. By selecting these product families, which have quite different characteristics, as part of the study, the most comprehensive picture of the product portfolio of the case company is obtained.

1.3 Research objectives and questions

The aim of this thesis is to explore what activities are carried out in the case company every year to maintain the active status of the products in the product portfolio. The assessment is refined by estimating the human resources required for implementation and quantifying these requirements in terms of both time and money. Quantitative assessment of the human resources devoted to these activities is carried out by applying the ideology and principles of TDABC. By exploring what challenges are posed by the large size of the portfolio, the study also attempts to understand the correlation between the size of the product portfolio, that is, the number of products in the portfolio, and the effort required to sustain the products. This information was used to identify products that add extra sustaining effort to a large product portfolio and to determine their proportion within the product families included in the study. The main objectives of the research can be summarised as follows:

1. To identify the typical activities and processes carried out annually in the case company that enable keeping products active in the product portfolio.
2. To identify the human resources allocated annually to product sustaining activities and quantify both the time and financial commitment by applying TDABC principles.
3. To explore the challenges involved in maintaining a wide and varied product portfolio.
4. To examine which product features are associated with higher maintenance requirements and determine the proportion of products with such features in the product families studied.

The above research objectives guide the execution of the research and thus serve as steps towards the main objective of the research. By breaking down the objectives into smaller parts, the aim is to provide a clear picture of the objective of the research and how this objective will be achieved stage by stage. The ultimate aim of the study is to provide information on how much human resources are used each year to maintain the products in the portfolio, how the size of the portfolio affects the maintenance of products, and which types of products are perceived to use redundantly resources in relation to their demand. This information allows the case company to make more informed decisions relating to product portfolio in the future.

This research aims to provide insight into product sustaining activities by answering three research questions. The first question examines the nature of the activities required to maintain the active position of products in the product portfolio and the amount of human resources annually spent on them. The second question examines the challenges of maintaining a broad product portfolio. The third research question in turn examines how to identify those products in the product portfolio that are perceived to contribute to extra maintenance and to determine their share of the product families selected for the study. These research questions are as follows:

1. What are the key activities that enable the case company's products maintain an active status in the product portfolio, and how much human resources are devoted to them annually?
2. What challenges can be detected in sustaining a broad product portfolio in terms of workload?
3. In the context of a large portfolio, which product features are linked to greater maintenance effort, and how significant role such products have in the product families covered by the study?

1.4 Structure of the thesis

The thesis is structured in accordance with academic standards and to support the research objectives. The thesis begins with abstract written both in English and Finnish, table of contents, list of figures and tables and abbreviations. This is followed by the five main chapters of the thesis: introduction, literature review, methods, results and analysis, and finally discussion and conclusions. The introduction chapter defines the scope of the study, provides background information on the study, explains the objectives of the study and provides an overview of the identified limitations of the study. The second chapter, the literature review, presents the theoretical basis of the study by establishing the definitions of product portfolio management, product sustaining activities and cost estimation with time-based activity-based costing (TDABC) and by providing justification why it is important to be aware of cost associated with resource use on product sustaining activities is relevant in portfolio decision-making by reviewing previous literature on these key concepts in more detail. The third chapter, methods, is devoted to providing details of the research design, the research methods used in the study and the data analysis methods. The purpose of this chapter is to ensure the reproducibility and reliability of the study by providing transparent information on how the study was conducted. The fourth chapter, results and analysis, presents findings from empirical research conducted at the case company. The aim of this chapter is to provide a comprehensive answer to the previously posed research questions. Finally, fifth chapter discussion and conclusions, summarises the main findings by research question. Also, study's contribution and managerial implications are discussed and recommendations for future research are provided in the discussion and conclusions chapter.

2 Literature review

This literature review is divided into four main chapters, which aim to provide a comprehensive theoretical basis and framework for both the conduct and motivation of the research. This first chapter provides an overview on product portfolio management, by discussing how it is usually implemented within companies, why it is important and what are common challenges. By addressing these aspects of product portfolio management in the literature review, the aim is to provide an understanding of the factors that influence product portfolio size, how product portfolio size is managed in organisations and why organisations may have overly broad product portfolio portfolios. Understanding these factors is important because the study examines the relationship between the size of the product portfolio and the resources required to maintain products in the portfolio. Product portfolio management therefore provides a contextual understanding of the underlying factors and is therefore an essential topic to address.

This is followed by a chapter that defines product sustaining activities and provides information how these activities can be identified. Third chapter presents ideology of time-driven activity-based costing (TDABC). The aim of this chapter is to provide a theoretical basis for using principles of TDABC for cost estimation. Finally, the last chapter reviews the literature and presents concepts and frameworks that justify the importance of understanding the costs associated with resource use and that can be applied in the decision-making process.

2.1 Product portfolio management from the perspective of product sustaining activities

Project Management Institute (PMI) (2017, p. 15) defines portfolio as a group of programmes and projects which, as a whole, aim to achieve strategic objectives. Hence, product portfolio is collection of product projects and refers to all company's products, that are usually divided into many categories by client segment, generation of technology, product family or product type, which can be for example hardware, software or services (Tolonen, 2016, p. 37; Kropsu-Vehkaperä & Haapasalo, 2011, p. 69; Mämmelä et al., 2022, p. 26). Thus, product portfolio consists of existing products in various lifecycle phases and also and upcoming products that have not been launch yet (Haines, 2014, p. 9).

Portfolio management refers to the set of processes that guides decision-making (Padovani & Carvalho, 2016, p. 628). Product portfolio management (PPM) in turn applies portfolio management in the context of product projects (Jugend & da Silva, 2014). According to Mustonen et al. (2020, p. 5) PPM involves determining which products to develop, sell, deliver, maintain, or phase out, aligning these decisions with company's business strategy. One of the first PPM definitions is presented by Cooper et al. (1999, p. 335), who defines PPM as a dynamic and iterative decision-making process in which company's product projects are continually evaluated, updated and refined in order to select, prioritize and allocate resources to projects based on their strategic objectives, while also deciding whether to accelerate or terminate existing initiatives.

Similar features emerged in an article written by Jugend and da Silva (2014), where they stated that the PPM guides decision-making on resource allocation by providing tools to prioritise projects so that often scarce resources are optimally allocated while ensuring that the most potential projects receive sufficient resources. Jugend and da Silva (2014) continue that PPM decisions not only guide the allocation of resources but also define the products with which the company competes in the market, as these decisions are related not only to the definition of new product projects, but also to the revision, upgrading and discontinuation of already manufactured and commercialised products. Jugend and da Silva (2014) thus see PPM as a factor that enables the successful development of new products and the achievement of business objectives

Kodukula (2014, p. 17) considers PPM as a subset of project portfolio management, where product portfolios are managed with a focus on developing and launching new products through a coherent strategy while optimising the benefit-cost-risk equation. That is because, according to Kodukula (2014, p. 29), a product portfolio can be considered a portfolio category if projects are assessed on the basis of project domains. This is also in line with PMI's (2017, p. 4) definition of a project, as they see a project as a temporary endeavour aimed at developing a unique product, service or outcome and portfolio is a set of these projects. Thus, it can be concluded that PPM according to PMI (2017, p. 15) refers to centralised management, which aims to ensure that the product portfolio is aligned with the strategic objectives of the organisation by selecting and prioritising the elements of the portfolio that maximise its value and enable the strategic objectives to be achieved. Vähäniitty (2006) states that, whether product or project portfolio, portfolio management aims to achieve organisational objectives by managing a set of essential activities that require the same resources.

In all these definitions summarised in the table 1 below, one really essential point stands out strongly. Based on these definitions, it can be concluded that PPM is in fact very much the implementation of an organisation's strategy in the form of decisions such as which product initiatives have potential, which products to invest in, which products to retire, and how to allocate resources between products so that the company's strategy is realised through these decisions. Thus, it can be summarized that PPM provides the tools through which an organisation's strategy can be put into concrete action in a manner such as allocating resources to strategically important items in a portfolio. Successful PPM can therefore be seen as shaping the product portfolio to reflect the organisation's strategy and thus enabling the achievement of strategic objectives.

Table 1. PPM definitions.

Definition of PPM	**Reference**
PPM is about determining which products to develop, sell, deliver, maintain, or phase out, aligning these decisions with company’s business strategy.	Mustonen et al., 2020, p. 5

Definition of PPM	Reference
PPM is a dynamic and iterative decision-making process in which company’s product projects are continually evaluated, updated and refined in order to select, prioritize and allocate resources to projects based on their strategic objectives, while also deciding whether to accelerate or terminate existing initiatives.	Cooper et al., 1999, p. 335
PPM is the portfolio management associated with product projects, which aims to ensure the success of the most potential product projects and determine the products with which the company will compete in the market, by guiding resource allocation decisions in a way that supports the company's business objectives.	Jugend & da Silva, 2014
PPM is a subset of project portfolio management, where product portfolios are managed with a focus on developing and launching new products through a coherent strategy while optimising the benefit-cost-risk equation.	Kodukula, 2014, p. 17
PPM refers to centralised management, which aims to ensure that the product portfolio is aligned with the strategic objectives of the organisation by selecting and prioritising the elements of the portfolio that maximise its value and enable the strategic objectives to be achieved.	PMI, 2017, p. 15
PPM is about achieving organisational objectives by managing a set of essential activities that require the same resources.	Vähäniitty, 2006

As mentioned, PPM involves continuous decision-making. This decision-making involves dealing with uncertain and evolving information and dynamic opportunities, balancing multiple objectives and strategic factors, addressing project interdependencies, and co-ordinating inputs from multiple stakeholders and locations (Cooper et al., 1999, p. 335). Product portfolio decisions can be divided into selection and prioritisation of the group of product projects that will contribute to the business strategy and decisions on the allocation of resources and investments in different product projects over time. According to Kester et al. (2011, p. 641), effective PPM decision-making is based on the interaction of three types of decision-making processes: evidence-based, power-based and opinion-based. These decision-making processes differ by different sources of input and influencing factors. Based on an article written by Kester et al. (2011, p. 641) evidence-based decision-making relies on processes such as cross-functional collaboration, critical thinking practices and market immersion practices. Whereas power-based decision-making is shaped by organisational politics and opinion-based decision-making is associated with subjective perceptions such as managerial intuition. Portfolio decision-making is influenced by cultural aspects of an organisation such as trust, shared ambition, and the leadership approach which determines how evidence-based, power-based and opinion-based processes are combined (Kester et al., 2011, p. 641). Thus, these factors determine whether organisation PPM decisions are made in a more rational and objective manner or shaped by political dynamics and intuitive judgement.

2.1.1 The importance of product portfolio management

According to Cooper et al. (2001, pp. 364 – 366) portfolio management is an important activity within a company that offers several benefits that contribute to strategic and operational success. These benefits of PPM enable companies to maintain or even strengthen their competitive position in the market by promoting sales and market share growth (Cooper et al., 2001, pp. 364 – 366). PPM is considered to have three key objectives which link the effective and successful implementation of portfolio management to the success of the organisation. These three objectives are 1. maximize the value of a portfolio, 2. achieve a balanced portfolio, and 3. ensure that portfolio is strategically aligned with overall business strategy (Cooper & Edgett, 2001, pp. 3 – 4; Martinsuo & Lehtonen, 2007, p. 57; Meskendahl, 2010, p. 808)

Portfolio value maximisation is the attempt to maximise the total value or commercial worth of active projects in terms of the business objective through decision-making (Cooper & Edgett, 2001, p. 3). This requires that all portfolio components go through thorough examination (PMI, 2017, p. 15). According to Cooper and Edgett (2001, pp. 3 – 4) components are often evaluated utilizing tools such as net present value (NPV), expected commercial value (ECV) or scoring models. These tools provide information on both the financial and overall potential of components. This information can be used to prioritise components, which in turn can guide the allocation of resources. In practice, this means that portfolio components that can be expected to generate high value and have a relatively high potential within the portfolio will receive resources and remain in the portfolio. This allows the return on investment to be maximised, thereby creating value for the shareholders (Kodukula, 2014, p. 10).

PPM also aims to achieve a balance between portfolio components based on different parameters (Cooper & Edgett, 2001, p. 4). By maintaining an appropriate mix of short- and long-term projects, as well as high- and low-risk projects, PPM can contribute to improving the likelihood that the targeted return on investment will be achieved (Cooper & Edgett, 2001, p. 4; PMI, 2017, p. 15). Therefore, a balanced portfolio and consequently portfolio management plays an important role in achieving an organisation's financial objectives (Cooper et al., 2001, pp. 364 – 366). In practice, according to Cooper et al. (2001, pp. 364 – 366) this is reflected in maximised returns and improved R&D productivity.

Strategic alignment, in turn, means that spending decisions must reflect strategic priorities (Cooper & Edgett, 2001, p. 4). PPM provides guidelines how organisation should make its investments decisions, and which projects should be included in the portfolio

(PMI, 2017, p. 15). In practice this means that PPM can be considered as a link between business strategy and product project selection as it contributes achieving strategic objectives by prioritizing projects based on their strategic importance (Cooper et al., 2001, pp. 364–366; PMI, 2017, p. 15). Thus, PPM ensures that the focus is on potential projects by making sure that they receive sufficient support and that the size of the portfolio is optimal to avoid spreading resources across too many projects (Cooper et al., 2001, pp. 364–366; PMI, 2017, p. 15).

Strategic alignment is also reflected in resource allocation as another important objective of PPM is to ensure that allocation of financial, team and physical resources is done in an optimal way (PMI, 2017, p. 15). By prioritising projects according to their strategic importance, PPM ensures that projects that are strategically essential are identified and thus properly supported (Cooper et al., 2001, pp. 364–366; PMI, 2017, p. 15). Thus, it can be noticed that the PPM concretises the strategy of the organisation precisely in terms of the resource allocation. The projects that are most critical in terms of strategy are the ones that receive the most investment in terms of resources, thus allowing the achievement of the goals.

Thus, it can be summarised that portfolio management enables an organisation to improve its decision-making with clear priorities and a structured execution. This allows greater objectivity in project selection, which enables to identify and terminate unviable projects (Cooper et al., 2001, pp. 364–366). Successful portfolio management can also enhance the daily operational activities of an organisation. Cooper et al. (2001, pp. 364–366) noticed that PPM facilitates efficient communication of priorities across organisation both vertically and horizontally. Thus, PPM also enhances collaboration.

2.1.2 Portfolio management process

Portfolio management is a process that can be divided into several steps. Depending on the source, process usually consist of four to five steps. Oltmann (2008) introduces portfolio management process that consist of five steps. These steps are as follows: 1. clarify the goals of the business, 2. collect and explore the requested ideas, 3. select projects using defined differentiating factors to form the most optimal collection, 4. validate the feasibility of the portfolio and launch projects and 5. manage and monitor the portfolio. These steps and their sequence are visualised in the figure 2 below. According to Oltmann (2008), these steps ensure that the portfolio is constructed and maintained objectively. He continues that objectivity is ensured by identifying differences between portfolio items using measures such as return on capital employed, risk, efficiency or strategic orientation. Using these metrics, the portfolio is formed by selecting the most appropriate mix of items through prioritisation. Once the portfolio has been established, its practical feasibility needs to be validated by reviewing, for example, resource requirements and availability, as well as the capability of the organisation. This is followed by portfolio monitoring to ensure that the portfolio remains in line with its initial objectives and make changes if necessary.

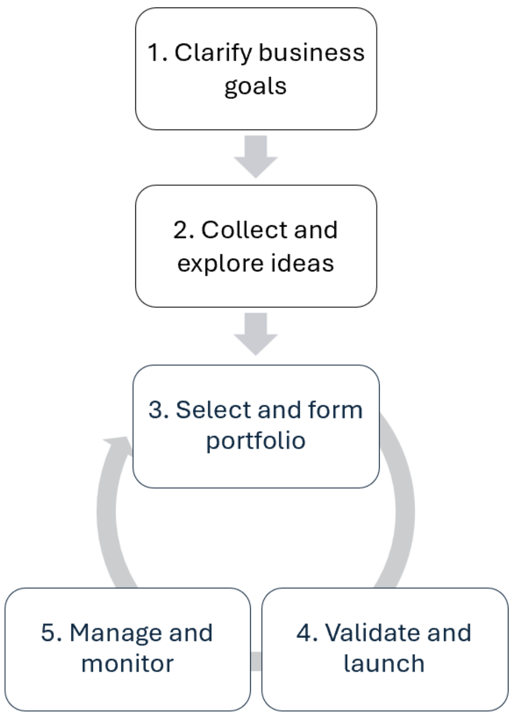

Figure 2. Portfolio management process by Oltmann (2008) (adapted).

Quite similar steps are also identified by Kodukula (2014, pp. 72 – 76). However, portfolio management process by Kodukula (2014, pp. 72 – 76) is divided into four phases instead of five. These phases are: “1. build foundation, 2. design portfolio, 3. construct portfolio and 4. monitor and control portfolio”. This process and its phases are presented in the figure 3 below. Similar to the process presented by Oltmann (2008) this process also starts with clearly defining strategic framework to ensure that portfolio management process aligns with business objectives and enables fulfilling organisation’s mission and vision. Once the strategic basis is defined, the standards and requirements of the portfolio are identified and established. The process continues with the construction of a new portfolio, which means ensuring that this new portfolio meets the set design requirements and is consistently aligned with the business strategy and organisational objectives. According to Kodukula (2014, p. 74) this means transforming the portfolio into steady state. According to Kodukula (2014, pp. 75 – 76) once the steady state of the portfolio is achieved the third step is dropped and the process becomes an iterative three-step process where the remaining three steps are performed continuously. Finally, the last phase of this process is monitor and control phase that consists of iterative ongoing processes and daily tasks. The aim of this phase is to ensure that the portfolio remains in the steady state by continuously evaluating and prioritising portfolio items and making go/kill-decisions to ensure portfolio balance and performance.

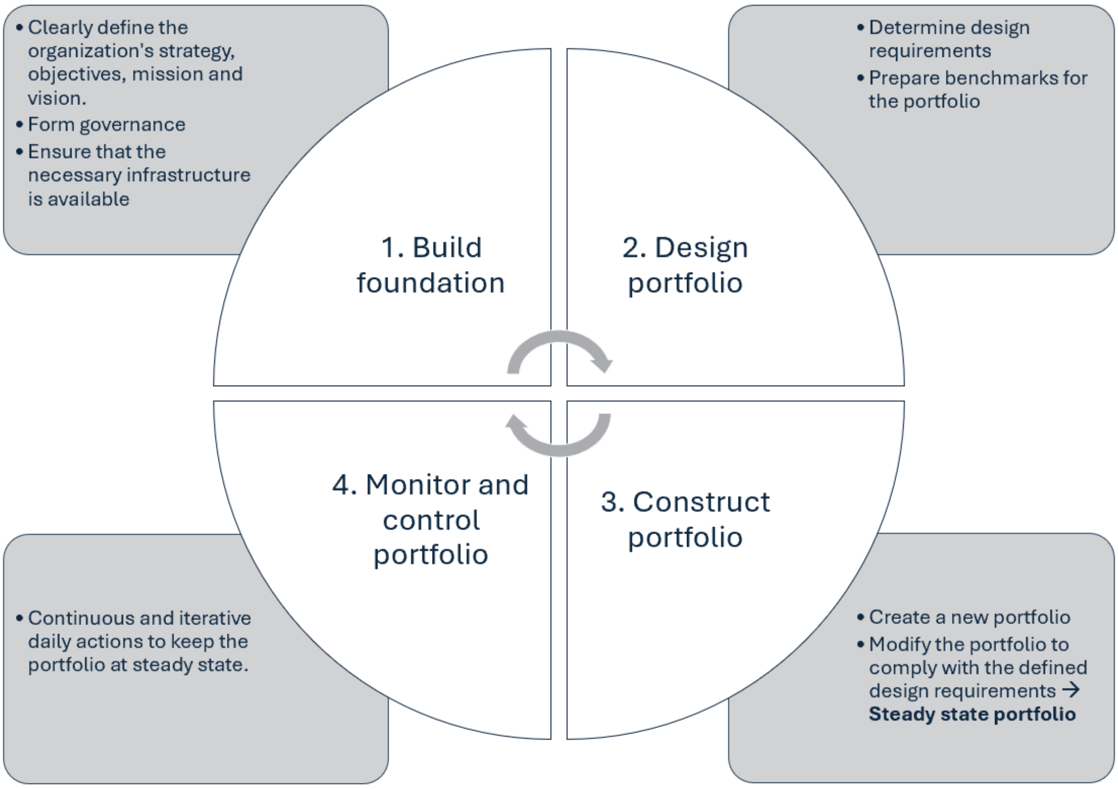

Figure 3. Portfolio management process by Kodukula (2014, pp. 72 – 76) (adapted).

It can be noticed that there are many similarities between the two portfolio management process presentations. Similarities include that the processes start with the clarification of strategic frameworks to ensure that portfolio management can be implemented in a way that supports the organisation's objectives. In addition, the two processes share an iterative format, where steps are taken on an ongoing basis to ensure consistent alignment with portfolio standards and business objectives. Thus, it can be concluded that the portfolio management process provides a framework for implementing an organisation's strategy through portfolio management.

According to Cooper et al. (2001, p. 274), there are two approaches to implement portfolio management process that emphasize different key components of the portfolio management process. These crucial key components are strategy, gating and portfolio reviews (Cooper et al., 2001, p. 269). These components and their relationship are presented below in the figure 4. The strategy guides portfolio management decisions in three ways: it determines which projects are included in the portfolio, as all projects must align with the strategy, it determines how spending is allocated between projects, and lastly it identifies and prioritises projects that are strategically necessary (Cooper et al., 2001, p. 271). The second crucial decision-making system utilised in portfolio management is the stage-gate process, which is often used in new product development to guide development projects from idea to launch (Cooper et al., 2001, p. 271). This process includes gate decision points, also called quality control checkpoints, where senior management makes decisions on individual project continuation and resource allocation on a regular basis, several times a year. Third component of portfolio management process is portfolio reviews (Cooper et al., 2001, p. 273). Portfolio reviews are less frequent meetings where all projects are examined as a single entity, a portfolio, with the aim of ensuring that the portfolio focuses on the right projects.

The difference between the two approaches is where decisions are made. First approach places more emphasis on the importance of gate meetings in the stage-gate process and the other places more emphasis on the portfolio review meetings. Thus, both approaches utilize similar tools but in a different way Cooper et al. (2001, p. 274). These approaches are called the gates dominate and the portfolio reviews dominate.

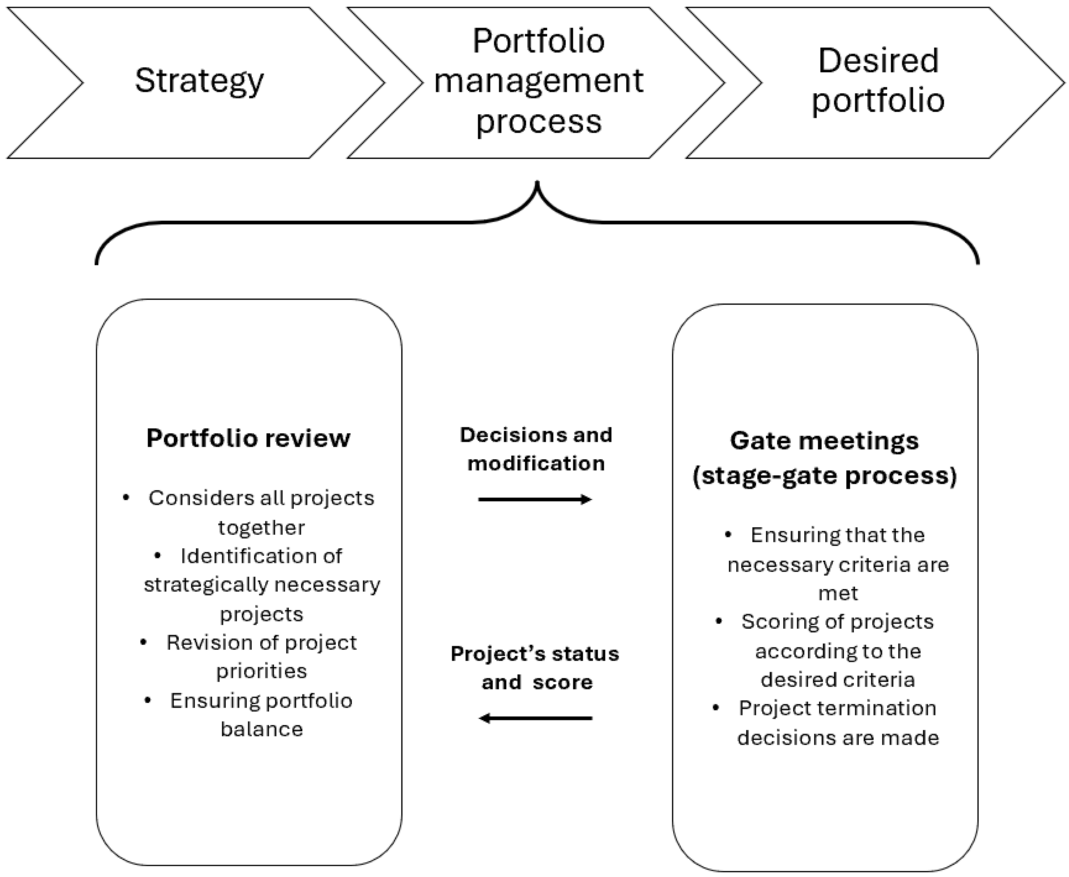

Figure 4. Decision-making process in portfolio management (adapted Cooper et al. (2001, p. 270).

Cooper et al. (2001, p. 274) states that the basic idea behind the first approach, the gates dominate, is that if a well-functioning gate process is in place, the portfolio will handle itself. They continue that this approach focuses on improving the decision-making process for individual projects. In practice this means that if successful individual project selections are made throughout the year, at the end of the year there will be a great portfolio of projects (Cooper et al., 2001, p. 274). According to Cooper et al. (2001, p. 274) often larger companies, which already have well-working stage-gate process in place and were project development cycles are long, tend to favour gates dominate approach.

According to Cooper et al. (2001, p. 274) and Kodukula (2014, pp. 51 – 52) project go through the stage-gate process, where the gates serve as an in-depth review point with real time decisions. These decisions are often made by senior management several times a year. The gates involve a two-step decision-making process, where projects are first evaluated against absolute criteria one project at the time, in other words, "go/kill" decisions are made to select projects that fit the portfolio, and then projects are compared with other active and on hold projects, meaning that "go/hold" decisions are made to decide which projects in the portfolio should receive resources (Cooper et al., 2001, p. 275, p. 289).

In the gate dominate approach, portfolio review plays a minor role, as the idea behind this approach is that the gate process should work efficiently and no major changes should be needed to make in the review meetings (Cooper et al., 2001, p. 283). These portfolio reviews are periodic meetings, often held once or twice a year, with the aim to ensure that real-time gate decisions have been made well (Cooper et al., 2001, p. 274). Cooper et al. (2001, pp. 284–288) state that the portfolio review includes three steps. First step is to identify strategic imperatives, meaning projects that are necessary for the achievement of the company's strategic objectives. The second step is to check project priorities, which refers to ensuring that projects are prioritised and ranked according to their value for the company. The third step is to check balance and alignment, which in turn refers to verifying that active projects form a balanced and strategically aligned portfolio. If necessary, as a result of the portfolio reviews, the combination of projects will be adjusted, and the gate model and the process itself will be modified (Cooper et al., 2001, p. 287).

The second approach, the portfolio reviews dominate, is more dynamic and results in constantly evolving project portfolio (Cooper et al., 2001, pp. 274–275). Thus, this approach is more suitable for faster-paced companies within fields such as software and IT. The idea behind this approach is that every project must compete against each other several times during a year in portfolio review meeting where all crucial decisions are made (Cooper et al., 2001, pp. 274 – 275, p. 299). Cooper et al. (2001, p. 275) note that it must take into account that this approach requires strong commitment from senior management as they must depth assessment for all projects together multiple times during a year.

Cooper et al. (2001, p. 292) state that a quarterly portfolio review meeting will screen all projects that have passed through Gate 2, in other words which have passed second idea screen, and all such projects may be terminated, continued or restarted at this meeting. According to Cooper et al. (2001, pp. 292–297) portfolio reviews consist of five different steps. First step is to review all existing projects, which means that all project despite their current status is assessed. Second step is that portfolio managers identify crucial projects whose continuation is necessary. These projects are typically either already up and running and in good shape, or strategic imperatives that enable the business to operate. The third step is that management must identify project that will be terminated immediately. Most often these are in simple poorly performing projects, or they do not show strong business case and thus are not worth to invest in. The fourth step involves assessing project in the middle, which refers to the evaluation of remaining projects with methods such as forced ranking or scoring models. A result of this step is a tentative portfolio. The aim of the fifth step is to balance this tentative portfolio and ensure its strategic alignment. At this stage, some projects may be replaced by others, resulting in a final project portfolio.

Although in the portfolio review dominate approach, all important and crucial decisions are made at review meetings, gates still play an important role but not to the same extent as in gate dominate approach (Cooper et al., 2001, p. 299). According to Cooper et al. (2001, p. 299) gates can be seen more as a check list of ensuring that projects are progressing as expected, stay on budget and in simple are worth to continue. Thus, also decision related to project termination are done at the gates. But the difference between gates dominate and project review dominate approach is that in this latter approach, no new projects are approved at the gate nor are any significant changes to resource commitments is made (Cooper et al., 2001, p. 299). These decisions take place in the portfolio review meetings.

According to Cooper et al. (2001, p. 300), both approaches have their own advantages and disadvantages. Project prioritisation has been found to be easier when all existing projects are considered together, as in the portfolio review dominate approach. It was also noted that in the gate dominate approach, it is confusing how resources are allocated to a project when projects are individually assessed in the gate meetings. However, it is thought that it would be fair for the project team to be able to provide up-to-date information and defend their project when making termination decisions, which is possible in gate dominate approach where these decisions are made in the gate meeting. Another drawback of the portfolio review dominate approach is the time-consuming nature of the review meetings.

2.1.3 Common challenges in product portfolio management

Research conducted by Tolonen et al. (2015, pp. 471 – 472) reveals that PPM is commonly considered challenging in the companies. According to Tolonen et al. (2015, pp. 471 – 472) this is due to the lack of attention paid to PPM and how it effects on company's strategic performance and different processes. In other words, the underlying causes of for most of these challenges are often related to the lack of a formal process and the misalignment of PPM with the overall business strategy of the company (Killen et al., 2008, p. 33).

Cooper et al. (2000, pp. 19 – 21) discovered that common challenge in PPM is related to balancing resources. They believe that this is simply because there is often a mismatch between the number of resources available and their demand. According to Si et al. (2022) this is because management tend to "overload the portfolio" in desire to maximise revenue. This leads to the situation where projects must compete for resources, which means that the implementation of one project incurs opportunity costs, while another project is discriminated against and loses value (Loch & Bode-Greuel, 2009, pp. 232 – 233). Yet, this is not the only problem in resource allocation as there is often lack of portfolio tools and methods that enable effective resource allocation. The tools often fail to properly check resource availability because they focus on assessing projects individually instead of looking at the availability of resources for the whole portfolio (Cooper et al., 2000, pp. 19 – 21). Also, Tolonen et al. (2015, pp. 471 – 472) found that companies tend to focus more on single products and modules rather than on the entire product portfolio.

Another challenge identified by Cooper et al. (2000, pp. 21 – 22) is related to project prioritisation and selection. According to them, the problem is that too many product projects are started or kept active because they pass the gateway barrier. According to Tolonen et al. (2015, pp. 471 – 472) increasing size and diversification of the product portfolio can cause challenges in PPM. The problem is that projects may look good based on objective values such as net present value and scoring models, but the projects are not necessarily evaluated against each other (Cooper et al., 2000, pp. 21 – 22). This leads to situation where there is not discrimination between projects and it is hard to identify go, kill and hold projects from each other. Another reason for the increase in the product portfolio may be an over-prioritisation of customer preferences and a failure to manage the portfolio throughout its life cycle, meaning that a clear PPM concept is missing (Tolonen et al. (2015, pp. 471 – 472). According to Cooper et al. (2000, p. 22) force-ranking project with each other enables the creation of a priority list, where all projects for which the company has resources are listed from best to worst, making it easier to identify the projects' potential and thus facilitate decision-making.

Tolonen et al. (2015, pp. 471 – 472) found that insufficient visibility across the portfolio due to lack of reporting capabilities creates challenges for PPM in companies. Cooper et al. (2000, pp. 22 – 23) also discovered that the lack of appropriate information to support decision-making creates issues in PPM. By this they mean that the evaluation of the potential of projects often fails to pay adequate attention to early-stage work such as preliminary market and technical assessment and business analyses. This leads to a situation where the quality of information used to support decision-making is not high enough, with the direct result that the quality of decisions is also affected. According to Cooper et al. (2000, pp. 22 – 23), this is particularly important when making go/kill decisions in PPM, as properly done early work provides high quality information to management, who can use it to create a stronger product portfolio with a higher success rate.

Also, literature review written by Eckert and Hüsig (2022, pp. 217 – 218) highlights the challenge identified by Gutiérrez (2014) related to PPM decision-making. This challenge is the ambiguity of decision-making, where ideas are allowed to evolve until their purpose and benefits are better understood in order to make more informed decisions. According to Eckert and Hüsig (2022, pp. 217 – 218), such prolongation of decision-making is an unnecessary use of resources. Moreover, Meyer (2014, p. 17) and Lechler & Thomas (2015, p. 1462) have argued that there are biases associated with PPM decision-making, and in particular with termination decisions. Meyer's (2014, p. 17) research introduces the optimism bias, where decision-makers allocate resources to weak projects because they believe that their impact will result in lower project costs than calculated in the project's business case and that the project will deliver greater benefits than originally expected. According to Lechler & Thomas (2015, p. 1462), there can be a misalignment between a manager's personal goals and the goals of the organisation, which is reflected in the favouring of so-called “pet projects”, which in turn has a significant impact on both project initiation and termination decisions.

According to Cooper et al. (2000, p. 23) that companies are missing major hits in their portfolio that have the ability to generate major revenue. Instead, portfolio is built on smaller more short-term projects, which do help to ensure competitiveness, but the problem lies in the fact that if these projects utilise all available resources. As in that case there is not enough resources for development projects. According to Cooper et al. (2000, p. 23) this kind of situation often results on missing product innovation strategy, which serves as a framework for business development and spending priorities. Similar observations were also made by Kester et al. (2011, pp. 641 – 642), Jugend et al. (2016, pp. 5098 – 5099) and Barczak et al. (2009, pp. 8 – 9). They found that a focus on more incremental innovations, rather than more radical long-run innovations, leads to an unbalanced product portfolio and has a negative impact on sales and profits.

Research by Tolonen et al. (2015, pp. 471 – 472) presents that cannibalisation inside product families is also typical challenge related to PPM. Product cannibalisation is related to expanded product portfolio as according to Wan et al. (2012, p. 323) it is result of increased product variety. General belief is that wider product variety will have positive effect on company's market share and its ability to satisfy customers (Ho & Tang, 1998, as cited in Wan et al., 2012, p. 316). Yet according to research by Wan et al. (2012, p. 323) too wide product variety can have negative effect on sales and thus company's competitiveness.

These challenges related to PPM are summarised in the table 2 below. Based on challenges identified in the literature, it can be concluded that product portfolio's size and the amount of product variations can be seen as the common factor that unites many challenges related to PPM. It can also be noticed that usually a large portfolio is perceived to be the result of inefficient decision-making in PPM. However, it is not the size of the product portfolio alone that is the problem, but the bad complexity it might bring with it (Distel et al., 2020). As it is quite evident that as the number of products in a portfolio increases, the complexity of the portfolio also increases. Of course, this is not always a bad thing. As mentioned above, a broad product offering is often a smart way to differentiate or reach different customer segments, and where this is the case, complexity is often a good thing, especially if it delivers more value than cost (Benedet et al., 2021, Distel et al., 2020; Ho & Tang, 1998, as cited in Wan et al., 2012, p. 316). But complexity can also be bad if it only adds complexity to the portfolio without providing additional customer value (Distel et al., 2020).

However, Benedet et al. (2021) points out in their article that, almost without exception, some of the complexity that comes with a wide product offering does not add value. Instead, they argue, products made for a narrow customer base, for example, are not cost-effective, or inefficient product life cycle management can mean maintaining products that have already lost their potential. Both of these examples add unnecessary complexity to the portfolio. It is also often found that a very small part of the large portfolio generates most of the gross margin and that unnecessary complexity actually adds a lot of costs that could easily be recovered with limited margin loss by optimising and simplifying the portfolio (Benedet et al., 2021). Thus, it can be reasoned that a large portfolio makes PPM more challenging. In practice, these challenges take the form of resource problems or product cannibalisation as mentioned before.

According to Benedet et al. (2021) when optimising a portfolio, it is often most beneficial to focus on identifying the drivers of complexity, which can differ depending on the company. Examples of the complexity drivers could be product groups, products or components. In most cases, the complexity does not directly arise from the number of product variations themselves, but more from the number of components that an organisation must design, procure, assemble and maintain to support these variations (Distel et al., 2020). In practice, optimising the portfolio could mean, for example, pruning unnecessary items. According to Benedet et al. (2021), ideal candidates for pruning are products that use a number of unique components and have a low impact on revenue. In this way, the complexity of the portfolio can be reduced with minimal sales loss.

Table 2. Summary of the general challenges in PPM.

Challenges	**References**
- Lack of a formal process. - Misalignment between PPM and the company's overall business strategy.	Killen et al., 2008, p. 33
- Mismatch between the number of resources available and their demand.	Cooper et al., 2000, pp. 19 – 23

Challenges	References
- Inefficient resource allocation. - Poorly implemented project prioritisation and selection. - Lack of appropriate information to support decision-making. - Inadequate product innovation strategy.	
- Excessive focus on individual projects, rather than the portfolio as whole. - Large size and excessive diversity of the portfolio. - Over-prioritising customer needs. - Lack of clear PPM concept. - Poor visibility across the portfolio. - Cannibalisation inside product families	Tolonen et al., 2015, pp. 471 – 472
- Postponement of decision-making.	Gutiérrez, 2014, as cited in Eckert & Hüsig, 2022, pp. 217 – 218
- Biases in decision-making.	Meyer, 2014, p. 17, Lechler & Thomas, 2015, p. 1462
- Excessive focus on small projects and neglect of major long-term innovations.	Cooper et al., 2000, p. 23, Kester et al., 2011, pp. 641 – 642, Jugend et al., 2016, pp. 5098 – 5099, Barczak et al., 2009, pp. 8 – 9
- Increased complexity resulting from a broad portfolio.	Distel et al., 2020

2.2 Identifying product sustaining activities

Product sustaining activities are one of the four levels of the ABC cost hierarchy (Cooper & Kaplan, 1991, p. 132). According to Horngren et al. (2015, p. 183), activity-based costing (ABC) systems often use a cost hierarchy that defines cost allocation criteria, that are cost drivers for activity cost pools. According to Ittner et al. (1997, p. 145) and Cooper and Kaplan (1991, p. 131) the idea behind cost hierarchy is that it provides a structured approach to allocate resources into specific activities and thus enable that only relevant costs are taken into consideration. Originally introduced by Cooper (1990, 1995) and Kaplan and Cooper (1995), the cost hierarchy framework of an ABC system classifies the activities that consume resources and thus generates costs into four levels: 1. unit level activities, 2. batch level activities, 3. product sustaining activities, and 4. facility sustaining activities (Ittner et al., 1997, p. 144; Horngren et al., 2015, p. 183; Cooper & Kaplan, 1991, p. 132).

Output unit level activities refer to those activities that are performed for each unit of product or service (Ittner et al., 1997, p. 144; Horngren et al., 2015, p. 183). Batch level activities in turn are related to a group of products or services instead of a single unit such as setup costs (Horngren et al., 2015, p. 183). Product sustaining activities refer to activities that support the product portfolio, in other words, enabling all products in the portfolio to be manufactured and sold (Ittner et al., 1997, p. 144; Horngren et al., 2015, p. 183). Finally, facility sustaining activities relate to the maintenance of the physical plant, in other words, enabling the production facilities and environment to exist and function properly (Ittner et al., 1997, p. 145; Horngren et al., 2015, p. 183 – 184). These activities and their descriptions are further summarised in the table 3 below.

Table 3. The four levels of the ABC cost hierarchy (Ittner et al., 1997, p. 144; Horngren et al., 2015, p. 183; Cooper & Kaplan, 1991, p. 132).

Cost hierarchy	**Description**
1. Unit level activities	Activities performed for each individual product or service unit.
2. Batch level activities	Activities performed for each batch or group of products or service units.
3. Product sustaining activities	Product-specific activities that contribute to maintaining each product type's active status in the portfolio.
4. Facility sustaining activities	Activities involved in the maintenance of the production environment and its proper functioning.

In this study the focus is on product sustaining activities. Product sustaining activities ensure that all products with an active status in the portfolio can be manufactured and sold (Kaplan, 2001, p. 4) Therefore product sustaining activities are product-level activities, meaning that they are influenced by the number of different types of products rather than by the number of units or batches produced (Cooper & Kaplan, 1991, p. 132; Ittner et al., 1997, p. 144; Horngren et al., 2015, p. 183). Thus, product sustaining activities play an important role especially when the number of products or components increases, which naturally adds complexity (Banker et al., 2021). This additional complexity arising from the variety of products is reflected, among other things, in the increased need for activities such as coordination, material transfers and storage, which cannot be taken into account if only manufacturing volumes are considered (Banker et al., 2021). This also means that resource requirements for product sustaining activities are not related to production volumes or batch quantities (Kaplan, 2001, p. 4).

Product sustaining activities typically include a range of actions related to process engineering, product specifications, keeping bill of material up to date, engineering change notices, preparation of routings and product improvements (Cooper & Kaplan, 1991, p. 132; Banker et al., 2021). Kaplan (2001, p. 4) also adds that product sustaining activities are also associated with different specific tests and tools for certain products. Thus, it can be concluded that engineering and R&D departments have a huge role in carrying out product sustaining activities in companies.

2.2.1 Activity analysis

Activity analysis is a process where activities are identified and defined, so that allocation of resources and cost to the activities and from there onwards to the cost objects can be done appropriately (Alhola et al., 2000, p. 215). According to Alhola et al. (2000, p. 215) the basic idea with activity analysis is that all organisational processes and actions are broken down to the level of activities. They continue that the result of activity analysis is more than an overview of current practices, as it also provides an idea of the kind and number of resources required for different activities. Thus, it can be summarised that activity analysis provides an insight into what is being done in a company and how resources are being used. Alhola et al. (2000, p. 216) state that often the activity analysis alone provides a lot of useful information for a company to support its decision-making.

According to Alhola et al. (2000, p. 215) and Lumijärvi et al. (1995, p. 32) activity analysis can be seen as a tool, which allows the company to understand how the different activities are interlinked, what value they bring, and how much it costs the company to carry out the activities. In addition, the activity analysis provides the company insight into where resources are actually being used and how much is being spent. This information can be used to assess whether the company is making resource allocation decisions that support the business objectives, in practice whether the most important activities for the success of the business are consuming the most resources or whether unnecessary amounts of resources are being spent on less important activities (Alhola et al., 2000, p. 215; Lumijärvi et al., 1995, p. 33).

Activity analysis begins with mapping activities (Alhola et al., 2000, p. 215; Lumijärvi et al., 1995, p. 32). According to Alhola et al. (2000, p. 215) and Lumijärvi et al. (1995, p. 40), this can be done by interviewing the people concerned, both managers and employees. Alhola et al. (2000, p. 215) note that, it is not necessary to interview everyone, but it is sufficient that the interviews are carried out to the extent necessary to obtain a sufficiently comprehensive picture of the activities. According to Lumijärvi et al. (1995, p. 37) the precision with which the activities should be defined depends on the purpose of the analysis. For example, if the analysis is used to estimate the costs of activities or to prune the product portfolio, it is sufficient to define the activities at a rough level, as a precise definition may rather obscure the overall picture. Lumijärvi et al. (1995, p. 37) note that more precise description is more high maintenance and does not necessarily add value to the decision-making process. Once activities are mapped, the resource use per activity is discovered (Alhola et al., 2000, p. 216; Lumijärvi et al., 1995, p. 42).

The number of activities included to the analysis depends on the situation and what the company wants from the analysis (Lumijärvi et al., 1995, p. 39). This is because in some cases it is unnecessary to break down activities at task level as it may not provide new relevant information. Lumijärvi et al. (1995, p. 39) state that the number of activities included to the analysis and also the precision of the definition of activities is determined by the company, since the most important part of the activity analysis is to provide the company with useful information for its desired purpose.

2.3 Cost estimation with time-driven activity-based costing (TDABC)

Cost estimation refers to the process where historical data is gathered and analysed and in which quantitative tools, models and techniques are utilised to forecast future cost of a product, program or task (Mislick & Nussbaum, 2015, p. 11). According to Fanny (2019, p. 59), similar objective was also identified by Owens (2007) and Li et al. (2008), who define the purpose of cost estimation as predicting the costs required to perform tasks and activities. There is a clear link between cost estimation and organisational performance and efficiency, which is why it has a major impact on design and operational strategies and plays a key role in various business decisions (Niazi et al., 2006, p. 563).

2.3.1 Activity-based costing (ABC)

Activity-based costing (ABC) was first introduced in the 1980s at Harvard Business School by Cooper and Kaplan (Kaplan & Anderson, 2003, p. 2). From this, over the next couple of decades, ABC replaced the so-called traditional costing, where costs were calculated on the basis of direct costs, such as labour or material, and indirect costs were taken into account only as a marginal constant of direct costs (Andrade et al., 1999, pp. 175 – 176). According to Andrade et al. (1999, p. 177) this shift was caused by changes in production environments as it was noticed that ABC was more suitable in modern production environments were the number of products and competition between companies were risen. This risen global competition has motivated companies focus on providing high quality product with competitive prices, which has led to increased desire to determine costs more accurately (Gunasekaran & Sarhadi, 1998, p. 231). It was found that the importance of indirect costs increased as production methods changed and costs associated with support, design, maintenance, data processing and marketing increased, making a more accurate assessment of indirect costs necessary (Andrade, 1999, p. 177). According to Andrade et al. (1999, p. 177) and Gunasekaran and Sarhadi (1998, p. 231), the ABC system is a more suitable cost estimation system for a wider range of products because it does not present the same inaccuracies in indirect and overhead cost estimation as traditional costing. These inaccuracies are caused by the allocation of indirect and overhead costs on the basis of direct costs, which does not give an accurate picture of the use of resources (Andrade et al., 1999, p. 177; Gunasekaran & Sarhadi, 1998, p. 232).

The basic idea behind ABC is that resources are consumed in activities and activities in turn are consumed by cost objects such as products, departments and suppliers (Andrade et al., 1999, p. 177). Thus, the ABC system aims to calculate the costs associated with activities such as processing, material transportation, inspection and all stages of production according to their resource consumption (Niazi et al., 2006, p. 569; Andrade et al., 1999, p. 177). Therefore, with the ABC system, the total cost of the product includes the cost of all value-added activities associated with the production of the product, in addition to the raw material costs (Gunasekaran & Sarhadi, 1998, p. 232). The ABC system takes into account what traditional cost accounting does not, namely that not all overheads increase in relation to the volume of products produced (Gunasekaran & Sarhadi, 1998, p. 232). According to Andrade et al. (1999, p. 177), such an approach allows all costs to be considered direct costs, as it ensures that costs are accurately traced to their cost object.

While ABC model was proven to be successful in initial studies its wider utilization has proven to be costly and challenging (Kaplan & Anderson, 2003 p. 2). Also, Siguenza-Guzman et al. (2013, p. 38) found in their literature review that although ABC overcomes the disadvantages associated with traditional costing, it is far from being the most optimal solution for cost estimation. Kaplan and Anderson (2003, p. 3) and Siguenza-Guzman et al. (2013, p. 38) have identified many challenges related to utilisation of ABC model which reveal that the ABC model, despite its potential, is not the best solution for most companies.

According to Kaplan and Anderson (2003, p. 3) costly and timely maintenance of ABC model has risen as a common barrier for its wider application within companies. This is because an outdated model cannot provide an accurate estimate of costs, thus ABC model must be updated every time when an activity is changed or removed (Kaplan & Anderson, 2003, p. 2; Kaplan & Anderson, 2004; Siguenza-Guzman et al., 2013, p. 38). This means that maintaining the ABC model requires a lot of resources in terms of continuous re-estimations, which means new interviews and surveys to take account of changes in the organisation.

The accuracy of cost drivers has also been a typical concern, as they are based on subjective estimates by individuals (Kaplan & Anderson, 2003, p. 4). Kaplan and Anderson (2003, p. 4) and Demeere et al. (2009, p. 297) has noticed that also biases can arise when people know the context in which the estimates are used. The accuracy of the data is also skewed by the fact that people tend to ignore idle time or unused time, so the information gathered from interviews may not be entirely accurate (Siguenza-Guzman et al., 2013, p. 38). According to Siguenza-Guzman et al. (2013, p. 38), the ABC model often assumes that resources are operating at full capacity, which distorts calculations. Kaplan and Anderson (2003, p. 5) and Siguenza-Guzman et al. (2013, p. 38) suggest that practical capacity would be a more realistic cost driver rate.

It has also been noted that the ABC model may not be able to reflect the heterogeneity of actual activity at the appropriate level, as the resources required to perform the same activity can vary greatly from situation to situation (Kaplan & Anderson, 2004; Kaplan & Anderson, 2003, p. 4). This also challenging because there is always subjectivity in the assessment of the proportion of time spent by employers on each activity (Siguenza-Guzman et al., 2013, p. 38). Scaling up ABC models is therefore challenging, as taking into account the heterogeneous nature of activities requires adding new activities to the model, which increases the complexity of the model (Kaplan & Anderson, 2003, p. 4). This is because the expansion of the functional dictionary places greater computational demands related to data storing and processing (Kaplan & Anderson, 2003, p. 4; Siguenza-Guzman et al. (2013, p. 38). Which can lead to the situation where common spreadsheet tools such as Microsoft Excel, and even the official software packages, do not have the capacity to run the ABC system or are extremely slow. According to Kaplan and Anderson (2003, p. 4), companies have often separated the ABC models of different sites into their own models to solve this problem. However, the problem is that it is practically impossible to calculate a cost estimate for products that pass through several different production plants in the manufacturing process and thus go through several different models.

2.3.2 Fundamentals of time-driven activity-based costing (TDABC)

In order to solve problems associated to ABC, in the early 2000s Kaplan and Anderson developed time-driven activity-based costing (TDABC) (Kaplan and Anderson, 2007, p. 8). Similar to the original ABC model, the TDABC process starts with an estimate of the costs associated with providing capacity (Demeere et al., 2009, p. 298). In TDABC, however, resource use no longer needs to be allocated to activities, instead it is estimated using time equations that express the time required to perform activities as a function of several time factors (Hoozée & Bruggeman, 2010, pp. 185 – 186). Based on these equations, the time needed to perform each activity in each transaction is obtained. Once this time has been calculated, it is multiplied by the cost per time unit of resources to estimate the cost of each individual activity in the transaction. Thus, TDABC only utilizes two parameters to allocate cost of resources to cost objects: 1. the cost of providing resource capacity per unit of time and 2. an estimate of the units of time needed to complete an activity (Siguenza-Guzman et al., 2013, p. 39; Kaplan & Anderson, 2007, p. 8).

According to Siguenza-Guzman et al. (2013, p. 39) and Kaplan and Anderson (2007, p. 10) this first parameter, capacity cost rate, is received by dividing the overall cost of providing the resource capacity by the practical capacity of provided resources. They continue that those overall costs refers to all cost associated with the provided resources such as personnel, equipment and technology in certain department or process. Whereas according to Kaplan and Anderson (2007, p. 10) practical capacity is defined as the time that employees work without idling. This can be calculated in two different ways; the first alternative is to consider practical capacity as a percentage of the theoretical full capacity such as 80 % or 85 % and the second alternative is to estimate actual values adapted to the company (Siguenza-Guzman et al., 2013, p. 39). Kaplan and Anderson (2007, p. 10) note that estimation of practical capacity does not need to be calculated precisely as minor errors are not dangerous and major errors will appear later, either as unexpected capacity problems or overcapacity.

Another parameter required to use the TDABC model is the required capacity, which in this case is the time needed to execute each event (Kaplan & Anderson, 2007, p. 10). Traditional ABC utilises transaction drivers and assumes that time required to perform each activity is standard, whereas in TDABC, the time needed to complete these individual activities within different events is estimated by the project team (Kaplan and Anderson, 2007, p. 10). According to Kaplan and Anderson (2007, p. 10) these numbers can be obtained either by interviewing or directly observing employees while they are working. They continue that similar to capacity cost rate rough estimate is sufficient accuracy as the capacity demand estimates of the time-based model can be easily observed and verified.

Figure 5 below shows the TDABC model, which provides information on how costs are allocated in TDABC (Everaert et al., 2008, p. 177; Siguenza-Guzman et al., 2013, p. 40). Based on this model, resource expenses are first grouped into resource pools and resource cost drivers are used to allocate these costs based on measurable factors. Once the costs have been allocated to resource pools, the capacity cost driver can be calculated using the practical capacity. Activity cost drivers allocate costs on the basis of the actual time required by using time equations. According to Kaplan and Anderson (2007, p. 12) time equations enable taking into account variation in the time demands by combining different event scenarios into a single equation instead of requiring a separate activity for each scenario. Thus, these time equations make cost modelling more flexible and scalable, as companies can easily adapt to new processes or operational changes simply by adding terms to existing equations, and time-consuming employee surveys are not needed to determine time demand. Once the cost per unit of time and an estimate of the time required to complete activities is known, costs are allocated to cost objectives such as products.

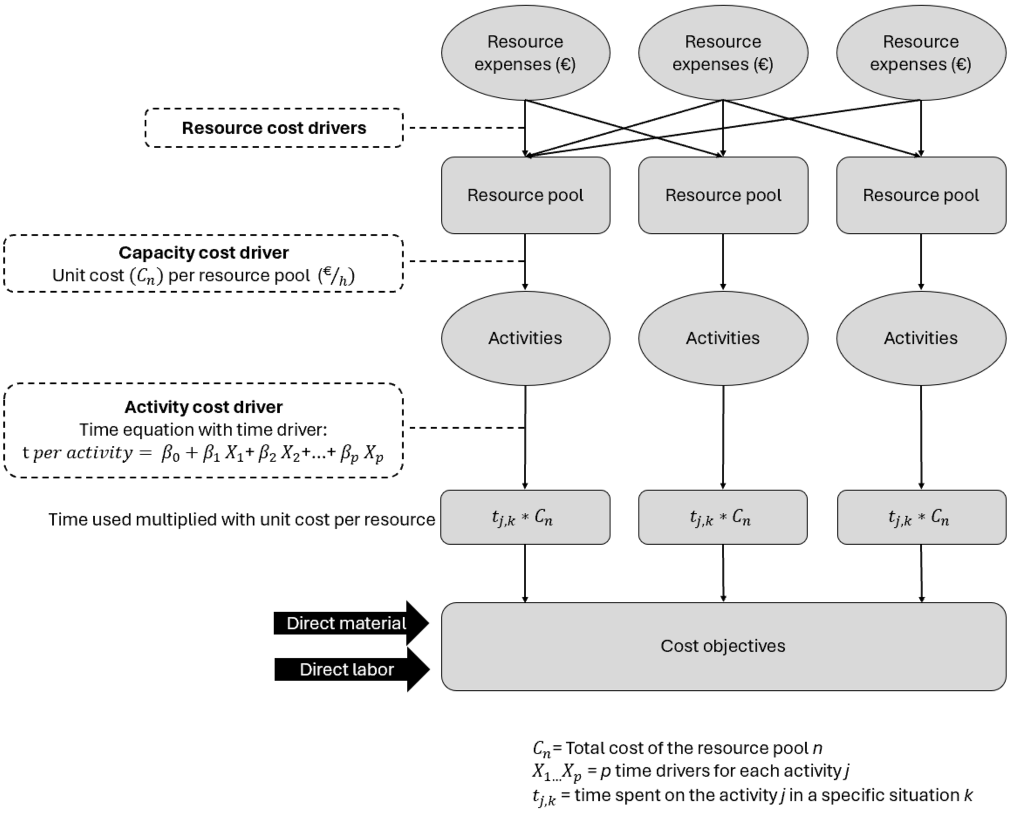

Figure 5. TDABC model (adapted from Everaert et al., 2008, p. 177 and Siguenza-Guzman et al., 2013, p. 40).

Updating the TDABC model when operating conditions change is a relatively simple and seamless process (Kaplan & Anderson, 2007, p. 13). When new variation of an activity or totally new activity is added to a department there is no need to re-interview employees as only the unit time required for new activity must be estimated (Kaplan & Anderson, 2007, p. 13). According to Kaplan and Anderson (2007, p. 13), changes affecting the cost driver can also be easily accounted for in TDABC model updates. The cost driver rate must be updated if there are changes in the prices of the resources supplied or in the efficiency of the operations. According to Kaplan and Anderson (2007, p. 13) possible factors causing these changes include salary increases that raise the price of the resource capacity supplied or, for example, the introduction of quality programmes such as six sigma or new technology that could increase efficiency and thus change resource requirements. Overall, Kaplan and Anderson (2007, p. 13) summarise that the TDABC model needs to be updated in response to changes rather than at fixed intervals. They continue that in ideal circumstances each process time equation would have an operational owner which responsibility is to keep equation up to date.

2.3.3 Rationale for application of TDABC

As discussed above ABC method is able to provide precise estimation of indirect costs and total costs per activities. Although ABC made cost accounting more efficient compared to traditional cost accounting. It was noticed that ABC was not the most suitable cost estimation system for most organisations especially with many functions (Kissa et al., 2023, p. 255). This because is because ABC system requires time consuming and resource intensive regular updates with thorough interviews and surveys to provide accurate information (Kissa et al., 2023, p. 255). Also to summarise what was previously discussed it is very challenging to take into account heterogeneity of nature of activities in the ABC model as it means adding new activities to the model, which in turn complicates the model and creates computational challenges. As discussed, TDABC is modified version of ABC system, that aims to simplify and correct inefficiencies in traditional ABC. The strengths of TDABC lie in its easier and less complicated maintenance and implementation. The main differences between ABC and TDABC that explain the choice of TDABC are presented in the table 4 below.

Table 4. ABC vs TDABC (adapted from Kissa et al., 2023, p. 255).

Feature	ABC	TDABC
Allocation of costs	In two phases	In one phase
Requirements for adding new activity	Survey	Only assessment of the time needed for a new action
Costs of the method	Expensive	Moderate
Schedule for system update	At specific time periods	When a new activity is to be added
System maintenance	Resource intensive → Expensive	Flexible in terms of resources → Simple to maintain

Feature	ABC	TDABC
Visibility	Great	Very good

TDABC is better suited to this study because the aim is to calculate the costs associated with the use of resources per activity, which is what TDABC is intended to do. Given the limited resources available for this study, it is not appropriate to carry out a comprehensive and more resource-intensive ABC analysis. The use of TDABC is also more useful for the case company because the TDABC model is easier and less burdensome to maintain. Due to these reasons, it seems more appropriate to continue with the TDABC method, as it better supports the nature and objectives of the research.

2.4 The importance of evaluating the use of resources in product sustainment

Evaluating resource use associated with product maintenance is crucial in product portfolio management as it provides important information that can be used to ensure portfolio's alignment with company's strategic objectives. Because of the Porter's five forces model 1980s, the interest towards strategic importance of company's heterogenous resources as a source of competitive advantage arise (Maijanen, 2020, p. 3). According to Maijanen (2020, p. 3) research papers written by Wernerfekt (1984), Rumelt (1984) and Barney (1986) highlighted the importance of internal company resources. Priem and Butler (2001, p. 23) highlighted the role of Barney's (1991) article as a forerunner of many resource-based studies by providing an initial framework. Barney (1991, p. 103 – 106) state that resource-based view (RBV) is based on assumption that company resources are both heterogeneous and immobile. According to Priem and Butler (2001, p. 25), heterogeneity refers to the ability of resources that are both unique and valuable to contribute to a company's ability to achieve competitive advantage. Whereas they consider that if these resources are also immobile meaning that they are not replicable, replaceable and buyable, company can achieve sustainable competitive advantage. The basic idea behind RBV is that company is able to achieve competitive advantage by leveraging

VRIN resources, in other words resources that are at the same time valuable, rare, inimitable and non-substitutable (Barney, 1991, pp. 105 – 112). However, it may not be enough for a company to have just the right resources, they must also be used in an optimal way to deliver value and contribute to competitive advantage (Heimonen & Takala, 2019, p. 186). It is therefore important to be aware of how these resources are used in the different activities of the organisation and how much resources are required for certain necessary activities in order to know whether the company is operating optimally (Kapur, 2024). When managing a product portfolio and trying to maximise its potential as well as value it can be seen as greatly important to be aware of given amounts of resources needed for different activities, to make informed decisions.

2.4.1 Life cycle costing (LCC)

Life cycle costing, or LCC, is a method that allows the assessment of a total cost-effectiveness of a given asset to be estimated over a specific period of time (Davis Langdon Management Consulting, 2007, p. 3). Based on the consulting report by Davis Langdon Management Consulting (2007, p. 3), the LCC assessment includes the acquisition, operating, maintenance, and disposal costs. LCC is therefore able to provide a holistic understanding of the costs incurred during the life cycle of a product. As costs are a key factor on the evaluation of products' importance and justification within the portfolio, cost related tools such as LCC can be seen as an important asset on product evaluation. Per the report by Davis Langdon Management Consulting (2007, p. 3), LCC is most commonly used when the consideration extends from initial cost of the product but also the subsequential operating cost of the product. LCC is fundamentally a decision-making tool, which for instance assesses the total cost commitment included, facilitates effective choices through metrices such as energy usage, helps to balance initial capital as well as future revenue costs, and helping to identify opportunities for better cost efficiency (Davis Langdon Management Consulting, 2014, p. 5). According to Sherif and Kolarik (1981, p. 287), LCC is defined as an analysis technique, where a product is inspected from its initial stages to its disposal. Thus, LCC is utilised in the attempt to minimising the given costs of having a certain level of constant output. The evaluation of the life cycle cost over the initial acquisition costs alone is widely known to be more beneficial (Davis Langdon Management Consulting, 2007, p. 5).

As life cycle cost can be defined as the sum of all the assets used to support a product from its initial design and manufacture through its use until the end of its life (White & Ostwald, 1976, as cited in Woodward, 1997), it is important to understand what kind of phases product life cycle consist of and how these phases effect on total cost of product. According to marketing literature, product life cycle typically consists of four phases: introduction, growth, maturity and decline (Bengü & Kara, 2010, p. 326). It is important to be aware of different life cycle phases of a product as it enhance systematic new product designing and development and thus prevent fluctuations in sales and also it enables companies to be aware of their products current market position (Demir ve Gümüşoğlu, 1998: 126, as cited in Bengü & Kara, 2010, p. 327).

According to Bengü and Kara (2010, p. 326) the introduction phase consists of product planning and manufacturing. They continue that in this phase sales are slowly increasing, faults are corrected, and the manufacturing experience increases. In the growth phase buyers have found the product and sales are increasing rapidly (Bengü & Kara, 2010, p. 326). This leads to increasing profits and products becoming profitable as incomes are bigger than the costs. Also at this point, the quality of the product is often improved, and the product may be modified with additional features. After growth phase product enter to maturity phase, which is according to Bengü and Kara (2010, p. 326) longest and the most important phase in the products life cycle as the sales are the highest. However, at the end of this phase sales start to drop which leads to decreasing profitability due to high competition and rising costs. After maturity products enter their last phase, called decline (Bengü & Kara, 2010, p. 326). In this phase new products have entered the market and their sales have increased, resulting in lower sales and production volumes of older products. According to Bengü and Kara (2010, p. 326), in a decline phase, the price of a product falls due to lack of demand, but the manufacturing costs of products still rise.

According to Bengü and Kara (2010, p. 327) Karakaya (2004) classifies cost occurring during product life cycle into three groups: 1. pre-manufacturing costs, 2. manufacturing costs, and 3. post-manufacturing costs. The characteristics of costs occurring at different stages in the product life cycle can be summarised as follows (Karakaya, 2004, as cited in Bengü & Kara (2010, pp. 327 – 328):

- Introduction: As previously discussed, sales are relatively low in this phase, however fixed unit costs are high due to lack of effective cost control. Thus, at this phase, the product may not yet be profitable.
- Growth: Once sales start to grow, fixed costs are decreased and exceeded, and thus the product becomes profitable. It should be noted that competitors may enter the market.
- Maturity: Now fixed costs are minimal as production and sales have reached the highest level and cost control is more efficient. However, at the end of the maturity phase after the product has been on the market for a while, sales tend to decrease, due to new competitors and technological advancements and improvement in the field. This will lead to an increase in fixed costs and a decrease in profitability, as competition in the market will remain fierce and the cost of maintaining sales levels will increase promotional costs.
- Decline: The decline in profitability is accelerating as sales constantly decrease and fixed costs increase. At some point of the decline phase, the decision to retire product must be made.

Below, figure 6 visualises and summarises how sales and profit vary depending on which life cycle phase the product is in.

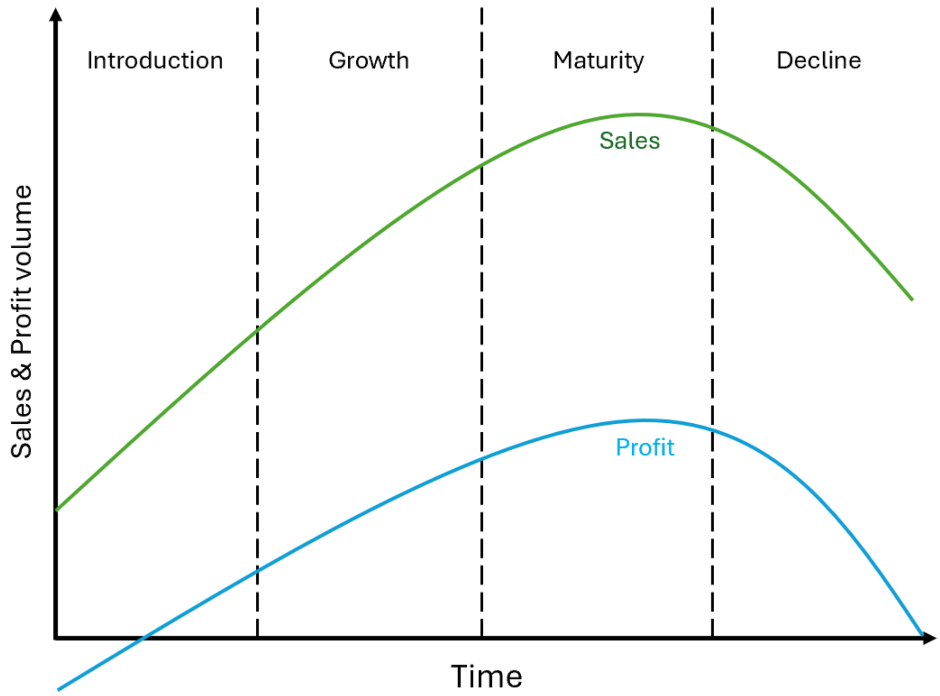

Figure 6. Product life cycle phases (source: author).

Sievänen et al. (2004, pp. 398 – 399) made observations on how product sustaining costs change depending on the phase of the product life cycle. They noticed that the cost structure of the product varies depending on which life cycle phase product is in. According to them, products in the decline phase has typically significantly higher product sustaining costs and unit cost compared to products in other phases. This was because the design of these product models was often outdated, with little focus on making the manufacturing and assembly process more efficient, leading to higher unit costs. Whereas higher product sustaining costs were the result of keeping up a production line, maintenance, product updates and technical support, while at the same time production volumes are decreasing. Thus, Sievänen et al. (2004, pp. 398 – 399) concluded that products in the decline phase are most unprofitable and unnecessary life cycle extension would increase product sustaining costs per unit as these costs remain almost same as in the maturity phase, but production volume will decrease.

Nowadays, product manufacturing activities have moved to mainly product design and development, thus the relevance of design and development cost have increased in the total cost of ownership (Bengü & Kara, 2010, p. 328). According to Bengü and Kara (2010, p. 328), this has increased the share of pre-manufacturing costs in total costs, forcing more attention to be paid to all costs during the product life cycle, before, during and after manufacture. The main purpose of LCC is to determine operating profit and costs that are not directly related to the manufacture of the product, optimise the cost structure and facilitate cost planning (Bengü & Kara, 2010, p. 328).

2.4.2 Total costs of ownership (TCO)

Total Cost of Ownership (TCO) is a tool used in purchasing to help understand the total cost of buying a product or service from a certain vendor (Ellram, 1995, p. 4). According to Ellram (1995, p. 4), TCO can be seen as complex, often requiring that the buying party identifies and determines the most significant costs related to the purchase, whether it is the purchasing price, possession and maintaining, use, or disposal costs. Thus, the given price may consist of many other values than just the price paid for the item, such as qualification expenses, transportation, inspection as well as possible downtime caused by error. TCO is another tool which can provide additional value when evaluating products relevance in a portfolio.

According to Carnicero et al. (2023, p. 7), TCO is a cost calculation method in which costs consist not only of the final acquisition cost, but it also takes into account, for example, of cost such as use, maintenance and other related cost. Thus, TCO helps in financial estimation of all related costs in a way that helps organisations to prepare and compare different alternatives and the long-term cost structures, which may prove that the initially more expensive option might be the most financially reasonable in long term. In the context of product sustainment, it can be conducted, that TCO can prove to be usable when estimating if the given product is worth it to keep in the product portfolio. The action of removing low performance and redundant products from portfolio has several benefits such as freeing consumed resources and rationalising sales levels, and the successful use of frameworks and tools may help in identifying these products to be removed (Leiter, 2011, p. 3).

2.4.3 Cost-benefit analysis (CBA) as decision-support framework

Cost-benefit analysis (CBA) is a technique that can be used to assess the profitability of a project or investment by comparing an activity's economic benefits with its economic costs (Shively, 2012, p. 1). According to Holland (2012, p. 1) and Shively (2012, pp. 6 – 7), CBA facilitates decision-making by providing information to assess the potential of a project, compare projects and decide whether a particular activity is worthwhile. She continues that CBA can also guide how to realise the benefits of a given activity, in other words, what are the requirements for its success and what further action should be taken, considering the benefits and costs. As CBA aims to decide whether certain activity should be performed comparing the costs and benefits of an activity (Holland, 2012, p. 1). According to Holland (2012, pp. 1 – 2). CBA consist of five basic steps, presented in the figure 7 below. She states that all steps are crucial, however first there step probably require most time, effort and knowledge.

Figure 7. CBA process (adapted from Holland, 2012, p. 2).

To be able to compare costs and benefits of an investment several financial metrics can be utilised such as net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IIR) to quantify benefits and costs as monetary value (Shively, 2012, pp. 5 – 6).

Net present value (NPV) determines the present value of the net benefits of a project (Shively, 2012, pp. 5 – 6). This is obtained in simplified terms by calculating the benefit minus the cost, and when calculating the sum of the net benefits over time, the future values are discounted using a discount rate. According to Shively (2012, pp. 5 – 6) if NPV is over zero project can be considered as a potential candidate. Benefit-cost ratio (BCR) in turn is obtained by dividing the present value of benefits by the present value of costs and if the value is over one project shows potential (Shively, 2012, pp. 5 – 6). The internal rate of return (IIR) is the maximum monetary value that can be spent on the project's resources, leaving enough money for other costs, such as operating costs (Shively, 2012, p. 6). According to Shively (2012, p. 6) criterion for a project to be approved should be that its IRR is higher than the project's discount rate.

According to Romijn and Renes (2013, p. 12), the decision-making process consists of several steps, from identifying the problem, to evaluating different options, to making the decision itself. They continue that CBA is commonly used at the latter stages of the decision-making process, however it can also be a useful tool at earlier stages of the decision-making process. In order to realise the best potential of the CBA it must be properly integrate as a part of decision-making process (Romijn & Renes, 2013, p. 12). CBA can be very useful tool in decision-making by providing a baseline for project evaluation forces to provide quantitative data in addition to qualitative justifications (Shively, 2012, p. 6). Thus, the most important benefit of CBA is that it is a tool to make more objective decisions by reducing the value of subjective reasoning and value judgements. CBA is also valuable when two alternatives are compared to make decisions which one is worth of investment as it compares alternatives using same methods and thus, makes it easier to identify better option (Shively, 2012, p. 6).

Although CBA has many benefits, there are also challenges associated with its use (Shively, 2012, pp. 6 – 7). According to Shively (2012, pp. 6 – 7) typical challenge associated with CBA is that it requires to determine monetary value for all benefits and cost, which can be very difficult for intangible benefits and costs. He continues that another challenge related to CBA is its sensitivity to chosen discount rate as the results are strongly affected by it. Finally, he adds that the main challenge is that it is impossible to see into the future and to predict all costs in advance.

According to Janatyan and Shahin (2020, p. 165) CBA is common technique to assess and prioritise products. Thus, it can be concluded that when assessing whether or not certain product sustaining activities should be undertaken to keep product active, that CBA could be a useful tool to facilitate decision-making by understanding the financial consequences of whether or not to implement activities. This is because CBA provides systematic way to assess for example products value by considering consequences (benefits and costs) (Janatyan & Shahi, 2020, p. 165). And also, because CBA can provide valuable information to help identify strategically essential products, enabling informed decisions to be made on the allocation of resources that support a company's strategy (Janatyan & Shahin, 2020, p. 176).

3 Methods

In this chapter research methodology is described and research design is presented. Here the research methods used to collect and analyse the data in order to meet the research objectives are discussed in depth. This is done by providing clear explanations and descriptions of how the research was carried out and how the results were achieved, including a detailed research design and the methods used to collect and analyse the data. The aim of this chapter is to ensure the transparency of the research process by allowing the reader to understand how the research results were obtained.

According to Helo et al. (2019, p. 14) research problems can be divided into two groups: nomothetical and normative. They continue that the nomothetical research problem refers to an examination of the current environment, while the normative research problem examines how to act in the future. The research problem in this study was that case company wants to get better understanding of activities performed across organisation that enable products active status in the portfolio, how much working time is spend on these activities and how does the size of the product portfolio effect on these activities. Thus, this research problem is nomothetical as this research focused on to understand current behaviour and practices at the case company. Yet, there is also characteristics of normative as the results of this research can be used to support decision-making to improve case company's operations in the future.

3.1 Research design

This study aimed to provide insights what kind of activities are performed across case company to keep alive their product portfolio, how much human resources are required to complete these activities in terms of percentage of working hours and what kind of effect does the product variety within product portfolio have on these activities. Therefore, this research was conducted as an exploratory single-case study by using sequential mixed method design with inductive approach. According to Saunders et al. (2023, pp.

133 – 134) interviewing experts in a typical way to implement exploratory research, which was also the method used in this study. The exploratory research design was chosen because, according to Saunders et al. (2023, p. 179), it is an appropriate way to explore and gain a better understanding of the issue, and it is flexible in nature, allowing for modifications to be made if new information emerges.

As a research method, a case study examines a current issue in a real-life context using empirical methods (Yin, 2009, pp. 18 – 19). According to Eriksson and Kovalainen (2015, p. 132) case studies are suitable for obtaining holistic and contextual in-depth information as it utilises multiple sources of data. According to Yin (2009, pp. 47 – 52), single case study design is a common way of conducting a case study in circumstances where a particular existing theory is to be examined, the circumstances are unique, the subject is a typical case or a revolutionary case, or a particular case is to be studied over a longer period of time. For this study, the single case study approach was considered suitable because the circumstances of this study were considered unique as it examined the topic from the view of one specific case company. The study therefore sought to get a particular company's perspective on the activities they carry out to maintain the active position of their products in their product portfolio. By interviewing people across the organisation in different departments, the most important activities and the amount of effort these activities require can be identified and defined. This information could in turn be used to estimate the monetary value of the human resources required for product sustaining activities annually, highlighting the issue from economic perspective. In addition, the interviews aimed to get an idea of whether the size of the portfolio affects the implementation of these activities in terms of challenges or increased workload, and whether certain product features pose challenges, especially for product sustainment.

A mixed-methods study combines both qualitative and quantitative data, with the assumption that the integration of both data sets provides information that neither data alone is capable of producing (Creswell & Creswell, 2018, p. 4). According to Creswell and Creswell (2018, pp. 180 – 181) qualitative data is usually collected by the researcher through direct interaction with individuals in the form of qualitative interviews. Whereas quantitative data is typically measurable and numerical and can therefore be analysed using statistical methods (Creswell & Creswell, 2018, p. 4). This study used qualitative data to better understand the complex nature of product maintenance from several different perspectives. As the case company wished to gain a concrete picture of the amount of resources they currently spend on product maintenance and understand what kind of products could potentially be pruned from the product portfolio to decrease the resources used for product maintenance. The inclusion of quantitative data in the study allowed the results of the qualitative data to be concretised and enabled the data to be provided to the case company according to its wishes. Thus, in this case, qualitative or quantitative data alone could not achieve the desired results, which is why a mixed-methods study was considered to be the most suitable research method.

In this study, qualitative research provided the basis for quantitative research, which is why the study closely followed an exploratory sequential mixed method design. The idea of an exploratory sequential design is to first collect qualitative data in order to study the phenomenon, as qualitative data helps to develop a quantitative method (Cassel et al., 2018). This is because, in this study, the variables used in the quantitative phase were unknown and must first be explored and identified using qualitative methods. In addition, the information gathered from the qualitative phase provided background information for the quantitative phase.

Research with an inductive approach starts with the collection of data essential to the study with specific focus and without predefined assumptions (DeCarlo, 2018, p. 209). After which the data is explored with the aim of identifying patterns and moving the view to a more general level. The identified patterns are analysed and sought to be explained by building theories. The inductive approach was chosen for this study because of the order in which it proceeded from data to theory, rather than seeking to prove theory as in the deductive approach.

3.2 Data collection

Both qualitative and quantitative data were utilised in this study. Qualitative primary data was collected from eighteen semi-structured interviews. According to Braun and Clarke (2013, p. 49) 10 – 20 participants is a sufficient sample size for interactive data collection methods such as interviews for medium or singular projects. This further confirms the chosen sample size of eighteen interviewees as appropriate for the research. Together with the secondary quantitative data, cost of one working hour were utilised to get the estimate of costs of sustaining activities by applying TDABC principles. The company provided a list of active products in their product portfolio as an Excel, which contained products variety codes and description of the products. This secondary qualitative data was used to obtain quantitative primary data, the consumption history of the portfolio products over the last five years, from the case company's SAP ERP system.

Case studies tend to use non-probability sampling (Taherdoost, 2016, p. 22). This study employed a purposive sampling method, to select relevant people from different departments in the organisation, in order to obtain a comprehensive overview of product sustainment across the organisation. For this decision-making process, a couple of persons in a managerial position were consulted in order to identify the individuals in the case company who could provide relevant information for this study, based on their job description and experience. The consulted personnel have long experience of working in the case company in different roles and therefore have a comprehensive picture of the work that different teams and individuals perform in the company and how they contribute to the overall performance of the organisation. The interviewees were selected from a variety of departments, as the maintenance of products is visible in very different ways depending on the department's responsibilities. The inclusion of several departments in the study therefore allowed a better understanding of the overall impact and role of product sustaining activities. Eventually, eighteen employees from the case company were included in this study, as this was found, in agreement with the case company, to provide a sufficiently broad coverage of the different departments and relevant perspectives within the case company. Available time and resources also had a significant impact on the selection of the sample size for the interviews.

The semi-structured interviews were hold through Microsoft Teams between 13th of March 2025 and 10th of April 2025. Before interviews, interviewees were given background information about this study and opportunity to ask questions, in addition, they were informed that their identity would remain anonymous in the study. All semi-structured interviews were guided by interview guide that was provided beforehand for the interviewees. The interview guide consisted of nine base questions, which were divided into three categories, with the aim of directing the discussion to the topics relevant to the study. The utilised interview guide can be found in the Appendix 1. The semi-structured interview format, allowed for additional and clarifying questions to be posed as the discussion progressed and also provided the possibility for interviewees to elaborate their answers in a flexible way.

All semi-structured interviews were transcribed using the Microsoft Teams transcription tool with the consent of the participants. This tool automatically converts speech into a transcript in text format using artificial intelligence. Afterwards, all the transcripts were read through, correcting any errors made by the transcription tool. These transcriptions enabled more effective analysis of qualitative data as it allowed reviewing and analysing interviews in written form. Table 5 below shows the interview data, including which department within the organisation the interviewee represents, the title of the interviewee and the length of the interview in minutes. Total eighteen interviews were conducted at the case company to cover all relevant departments from the case company.

Table 5. Interviewees.

Department	Title	Length (min)	No
Product Engineering	Production engineering specialist	24	1
	Production engineering specialist	37	2
	Production engineering specialist	28	3

Department	Title	Length (min)	No
	Production engineering specialist	32	4
Quality	Quality manager	33	5
	Production quality control manager	23	6
R&D	Product owner	31	7
	Product owner	28	8
	Certification engineer	32	9
Procurement	SCM data specialist	31	10
	Sourcing manager	34	11
Purchasing	Planning and fulfillment manager	20	12
	Material planner	32	13
Technical sales support	Global sales support team leader	35	14
Production	Production manager	40	15
Logistics	Planning and fulfillment specialist	29	16
Customer care	Customer support manager	20	17
Continuous improvement	Continuous improvement manager	23	18

3.3 Data analysis process

Once research design and sampling were determined and data collection was conducted different data analysis methods were used to receive results. In order to answer the research questions, the analysis of qualitative and quantitative data must be carried out sequentially. For the first research question, qualitative analysis provided the basis for quantitative analysis by generating variables that can be used in quantitative analysis that applies the principles and ideology of TDABC. For the second research question, only qualitative data was utilised. However, for the third research question, again the qualitative analysis also provided the necessary background information to move on to the analysis of quantitative data.

Thematic analysis was the main method used to analyse the qualitative data, as it allows the identification, analysis and reporting of specific themes and patterns in the data (Braun & Clark, 2006, p. 6). Thematic analysis was also suitable for this study because of its flexible and straightforward nature, which allows for a thorough analysis of the data (Saunder et al., 2023, pp. 664 – 665). This was done by integrating information from the different interview transcripts and literature, developing explanations and drawing conclusions about the identified key themes. Taking into account, the inductive approach to this study, themes were identified from the data (Saunders et al., 2023, p. 664). In this study thematic analysis followed steps presented by Saunders et al. (2023, p. 665) and Braun and Clark (2006, p. 35), which are visible in the figure 8. These steps were followed when analysing literature and interview transcripts.

Figure 8. Thematic analysis process (adapted from Saunders et al., 2023, p. 665 and Braun and Clark, 2006, p. 35).

To answer the first research question, thematic analysis was used together with the TDABC methodology. The thematic analysis of the semi-structured interview transcripts revealed how much time product sustaining activities required within different departments or, alternatively, how large a proportion of total working time departments spent on these activities each year. This information together with the quantitative secondary data, cost of one working hour and average working days per year formed a foundation for cost estimation. Based on this information, it was possible to estimate the annual cost of human resources for the activities required to maintain the organisation's product portfolio by applying the principles of TDABC. Thematic analysis of the interview was also used to answer the second and third research questions.

In order to fully answer the third research question, content analysis was applied to analyse secondary qualitative data provided by the case company, list of active products in the portfolio. Since the analysis of consumption/sales data in the study was limited to three product families, the products in these three product families must first be identified from all active products. The identification of these three product families was therefore carried out by content analysis of product descriptions and variety codes. Mainly, the identification of product families was based on the use of variety codes, whose structural pattern allowed to identify a product family, as the case company has a certain product classification logic. If the product family could not be identified by the variety codes, the product descriptions were used to identify the product family by searching and identifying recurring keywords.

Once these three product families had been identified from the list provided by the case company, the variety codes of these products were used to retrieve consumption/sales data from the case company's SAP ERP system. This quantitative data was analysed using time series analysis and descriptive statistics. Time series analysis was used to identify products with zero demand over the last five years. A five-year time period was considered, together with the case company, to be a long enough period to review the products' sales history. Descriptive statistics in turn were used to calculate the percentage of these zero demand products within each predetermined product family.

From the interview transcripts it was possible to identify product features that increase the workload associated with keeping product active status in the portfolio. These features can most often be identified by product variety codes, with a specific code structure representing specific or atypical product variants. Therefore, these products were identified using a pattern-based classification of variety codes, and these identified products were further validated by the case study company to ensure that the correct products were identified. Descriptive statistics were again used to determine the proportion of products for which demand was zero and which are also particularly labour-intensive to sustain. Utilised datasets and the ways of the analysis are further combined in the table 6.

Table 6. Utilised datasets.

Data collection	Data format	Description	Analysis
Literature review	Qualitative	Journal articles, research reports, books, consultancy reports and theses.	Thematic analysis
Semi-structured interviews	Qualitative	Interview transcriptions	Thematic analysis
Data provided by the case company	Quantitative	Cost of one working hour	TDABC
Data provided by the case company	Qualitative	List of active products in the portfolio	Content analysis
Data extracted from the case company's SAP ERP system	Quantitative	Consumption/sales history	Time series analysis / Descriptive statistics

3.4 Validity and reliability of the research

Quality and credibility of the research results is often assessed through validity and reliability (Andersson et al., 2024). According to Andersson et al. (2024) validity refers to the extent to which the research is capable measure what is desired and reliability in turn refers how consistent the research results are over time.

There are three types of validity: internal validity, external validity and construct validity (Andersson et al., 2024). In this study internal validity was enhanced by using purposive sampling based on expert input to ensure that interview participants had relevant knowledge and expertise. The single case study research design poses challenges to external validity, as the results are not directly generalisable outside the case company. However, the application of established theoretical frameworks, such as TDABC and PPM, allowed for theoretical generalisation and thus also addressed external validity. Construct validity was addressed in this study by validating the appropriateness of the interview questions by the case company to ensure that they captured relevant concepts and reflected the key objectives of the study. In addition, the application of TDABC principles to cost estimation ensured that the calculations followed the ideology of a well-established theoretical framework, which also contributed to the construct validity.

To ensure reliability in this study standardised procedures were applied in data collection. All interviews were conducted using the same interview guide, with themes and questions developed in cooperation with the case company. Combining the interview guide with the semi-structured approach to the interviews ensured consistency between the individual interviews through pre-defined base questions and themes, while still allowing flexible discussion. The reliability of the data collection was also ensured by transcribing all interviews using Microsoft Teams' own tool and manually correcting any errors in the transcripts, thus minimising the risk of data loss or incorrect interpretation. Reliability was also addressed by documenting data collection transparently so that another researcher could repeat a similar study. By following these principles, the aim was to ensure that the data is reliable, which adds credibility to the analysis and ultimately to the research results.

4 Results

This chapter contains a presentation of the results of the study. It is divided into three separate sections. The first section reviews the results of the eighteen semi-structured interviews conducted during the study from the perspectives guided by the research questions. This is followed by an application of the TDABC ideology and a presentation of the results of this analysis. At the end of this chapter, the results obtained by analysing quantitative data obtained from a case company's ERP system are outlined.

4.1 Findings from interviews

In this section, findings from the semi-structured interviews are discussed. This chapter begins by going through product sustaining activities carried out in the case company by departments. This is followed by a section summarising how much the interviewees estimate their team/department spends on product sustaining activities annually. This section finishes by outlining how the size of the portfolio is reflected in the implementation of product sustaining activities, especially in terms of workload.

4.1.1 Product sustaining activities carried out in the case company

The various product sustaining activities that take place across the organisation are discussed below by department to maintain clarity. Finally, the different actions are summarised by department in the table 7.

4.1.1.1 Product engineering

During the interviews, it became evident that the product engineering department performs the most product sustaining activities of all departments in the case company. This is logical, as the interviews also revealed that this department is locally responsible for keeping the products in the portfolio alive by implementing various projects to ensure the viability of the products. This responsibility was also highlighted by the different departments, as interviewee 7 also highlighted the local responsibility of the product engineering department for product sustainment. Within the department, the nature of product sustaining activities varies depending on the responsibilities of individuals.

According to interviewee 2 typical product sustaining activities include updating and approving product documentation and structures in different systems. These documents are for example guidelines for random testing, 3D models, quality instructions and guidelines in Integrated Management System (IMS). Interviewee 1 also identified similar maintenance activities in their area of responsibility. According to interviewee 2, these are either carried out on a regular annual basis or whenever necessary, for example in response to a quality incident or when certain standards change, if it is found that modifications must be made. Interviewees 1 and 2 stated that procurement of new tooling and the renewal of old tooling for component manufacturing, including tool approval and the design of tests to ensure tooling quality, is also one of the most important sustaining activities performed by product engineering department.

Interviewee 3 highlighted that in order to keep products alive, they are continuously communicating with different manufacturers and suppliers to solve different issues related to for example availability of components and testing issues. Availability challenges are solved by finding alternative components that are similar to the original ones. Interviewee 1 also mentioned a similar type of activity, instead of alternative components, they referred to the process of finding an alternative raw material. According to them, the search for an alternative raw material is often motivated by a decrease in the availability of the original, a better price or quality. Depending on the situation, these alternative components/raw materials may be approved by the production engineer themselves, or approval may have to be sought from the product designer depending on the extent of the change. In addition to finding alternative components interviewee 3 also mentioned that they maintain a list of alternative components to suppliers.

Interviewees 1, 2 and 3 also mentioned that, in order to maintain the viability of the products, they are actively involved in solving various quality cases and overall, their job involves working closely with the quality department to improve the quality of products and processes. These quality cases can arise either from the case company's own production, from the supplier's production or from customer complaints. The tasks associated with quality cases often involve investigations aimed at identifying the root cause of a quality problem, according to interviewee 3, which in turn often triggers product sustaining activities in other departments.

Interviewee 4 has slightly different responsibilities within the product engineering department compared to interviewees 1, 2 and 3, which is also reflected in the product sustaining activities they perform. Product sustaining activities carried out by interviewee 4 include updating product rating labels, product packaging labels, product bill of materials (BOMs) and purchasing norms. All interviewees in the product engineering department emphasised that the product sustaining activities they perform are related to the implementation of various modifications and besides implementing modifications, one important sustaining activity is also to document all changes made, so that afterwards it can be easily traced what has been done, why it has been done and when it has been done.

4.1.1.2 Quality

The quality department of a case company can be divided into a team of quality specialists and a measurement team, which carries out various measurements and tests for example on products, components and tools in the factory. According to interviewee 5 product sustaining activities performed at quality department are strongly connected to ones done by product engineering department. Interviewee 5 explained that quality specialists within quality department are responsible for the continuous review of quality cases and reclamations. If quality cases or reclamations lead to the need to implement changes in products, the quality specialists lead the implementation of this change, while the product engineering department is in practice responsible for the implementation of the change, for example in finding a new alternative component or raw material for the product, or in replacing a tool. Quality specialists also report all changes for example to the customer, if the change has been triggered by a complaint from them.

According to interviewee 6 measurement team in turn is responsible for ensuring that the products produced by the case company comply with specifications, standards, requirements and customer demands. Thus, measurement team implements routine inspections, carried out according to an annual programme, such as random tests, which guidelines are approved by a product engineering specialist. According to interviewees 5 and 6, the measurement team also supports other departments in implementing changes by carrying out examinations and tests, for example to ensure that the change is in line with standards or to identify the root causes of quality problems.

4.1.1.3 R&D

According to interviewee 7 product sustaining activities carried out in the R&D department are also strongly connected to ones implemented by product engineering department. This is because as mentioned above product engineering department has local responsibility for sustaining the vitality of products. In practise according to interviewee 7 the product engineering department acts as a filter, in front of any quality or customer issue and then if they think its design related, then R&D goes on from there. Thus, in its simplicity, it can be concluded that R&D is responsible for all design related sustainment. This was also pointed out by interviewee 8.

According to interviewees 7 and 8, design related sustainment involves providing consultancy and assistance to other functions. The R&D department is responsible for consulting on the search for alternative components and raw materials by providing information on, for example, the criticality of the component and its impact on the product design. Interviewee 8 also points out that procurement may want to improve the cost-effectiveness of the product through certain component modifications, and R&D is also heavily involved in these as a consultant and approver. This means that R&D will also approve all the so-called high-level modifications that may affect the design of the product. This is because, especially in the case of electronic components, component changes can be very complex and the chains of influence very long, which is why product development expertise is also required to implement change. Interviewee 7 also stated that when tools are in active use for long periods of time, the dimensions of the components they produce can often vary as a result of tool wear, and R&D accepts whether these dimensional tolerances are acceptable for product design.

Within R&D department interviewee 9 is responsible for product certifications and life cycle assessment calculations. According to interviewee 9, one of the product sustaining activities they carry out is to update existing certificates at certain intervals, for example every five years, to ensure that they remain valid. Another activity mentioned by interviewee 9 is, for example, modifying the labelling of products if the standard is updated. Interviewee 9 is also responsible for approving any changes to the rating plates before they go into production. All certificates are accompanied by annual audits in which interviewee 9 participates as a factory representative.

4.1.1.4 Procurement

According to interviewees 10 and 11 within procurement department product sustainment refers to maintaining material data and material prices up to date. Maintaining material data means keeping up-to-date information on from whom the material is purchased and if there are two or more suppliers for the material, which one is the main supplier and the split between them. Procurement will only make changes to the material data if necessary. Another important task carried out regularly by procurement is updating the prices of materials and components into the ERP system, which was particularly emphasised by interviewee 11. Interviewee 10 stated both of these activities are carried out manually. Thus, in its simplicity, in terms of product sustainment, procurement is responsible for ensuring that materials and components are purchased from the right supplier at the right price. This is done by ensuring that all necessary information is up to date and available for purchasing who in practice place the orders to suppliers.

4.1.1.5 Purchasing

Interviews with participants 12 and 13 revealed that forecasting for suppliers, keeping material safety stocks at the appropriate level and maintaining material data in the ERP system according to the responsibility of their function are product sustaining activities carried out by the purchasing department. Forecasting and safety stock level analyses are regular activities that contribute to the overall efficiency of supply chain operations. And forecasting in particular, according to interviewee 13, is an important communication with the supplier to facilitate a partnership where both parties are on the same page. Material data, such as delivery time or purchasing parameters, will only be updated, if necessary, in case of changes.

4.1.1.6 Technical sales support

Technical sales support, as the name suggests, provides customers both technical and sales support for products, as stated by interviewee 14. Interviewee 14 mentioned that their team is indirectly involved in product sustainment through pricing. In the case of product launches, the technical sales support team only supports other functions and is not directly responsible for pricing, as strategic pricing is not the responsibility of the team according to the interviewee 14. The team is responsible for individual pricing, which means that if a particular product does not have a price in the price list for a specific country, the technical sales support team will price that individual product into that country's price list. An important point mentioned by interviewee 14 was that the need for this is decreasing all the time. This is firstly because a few years ago the approach was changed so that now all products and their possible variations are priced in the price lists of different countries at launch using a specific pricing tool, and secondly because so many enquiries have been received over the years that there are not so many missing prices anymore. Therefore, individual pricing is only done for products if necessary.

Interviewee 14 stated that when pricing individual products on a price list for a particular country, the process is fairly standard. The process starts by checking the life cycle status of the product, which reveals the current life cycle stage of the product and whether it is active at all. Only active products will be priced. Then the price level in the country is reviewed, the profitability of the product is checked and finally, the price level of the existing price list is examined. For the pricing itself, a specific tool is used with built-in logic to ensure that prices between different variations would be logical.

4.1.1.7 Production

According to interviewee 15 in general, the team of production supervisors is responsible for production scheduling, including the management of lead times and delivery times, as well as the resourcing of production lines. This means that the product maintenance activities carried out by production are therefore related to the maintenance of phasing times as well as delivery times for finished goods in the SAP ERP system. According to interviewee 15 phasing times refers to the calculated production time of the product, including assembly, testing and packaging time, taking into account variations. According to interviewee 15, the phasing times only need to be adjusted if there are changes to the production process, such as adding a new testing step or modifying the packaging process.

Updating delivery times for finished products, on the other hand, is a much more frequent activity, state interviewee 15. Delivery times are updated taking into account the overall situation, material availability, quality challenges and line capacity constraints. Depending on the situation, delivery times can be adjusted on a three-tiered scale (short, medium, long) to either longer or shorter depending on the situation. This ensures that the delivery time reflects the actual situation as closely as possible and can be realistically achieved, in other words, that the customer can be served as promised. Interviewee 15 also points out that in addition to keeping the phasing times and delivery times up to date, it is the responsibility of production supervisors to ensure that all work instructions, quality reports, quality instructions and parts lists, assembly drawings are available in the manufacturing execution system.

4.1.1.8 Logistics

Interviewee 16 conducted that in the logistics department, product sustaining activities are very much related to the storing of products in the factory and in external warehouses of the company. Typical product sustaining activities include entering product warehouse information into SAP ERP when products are opened and maintaining this information throughout the lifecycle of the products. According to interviewee 16 this information includes where the product is stored, what kind of packaging the product is in and how many products are in the package. In addition to this, a very large and labour-intensive task every year is to take an inventory of all the products in the factory, to know how much is actually in stock and how much monetary value is tied up in the inventory. Interviewee 16 also mentioned that in addition to these tasks, the logistics department has to analyse various data, such as material consumption, in order to optimise storage.

4.1.1.9 Customer care

Based on interview with participant 17, customer care team at the case company is responsible for order processing and customer service, export documentation, freight forwarding and trade compliance export issues. According to interviewee 17 customer care team does not perform a lot of product sustaining activities, however they were able to identify one specific activity they regularly do. This product sustaining activity that they identified is the updating of ready-made price lists for each customer in the SAP ERP system. The team is not responsible for the pricing itself, but they receive the price lists from another source whenever changes are made and run the new updated prices on a per customer basis in SAP ERP. These price lists contain product codes, prices and information on validity periods.

4.1.1.10 Continuous improvement

According to interviewee 18, the continuous improvement team is responsible for developing production through automation and digital solutions in the factory. Therefore, the product sustaining activities they perform are also strongly linked to these automation and digital solutions. According to interviewee 18 typical product sustaining activities continuous improvement team perform are keeping manufacturing execution system up to date and to ensure that the software of the various robots used in the factory works as it should. In other words, the team will make sure these solutions work as intended and solve any problems that disrupt their functioning.

According to interviewee 18, these systems play an important role in ensuring that all the products in the portfolio can be manufactured in the factory, as the systems contain so-called individual recipes for the manufacture of each product. The systems control that the products are tested as designed for them, and the limits of these tests are also defined in these systems. In this way, these systems are involved in ensuring that products are subjected to all the right tests during manufacture and that they are passed within the right values. These systems also ensure that different devices work together, for example by ensuring that printers print the right labels on products. According to interviewee 18 systems are updated and information is added whenever necessary.

Table 7. Summary of product sustaining activities per department.

Department	Product sustaining activities
Product engineering	- Ensuring that product documentation and structures in different systems are up to date. - Strong involvement in the procurement of new tooling. - Implementation of product modifications. - Exploring alternative raw materials and components. - Providing support in quality cases. - Updating product rating labels, product packaging labels, product BOMs and purchasing norms when necessary. - Documentation of all changes made.
Quality	- Continuous review of quality cases and reclamations. - Managing the implementation of product modifications. - Reporting the product modifications made.
R&D	- Providing consultancy and assistance to other functions. - Implementing product modifications related to the design of products. - Ensuring that products meet their specifications and correspond to the planned design. - Updating existing certificates at certain intervals. - Making changes to product labelling if required by a standard update. - Approval of any modifications made to the rating plates.

Department	Product sustaining activities
Procurement	- Keeping material data up to date in the SAP ERP system. - Updating prices for purchasing components.
Purchasing	- Forecasting component demand for the supplier. - Maintaining safety stocks at the appropriate level. - Keeping material purchase information up to date in the SAP ERP system.
Technical sales support	- Pricing of individual products in situations where there is no price for that particular product in a given market sector.
Production	- Maintaining phasing times in the SAP ERP system. - Update delivery times for the end products, when necessary, in the SAP ERP system. - Ensure that the necessary assembly instructions are available on the production lines in the production execution system.
Logistics	- Entering logistics data into SAP ERP system when products are released and maintaining this data throughout the lifecycle of the product. - Inventory of stocks. - Analysis of material consumption and identification of slow-moving materials.
Customer care	- Updating defined prices to customers in the SAP ERP system.
Continuous improvement	- Maintaining the production execution system up to date and ensuring that it is working as expected. - Ensure that the software of the different robots used on the production lines in the factory works as it should.

4.1.2 Time usage on product sustaining activities carried out

The calculations in this chapter are based on full annual working time. Full annual working time used in this study was determined based on statistics presented by Teknologiateollisuus ry (2025) as the case company is a manufacturing company in the technology industry. Average figures over a 28-year period are obtained from Teknologiateollisuus ry website. Since the majority of white-collar workers in the case study company work 37,5-hour weeks, the corresponding figures have also been used in this analysis. Average values of annual working time presented by Teknologiateollisuus ry are summarised in the table 8 below.

Table 8. Average annual working time (Teknologiateollisuus ry, 2025)

Description	Quantity
Total days of the year	365,25
Saturdays and Sundays	104,35
Public holidays, which fall on weekdays and reduce the number of working days per year.	9
Annual holiday	25
Working days per year	226,9
Working hours per year	1702

The table 9 below summarises the time spent on product sustaining activities by all teams/departments represented by the interviewees, as a percentage of full working time, and the number of white-collar workers working in the team. A team or group of people working on a similar topic in the same department, viewed as a resource pool in the table 9, is represented by the letters A to M. So effectively the resource pool displays the number of workers in an examined group of a function. A couple of resource pools include only a part of the whole team if the sub-group was detected to have a separate viewpoint due to the roles. This was viewed as the most accurate way of evaluating different perspectives as sometimes functions or teams do not represent the roles and activities in the most comparable way. This is because within a team there may be people working on different subjects. The department column in the table 9 indicates which department each resource pool represents, and the interviewee column in turn defines which department, and thus which resource pool, each interviewee belongs to.

The time used on products sustaining activities is presented as a percentage of full working time. This was found to be the easiest way for participants to assess their time use. The percentages used were primarily determined by the interviewees themselves, based on how much working time they estimated spending annually on activities related to product sustainment. However, if the interviewee was able to determine how many working hours they spent annually on product sustaining activities, the percentage was calculated by dividing the interviewee's estimate by the statistical total annual working time. Participants also found it almost impossible to estimate the time spent on individual activities as time varies quite a lot depending on the situation. Thus, in this case, these percentages in the percentage of annual working time column in represents the time spent annually on all product sustaining activities within a given resource pool.

Table 9. Time spent on product sustaining activities per team represented by interviewees.

Resource pool	Department	Interviewee	% of annual working time	Number of people in the resource pool
A	Product engineering	1	50 – 80 %	9
		2		
		3		
		4		
B	Quality	5	20 – 30 %	10
C	Measuring team (Quality)	6	100 %	15
D	R&D	7	20 – 25 %	11
E	R&D	8	30 %	11

Resource pool	Department	Interviewee	% of annual working time	Number of people in the resource pool
F	Certifications (R&D)	9	30 %	1
G	Procurement	10	5 %	8
		11		
H	Purchasing	12	5 %	6
		13		
I	Technical sales support	14	25 %	9
J	Production	15	5 %	7
K	Logistics	16	30 – 40 %	4
L	Customer care	17	< 1%	10
M	Continuous improvement	18	10 %	9

4.1.3 The size of the product portfolio and related challenges

Based on the interview responses it can be noted that the size of the product portfolio has an effect on product sustaining activities within most departments. This impact was mainly reflected in an increased workload to perform these activities. In all departments this effect was not as clear. For some of the interviewees, the large portfolio size increases the time spent on product sustainment significantly, while for others the impact is very small or non-existent. Interviewees 6, 9 and 17 for example did not recognise that the number of products in the product portfolio would affect the amount of time they spend on maintaining the products. Whereas especially interviewees 4, 5, 12, 15, 16, and 18 highlighted that large portfolio makes product sustainment more burdensome. Table 10 summarises, by department, the issues discussed below where portfolio size is considered a challenge or a workload factor.

The size of the product portfolio refers to the number of different end products and variations that can be sold to the customer. The portfolio of a case company includes several different product families consisting of variations of the product due different characteristics. In some departments, each separate variation increases the time required for sustainment, especially when changes are made to the products. This is not the case in all departments as in most, each of these variations does not increase the effort required to sustain the portfolio. Based on various interview responses the workload, specifically from a sustainment perspective, is increased by variation at the component level. This means that the effort required to maintain products tends to increase as the number of components increases.

The interviews revealed that the challenges are mainly related to the fact that with a wider product portfolio the amount of data to be maintained also increases. With a larger product portfolio, there is also more information to keep up to date in the different systems. For example, from a procurement and purchasing perspective, interviewees 11, 12 and 13 pointed out that when there are many end products, the number of components to be purchased also inevitably increases, which means that procurement also has more information to keep up to date. With the large number of different components to be purchased, there is a risk that the updating of material data will be neglected. This is especially the case for infrequently consumed materials, such as volume models take up all the attention. There is also a risk that they may be inadvertently ignored in various analyses because they are consumed so infrequently that they fall outside the scope.

The same type of challenges from a logistics perspective were also identified by interviewee 16. The number of components is directly reflected in the amount of information, such as storage locations and inventory data, that needs to be maintained. Interviewee 16 also points out as an example, that a wide product portfolio increases the workload of the annual inventory in a linear way, because the more different products SAP has as end products or components, the more materials need to be counted.

According to interviewee 11 from a procurement perspective it cannot be justified to keep alive products with low and occasional demand, especially if they contain unique components that are not used in many other products. This is because procurement must ensure that every supplier has the ability to produce each component in their portfolio. Ensuring that a supplier has the capacity and capability to produce components that have low and irregular demand is more challenging. Interviewee 11 points out, that often in such situations a smaller quantity has to be purchased from the supplier as a special batch, resulting in a higher unit price than is actually taken into account in the total cost of the product, thereby reducing the profitability of the final product. Interviewee 16 also pointed out that it does not necessarily make sense from a logistical point of view to keep slow-moving products alive, as they require, for example, storage facilities, which are not free. Therefore, the logistics department must constantly analyse these slow-moving materials, as storage space is limited and it is therefore necessary to exploit it optimally.

Interviewee 5 also recognised that low-demand products in particular present challenges in terms of sustainment. The more products in the portfolio, the more the focus needs to be spread across products, while a narrower portfolio would allow a better focus on keeping up the quality of volume products. Indeed, interviewees 5 and 6 mention that volume products require much more effort in terms of maintenance, as, for example, tools wear out much faster.

Even though component level complexity is primarily considered as a factor that increases workload in portfolio maintenance, it is important to note the impact is not limited to products with unique components. In fact, all products contribute to the time needed to maintain a portfolio. This means that regardless of whether the products contain the same components, each product row in the portfolio requires attention and thus affects the process of some sustaining activities. This can be seen, for example, in product engineering, continuous improvement, quality and R&D departments, especially when implementing changes to products. This is because change often starts with the desire to modify a particular component or to change the raw material of a particular component in order to improve certain product's performance. However, often this change affects not only this one product, but many others that use the same component. Implementing a change therefore requires a huge amount of testing to be sure how the change will affect every product that uses the same component. In the continuous improvement department, these changes are reflected in the need to ensure that all systems and test equipment work correctly after the change. The responses reveal that the more complex the product, the more testing and expertise is required to investigate these consequences and to ensure that the change works for all products it effects.

Also, for example, an important point raised by interviewee 4 is that, at least for the now, updating the rating plates of some product families in the event of changes is a very slow process. This is because in some product families, such as product family 1 included in the quantitative analysis, each variation has a unique rating plate in its bill of materials. In practice this mean that currently at least, the updating of the rating plates for certain product families has to be done individually and manually for each variation, so that the size of the portfolio is directly reflected in the time needed to do this. They mentioned that to do this particular update alone for this product family 1 would take them four weeks if they were not doing anything else at the same time.

Interviewee 15 stated that from a production perspective, the size of the portfolio has also been identified as a factor that delays the implementation of delivery time updates, as there is more data to analyse. Changes in delivery times are mostly triggered by a specific reason, such as difficulties in component availability or line capacity. This means that a change must be made for all the end products concerned. For example, in the case of a component availability challenge, the change must be made for each end product for which the component is required. Or, in the case of a line capacity problem, the change is likely to apply to all products manufactured on that specific line. This means that in order to make the change, it is always necessary to examine which end products will need to have their delivery times changed.

Production also works with product engineering and quality to ensure that accurate and up-to-date assembly instructions are available for all products. The more end products there are, the more instructions there are whose availability and accuracy must be ensured. Interviewee 15 noted that in some cases assembly instructions for infrequently manufactured products were accidentally neglected, resulting in incomplete documentation. As a result, the assembled product did not fully meet its specifications, leading, for example, to customer complaints. This kind of situations are likely connected to previously discussed challenge highlighted by interviewee 5. When maintaining a broad portfolio, the focus needs to be spread across multiple product families and products to such an extent that the likelihood of such situations increases.

From a product pricing perspective, interviewee 14 pointed out that the large number of variations poses challenges in terms of logical pricing, ensuring that prices between variations are reasonably consistent with each other. The number of product variants also increases the effort required from the continuous improvement team in terms of product sustaining activities, because if there are any software-related updates to the products, every product on the product line has to be updated, so the more products there are in the portfolio, the more work there is to update.

Table 10. A summary of the issues where the size of product portfolio poses challenges.

Department	**Issues affected by the size of product portfolio / The challenge posed by a wide product portfolio**
Procurement	- Data maintenance (prices, supplier data). - Ensuring the supplier's production capability and capacity for all components, including low demand ones.
Purchasing	- Data maintenance (material data). - Review and analysis of data.
Logistics	- Data maintenance (storage locations, inventory data).

Department	**Issues affected by the size of product portfolio / The challenge posed by a wide product portfolio**
	- Annual inventory. - Review and analysis of data.
Quality	- The focus needs to be decentralised, rather than concentrating mainly on the volume, high-demand products that require the most attention.
Product engineering	- Ensuring the functionality of the product modification. - Maintenance of product-specific documents. - Ensuring the availability of assembly instructions.
R&D	- Ensuring the functionality of the product modification.
Continuous improvement	- Ensure the functionality of systems and test equipment.
Production	- Updating information related to the manufacture if necessary for all relevant products (delivery time). - Ensuring the availability of assembly instructions.
Technical sales support	- Ensuring logical pricing between different product variations.

4.2 Application of TDABC principles

The application of the TDABC principles in this case refers to the application of the TDABC ideology where the company's cost of the resources spent on activities is assessed based on the time spent on them. TDABC calculations start by allocating resources to resource pools. In this study, this means that the resources needed to maintain the products are considered on a department basis. TDABC calculation requires two values: required capacity and capacity cost rate. In general, the basic principle of TDABC would be to determine the cost of an individual activity on the basis of the time spent on each activity. However, this was proven challenging in the case company as all interviewees were not able determine time usage per activity. Therefore, the capacity required for this study has been determined on the basis of interviews as a percentage of the total annual working time of each team or group of people working on the same topic. This value per resource pool represents the average time spent by the team/group of people on all activities related to product sustainment. It should be noted that the conducted calculations are done with estimations made by the interviewees chosen into the scope of the research. This means, that whereas the obtained results of the calculations could be formatted in high precision, due the approximate nature of the input data, the results are considered also as rough indications. The results are used in the research to give an idea of how the resources are allocated in the organisation through employees working hours to maintain the product portfolio.

The annual working time of the entire resource pool was calculated by multiplying the number of people in the resource pool by the average working time of one person in hours, based on the statistics of the Teknologiateollisuus ry (2025). The annual capacity per resource pool required by the product sustaining activities was then determined as a percentage of the total annual working time of the resource pool by multiplying the interviewees' estimate by the total working time of the resource pool. Thus, estimates of the required capacities are shown in the table 11 below.

Table 11. Capacity required to carry out product sustaining activities.

Resource pool	% of annual working time	Number of people in the resource pool	Annual working time per resource pool	Required capacity
A	50 – 80 %	9	$= 9\,x\,1\,702\,h$ $= 15\,318\,h$	~8 000 – 12 000 h
B	20 – 30 %	10	$= 10\,x\,1\,702\,h$ $= 17\,020\,h$	~3 000 – 5 000 h
C	100 %	15	$= 15\,x\,1\,702\,h$ $= 25\,530\,h$	~26 000 h
D	20 – 25 %	11	$= 11\,x\,1\,702\,h$ $= 18\,722\,h$	~4 000 – 5 000 h
E	30 %	11	$= 11\,x\,1\,702\,h$ $= 18\,722\,h$	~6 000 h
F	30 %	1	$= 1\,x\,1\,702\,h$ $= 1702\,h$	~500 h
G	5 %	8	$= 8\,x\,1\,702\,h$ $= 13\,616\,h$	~700 h
H	5 %	6	$= 6\;\,x\,1\,702\,h$ $= 10\,212\,h$	~500 h
I	25 %	9	$= 9\,x\,1\,702\,h$ $= 15\,318\,h$	~4 000 h
J	5 %	7	$= 7\,x\,1\,702\,h$ $= 11\,914\,h$	~600 h
K	30 %	4	$= 4\,x\,1\,702\,h$ $= 6\,808\,h$	~2 000 h
L	< 0,4 %	10	$= 10\,x\,1\,702\,h$ $= 17\,020\,h$	~70 h
M	10 %	9	$= 9\,x\,1\,702\,h$ $= 15\,318\,h$	~1 500 h

In this study, the cost per time unit of the resources provided, that is, the employees, was based on the value offered by the case study company, 37 euros per hour. According to statistics (Teknologiateollisuus ry, 2025), one person works around 1702 hours per year, and if the cost of one hour of work is estimated at 37 euros, the theoretical cost of one person's annual working hours is $1702\ h\ x\ 37\ {}^{€}/_{h} = 62\ 974\ €$. Thus, the cost of the provided resources for a single resource pool can be estimated by multiplying the theoretical cost of one person's annual working hours by the number of employees in the resource pool.

The practical capacity used in this study is the working time of the employees, excluding any breaks. In the case company, almost all white-collar workers have a standard working week of 37,5 hours, which means 7,5 paid hours per day. Although the total length of the working day is 8 hours, a 30-minute unpaid lunch break makes up the difference. Employees are entitled to two 15 minutes paid coffee breaks during the 7,5 paid hours, so the effective working time is 7 hours per day. Thus, since statistically, according to the Teknologiateollisuus ry (2025), one employee works 226,9 days per year, the practical capacity of one employee can be considered to be $226{,}9\ x\ 7\ hours \approx 1\ 588\ hours$.

The capacity cost rate is calculated by dividing the cost of the resources provided by the practical capacity of the provided resources. In this study, only one standard cost for a working hour is used, which is 37 euros. Meaning that no matter how many people are working in a department, the capacity cost rate of each resource pool is the same. This is because the differences between resource pools in the cost of provided resources and the practical capacity of resource pools are only due to differences in the coefficient, the number of people. Thus, the capacity cost rate of all resource pools can be calculated by dividing the previously calculated cost of one employee's annual working time by the practical capacity of one employee: $\frac{62\ 974\ €}{1\ 588\ h} \approx\ 39{,}70\ {}^{€}/_{h}$. This represents the cost of one effective working hour per employee to the organisation.

Table 12 below summarises the values required for the cost estimate using TDABC, the required capacity in terms of time and the capacity cost rate. The table 12 also shows the annual cost of product sustaining activities for the departments considered in the study by multiplying the required capacity by the capacity cost rate. It is important to note that these are not additional costs but rather represent in monetary terms how existing resources are allocated each year to maintain the portfolio. As the costs are based on a proportion of the total working time of existing resources, they are incurred regardless of whether certain activities are carried out. The purpose is to provide an indication of the financial effort involved in maintaining existing portfolio. As shown in the table, the resource pools included in the study are estimated to spend human resources worth more than 2 million euros annually on product sustaining activities.

Table 12. Estimated personnel costs associated with product sustaining activities using TDABC.

Resource pool	Required capacity	Capacity cost rate	Cost of resources used on product sustaining activities
A	~8 000 – 12 000 h	39,70 €/h	~318 000 – 476 000 €
B	~3 000 – 5 000 h	39,70 €/h	~119 000 – 199 000 €
C	~26 000 h	39,70 €/h	~1 032 000 €
D	~4 000 – 5 000 h	39,70 €/h	~159 000 – 199 000 €
E	~6 000 h	39,70 €/h	~238 000 €
F	~500 h	39,70 €/h	~20 000 €
G	~700 h	39,70 €/h	~28 000 €
H	~500 h	39,70 €/h	~20 000 €
I	~4 000 h	39,70 €/h	~159 000 €
J	~600 h	39,70 €/h	~24 000 €
K	~2 000 h	39,70 €/h	~79 000 €

Resource pool	Required capacity	Capacity cost rate	Cost of resources used on product sustaining activities
L	~70 h	39,70 $^{€}/_{h}$	~3 000 €
M	~1 500 h	39,70 $^{€}/_{h}$	~60 000 €
		Total	2 259 000 – 2 537 000 €

4.3 Findings from the quantitative data analysis

Based on the semi-structured interviews, it can be concluded that it is possible to identify products within the case company's product families that require extra effort from the company's human resources to maintain them. This extra maintenance can be linked to products that have not been sold for a long period of time. This is due these products not adding value to the company through sales.

However, the interviewees' answers reveal that it would be an oversimplification to say that maintaining all zero demand products would generate extra work. This is because some zero demand product may use the same components as a volume product, but for example the number of components may vary, or they may be assembled differently. Such variation is not directly reflected in the workload of most departments in the company. Of course it is worth noting that there are also product sustaining activities where ensuring the viability of such product variations is also reflected in the time required for the activities.

Thus, it can be concluded that the number of active products in the product portfolio affects the effort required to carry out product sustaining activities. However, since it cannot be directly generalised that every zero demand product would require additional effort within most departments of the case company. The aim was also gain understanding which product characteristics increase the effort required to carry out product sustaining activities. Based on the interview responses, it was possible to understand which specific product features increase the time spent on product maintenance. Most respondents felt that the special models of products in particular present a challenge and thus affect the effort they put into product sustaining activities. This is because, according to the interviewees, special models add complexity into portfolio through increased component variety. Increased component variety is related to fact that special product designs mostly use components that are not widely used across product families. This means that the number of end products that use them is often small, which means that the demand for such components is often significantly lower than for components that are more widely used. Such special designs therefore increase complexity, which in turn has a positive impact on the time spent on maintaining the product family.

Thus, it can be seen that when assessing which product features cause unnecessary maintenance work across the product families, attention should be given to products with low demand and specialised components. Using this information, the aim was to identify, from three pre-selected product families, both the number of products with zero demand over the last five years and the number of products that can be perceived as special models. This information, in turn, allowed to understand the share of special models with zero demand within the product family. By determining the share of these products in the product family, it was possible to understand how large role such products play in each product family.

As previously mentioned before, the three product families pre-selected for quantitative analysis differ slightly in their characteristics. Product families 1 and 2 consist of the final products manufactured by the case company. The differences between them are that product family 1 contains more complex products and is significantly newer than product family 2. The third product family contains accessories which are sold by the case company alongside or in addition to its own final products. Product family 3 consists mainly of products purchased from suppliers, which are traded by the case company instead of being manufactured by the case company. Thus, for this product family, the role of special components is less important compared to the products manufactured by the case company itself. Consequently, the share of special models has not been estimated for this product family. Instead, for product family 3, the share of zero demand products has been assessed. This is due to the product level variation in product family 3 is comparable to the component level variation observed in product families 1 and 2. The reason for this is that resale products and components play a rather similar role in the case company. This means that for product family 3, analysing only the share of products for which there has been no demand, gives results similar to those for product groups 1 and 2 when analysing the share of special model with no demand.

Figure 9 illustrates how the 614 different products in product family 1 are divided into four different categories: zero demand, special model, special model and zero demand and others. As can be seen from the graph, only 5 products in this product family 1 are special models for which there has not been any demand. Figure 10 in turn presents a similar graph, but for product family 2. Product family 2 consists of 1239 products, meaning that product family 2 is about twice as large as product family 1. The proportion of products that are special models and for which there has been no demand is also significantly higher compared to product family 1. Product family 2 contains 194 products whose keeping active to some extent can be perceived to increase redundantly the time spent on product sustaining activities.

From the results presented in the figures 9 and 10, it can be concluded that product family 1 is significantly more optimal from a maintenance point of view compared to product family 2. This is because there are very few products in product family 1 with zero demand and unique components that add complexity redundantly. In contrast, product family 2 contains considerably more, almost forty times as many as product family 1. It can therefore be concluded that the structure of product family 2 is not favourable in terms of its maintenance. The optimisation of product family 2 could reduce the amount of resources needed to maintain all products in this product family, allowing these resources to be used elsewhere. These results indicate that a similar analysis may not be necessary for product family 1.

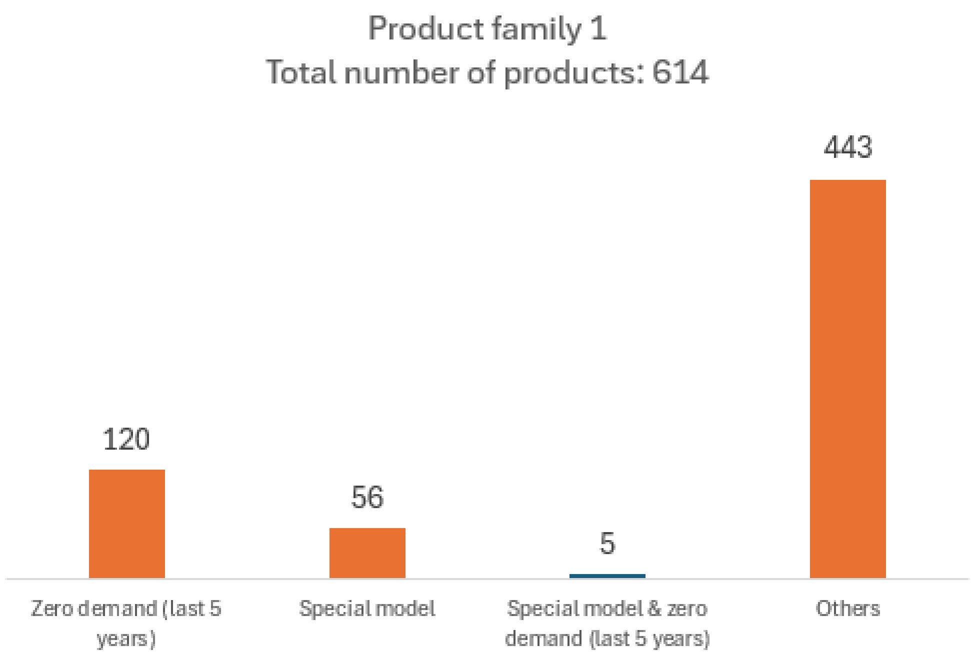

Figure 9. Products of product family 1 divided into four different categories.

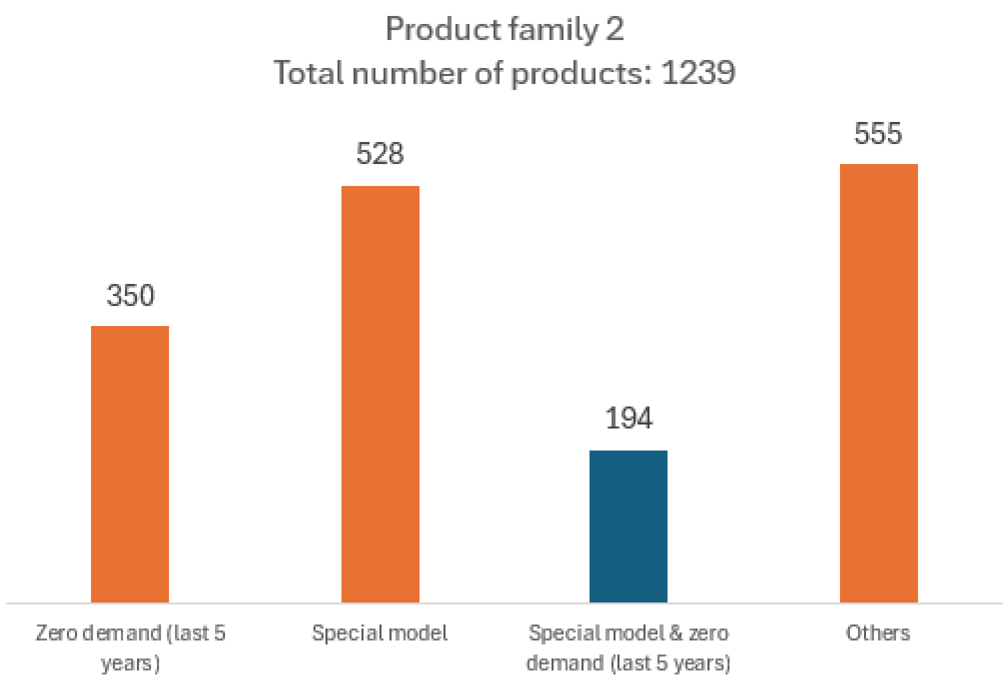

Figure 10. Products of product family 2 divided into four different categories.

Pie charts presented in the figures 11, 12 and 13 show the proportions of products in product families 1, 2 and 3 for which maintaining an active position can be perceived to increase, at least to some extent, the time spent by the different departments on product sustaining activities. As can be seen from figure 11, for product family 1, the proportion of products that would redundantly increase the effort spent on maintenance is very small. Figures 12 and 13 show that the proportions are much higher for product families 2 and 3. Nearly one sixth of the products in product families 2 and 3 can be perceived as products that do not add value to the company in terms of sales if they are kept active. Nevertheless, due to their characteristics, they still have a positive impact on the effort spent on product sustaining activities.

As mentioned before, product family 1 is a significantly newer part of the product portfolio compared to product families 2 and 3. Given this, it is possible that this difference between product family 1 and product families 2 and 3 can be explained, at least to some extent, by the relatively new position of product family 1 in the case company's product portfolio. It could be possible, for example, that when designing product family 1, the maintenance aspect was deliberately taken into account and the product family's products were designed in a way that the number of products with unique components that add complexity was kept to a minimum. The product sustainment perspective may have been better addressed for the newer product family because of the challenges that might have emerged with the older product families and the desire to address them. This would also explain why the proportion is higher for product families 2 and 3.

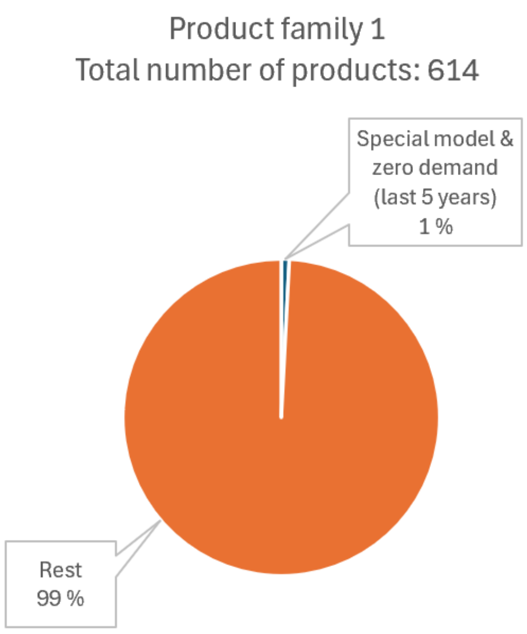

Figure 11. Proportion of products in product family 1 whose maintenance increases the resource use without clear added value**.**

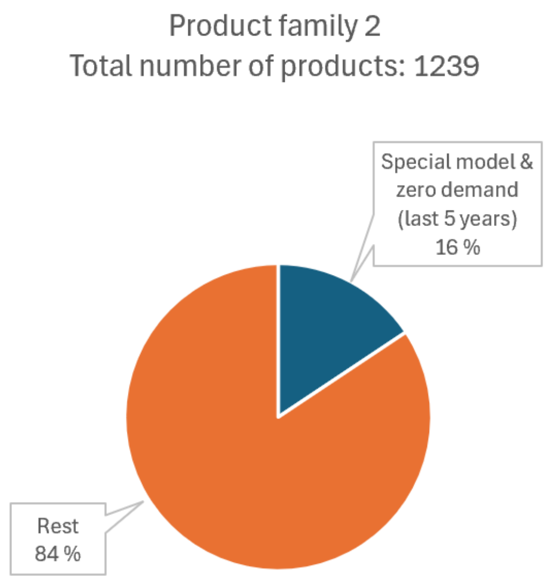

Figure 12. Proportion of products in product family 2 whose maintenance increases the resource use without clear added value.

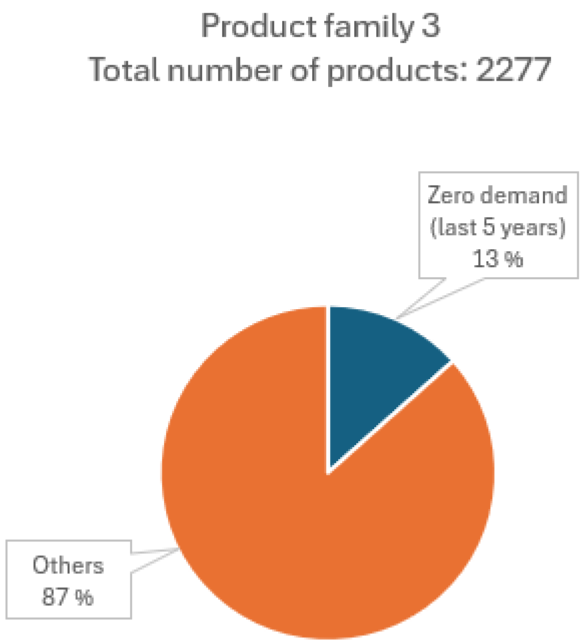

Figure 13. Proportion of products in product family 3 whose maintenance increases the resource use without clear added value.

5 Discussion and conclusions

In this chapter, research results are discussed, and conclusions are presented. The aim of this chapter is to critically evaluate the implementation of the study, and the results obtained, as well as to examine their alignment with the previous knowledge and theories discussed in the literature review. Thus, this chapter relates the study's findings to the existing body of knowledge and acknowledges this study’s theoretical contribution. This chapter also highlights the practical implications and provides recommendations for the case company. Finally, the limitations of this study are discussed in order to provide suggestions for future research.

5.1 Summary of the study and its findings

The aim of this study was to explore what activities are carried out by the different departments of the case company to ensure that all the products in the case company's portfolio are kept alive and can be sold to customers. The study also focused on estimating how much human resources are used to carry out these activities and what are the costs involved. In addition, this thesis sought to understand how portfolio size affects the sustaining effort required and which products in the portfolio have an increasing effect on the required effort. This allowed to determine the proportion of products in the predefined product families of the portfolio that have not had any demand but whose characteristics increase the workload from a sustainment point of view, at least for some of the case company's departments.

To achieve these objectives, a combination of qualitative and quantitative data and analysis was used. Combining the qualitative data with the TDABC analysis, made it possible to determine what kind of product sustaining activities are carried out in a manufacturing technology company and to estimate the cost of carrying out these activities in terms of human resources. The qualitative data also allowed to understand which features of the product in particular increase the effort required to maintain it and how the size of the portfolio affects its upkeep. Using this information and quantitative analysis, it was possible to identify products from pre-selected product families that have not had demand over the last five years but are perceived to increase the workload of product sustainment in several departments. This process was guided by three research questions:

1. What are the key activities that enable the case company's products maintain an active status in the product portfolio, and how much human resources are devoted to them annually?
2. What challenges can be detected in sustaining a broad product portfolio in terms of workload?
3. In the context of a large portfolio, which product features are linked to greater maintenance effort, and how significant role such products have in the product families covered by the study?

The first research question explores the kind of product sustaining activities carried out in the case company and the costs involved, taking into account the time spent by employees on these activities. This was addressed by interviewing eighteen employees from different departments of the case company. Through the interviews, it was possible to identify the key activities that enable products to maintain an active position in the portfolio. These key activities are summarised for each department in the table 7. It can be concluded that most of these activities are related to keeping up-to-date various types of data related to products, such as product documents for finished goods, assembly instructions, rating plates, component data, prices, delivery times or storage locations. The results of the interviews also showed that a large proportion of the activities involve changes that need to be made to the product or its manufacture, which may be the result of quality issues, complaints or a system update, for example. Interviewees underlined that when implementing activities related to product modifications, it is important to ensure that they do not adversely affect any product variations that may be affected. In other words, it is necessary to guarantee that all products will continue to function appropriately despite the change, even if the change itself is not necessary for each product it affects. This usually requires extensive analysis and a thorough understanding of the potential downstream consequences.

To answer the second part of the first question, qualitative data from the interviews and secondary quantitative data were used. Based on the interviews, it was possible to determine the proportion of annual working time that each department spends on average on various product sustaining activities. From the interview responses it could be noticed that the proportion of working time spent on product sustaining activities varies a lot between departments. Some departments spend easily the majority of their working time on these, while many departments spend around five to ten percent, if not less. Clearly, therefore, the department's responsibilities have a major impact on how many and how labour-intensive product sustaining activities they perform.

From the results of the interviews, it can be concluded that, within the case company, the majority of the workload in terms of product sustainment is concentrated in the product engineering, quality, R&D and logistics departments. Within product engineering, quality and R&D, it is more about ensuring product vitality, maintaining their performance and solving potential problems. Thus, it can be concluded on the responses of the interviewees that these departments are directly involved in the maintenance of the products. Whereas the logistics department's considerable workload is mainly related to annual inventories, continuous maintenance of reliable inventory data and ensuring efficient storage rather than the direct maintenance of the product. All of which significantly engage departmental resources each year. Other departments, such as logistics, may contribute to product sustainment more indirectly. Despite their indirect involvement, their participation is still essential for the successful manufacture and sale of products. Thus, even if these activities may be less resource intensive meaning that they require less time from employees, they still play an important role in the company's operations.

Using this information together with secondary quantitative data, including the cost of one employee working hour to the organisation and average annual working times based on the long-term statistics of Teknologiateollisuus ry (2025), the TDABC principles could be applied. Applying the TDABC ideology, the amount of human resources needed to maintain products could be quantified in monetary values based on the estimated time spent on them. Ideally, TDABC would seek to estimate the cost of individual activities in terms of the time taken to perform them. However, in this study, the time spent on all activities was quantified as a proportion of total annual working time. This was due to resource constraints, as the time spent on activities was determined through interviews and the interviewees found it challenging to determine the time spent on individual activities due to the high degree of situational variation. The conducted calculations revealed an estimated cumulative annual cost of close to 2,5 million euros, when all the investigated departments were considered.

The second research question explores how the number of products in the product portfolio affects the amount of resources that need to be spent on product sustaining activities. The interviews revealed both similarities and differences between the departments. Some departments felt that the number of variations of the final products does not affect their operations in any way. These activities, which were not significantly affected by the size of the product portfolio, were mainly related to the activities of the customer care or measurement team, or within R&D on certificates. However, in most departments this was seen at least to some extent as a workload factor, meaning that the number of products in the product portfolio contributes to the resources departments spend on product sustaining activities. This is because more products mean more elements that need to be maintained and taken into account in different activities, meaning that more resources need to be devoted to maintenance in terms of time and effort. Interviewees also highlighted the fact that a wide product portfolio can disperse the focus on many products and potentially limit the attention that can be spent on the most important high-volume products.

To answer the first part of the third research question, through the interviews the aim was to understand which product features in the large product portfolio increase the amount of work required, especially for product maintenance. Based on the interviews, it can be concluded that the reasons for the increase in workload related to the size of the product portfolio vary depending on the activity or department of the company. In some departments, the increase in the number of finished products has a direct impact on the time required to use on product sustaining activities. This applies in particular to the implementation of product modifications. As mentioned above, the functionality of the modifications must be ensured for all products affected. Therefore, a comprehensive analysis is needed, involving a lot of product data. In particular, the interviews revealed that the number of products has a direct impact on the time needed to update the rating plates of products. This is because in some product families, each product has its own rating plate, which means that the update has to be done separately for each product variant. Therefore, it can be concluded that the extent to which the product variety alone increases the workload depends greatly on the type of activity.

This is underlined in particular by the fact that it was discovered that in many departments the workload was not so much influenced by the number of products in the portfolio as by the variety of components needed to produce them. This leads to the conclusion that the workload is not only influenced by the number of products in the product range, but rather by the increasing complexity of component diversity that comes with the larger size of the product portfolio. It therefore can be viewed, that in terms of product characteristics in particular, the use of specific components in small number of products increases the effort required to maintain the whole portfolio. This is particularly evident in cases where unique or special components are needed for low-demand products, which creates additional workload despite low demand. Due to their specific nature, these components are not widely used across the product portfolio and total demand is often quite low. This is because typically the end products that require these special components are modified versions of the standard models and compared to them, demand is significantly lower. Even if the end products that need them have not been sold recently and therefore have not been produced, keeping them active in the portfolio requires a continuous effort from different departments. This is because teams need to ensure that information about these products and the components needed to produce them, such as technical data, stock balances and sourcing data, is up to date so that these products can be manufactured if a customer orders them.

To answer the second part of the third research question, the quantitative data from the case company's SAP ERP system were analysed using content analysis, time series analysis and descriptive statistics. By analysing the product families selected for the study in this way, it was possible to understand the role played by those products in the product families whose active presence increases the effort required from the company's existing resources to maintain them.

Depending on the product family, the share of such products varied slightly. In product family 1, the share was only around 1 %. This means that for this product family, resources are used quite optimally for the product sustaining activities. Of course, there may be exceptions for specific activities, such as previously discussed example related to rating plates. For product families 2 and 3, the proportion of such products was significantly higher. For these product families, these products account for just under one sixth of all products. It can therefore be concluded that these product families face greater difficulties, as maintaining a higher share of low-demand special models puts additional pressure on resources.

5.2 Theoretical contributions

This study provides valuable insights into product maintenance from the perspective of a manufacturing company operating in the technology industry. According to Kaplan and Cooper (1998, pp. 90 – 91), Kaplan (2001, p. 4) and Banker et al., (2021), product sustaining activities are often related to keeping product specifications up to date, various testing, tools, services and technical support for products. This was also supported by this study. The results of this study indicated that the primary responsibility for product maintenance in the case company belongs to the quality, product engineering and R&D departments. Their roles in terms of product maintenance align closely with common product sustaining activities identified by Kaplan and Cooper (1998, pp. 90 – 91), Kaplan (2001, p. 4) and Banker et al., (2021). However, there is currently relatively limited research available on product sustaining activities. In the current literature, it is therefore challenging to find more detailed information on product sustaining activities specifically in the manufacturing industry, as the topic is usually dealt indirectly or in the context of other issues.

Consequently, when there is relatively limited information available on product sustaining activities, there is also rather little theoretical evidence on their resource requirements. Another reason for this is possibly the challenge identified by Kaplan and Cooper (1998, pp. 90 – 91) of linking resource use and activity. According to them, determining the amount of resources required to carry out product sustaining activities is often perceived quite difficult, as they are not related to production volumes or batches. This challenge was also identified in this study. In addition to the fact that resource use is not linked to production volumes, a significant challenge in evaluating resource use was the context-specific nature of these activities. Interviewees found it difficult to accurately estimate the amount of time spent on individual product sustaining activities.

It could be also noticed that even though TDABC is very commonly used cost estimation framework, it has not been widely utilised within manufacturing industry. The current literature tends to focus more on applying the framework within other industries. Particularly in health care, the application of this framework seemed to be quite popular. In addition, TDABC has not been widely applied specifically to estimate the costs of product sustaining activities.

Examining the relationship between the size of a portfolio and the amount of resources needed to maintain it showed similarities with findings in the literature on the challenges of managing large portfolios. Cooper et al. (2000, pp. 19 – 21) pointed out that a common challenge with a large portfolio is that it requires more resources to manage and maintain than an organisation can devote to it. Si et al. (2022) use the term "overload of portfolio" to describe this phenomenon. According to Loch and Bode-Greuel (2009, pp. 232 – 233), this leads to a situation where the prioritisation of one product has a potentially negative impact on another product. This issue was also apparent in this study. Many interviewees stated that resource constraints often led to less attention being paid to low demand products in terms of maintenance, as maintaining production capabilities for volume products was a priority.

Distel et al. (2020) also raised the point that it is not the size of the portfolio alone that poses a challenge, but rather the complexity brought by the increased number of products. This observation by Distel et al. (2020) was also strongly present in this study. Many interviewees emphasised that the effort and resources required to maintain a wide product portfolio are not solely driven by the number of products, but rather by the diversity of products. Greater product diversity increases the overall complexity and component level variation in the product portfolio, which is perceived to affect the required sustaining effort. Benedit et al. (2021) underline that while the complexity of a portfolio up to a certain point provides important benefits, such as the ability to reach a wider customer base, not all complexity can be considered as a value-adding factor. For example, they point out that products with low demand may not be cost-effective. This was also raised by interviewees, as often the cost structure of low-demand products differs from initial estimates, especially if special components are involved.

Overall, this study contributed to filling this gap in the literature by providing empirical information on the types of product sustaining activities performed in a manufacturing company, how much human resources these activities demand, and how the TDABC ideology could be applied to assess the costs associated with these human resources. By combining these areas that have been limitedly researched in the past, this study has the potential to bring new knowledge to the field. This study could therefore serve as a basis for future research, which could explore the phenomenon in even greater depth and scope. In addition, this study contributed to a broader understanding of product portfolio management by demonstrating how the challenges associated with a large portfolio are reflected in the actions related to product and portfolio maintenance.

In addition, by exploring the resources spent on maintaining products, this study also supported the underlying ideas of many widely used frameworks such as RBV, LCC and TCO. The RBV emphasises the importance of a company's resources and their optimal utilisation when it comes to maintaining the organisation's competitiveness (Maijanen, 2020, p. 3; Priem & Butler, 2001, p. 25; Heimonen & Takala, 2019, p. 186). LCC, on the other hand, strongly emphasises the fact that the life cycle stage of a product has a significant impact on the profitability of the resources spent on product maintenance. According to Sievänen et al. (2004, pp. 398 – 399), this is because demand is often low towards the end of a product's life cycle, but product maintenance involves very much the same elements as in earlier stages of the product's life cycle where demand is typically higher. In turn, TCO as a costing method emphasises that indirect costs, such as maintenance costs, should also be taken into account when considering the cost of a product, in addition to the direct acquisition costs alone (Carnicero et al., 2023, p. 7).

Overall, this research also supported the use of frameworks such as CBA in portfolio decision-making. The CBA ideology is based on comparing the benefits and economic costs of activities in order to make the most objective choices possible (Shively, 2012, p. 1). This could therefore also be applied to product sustaining activities to assess whether their implementation, and thus the maintenance of the product, is worth the total cost of the activities. However, exploiting this framework is not possible without a comprehensive understanding of the costs of actions, such as resource demands. Thus, studies such as this one, which investigate the use of resources for specific activities, facilitate the use of decision-support techniques such as CBA.

5.3 Practical implications for the case company

This study can provide useful information for the case company to support portfolio decision-making. The study will help to understand the activities through which different departments across the organisation support the manufacturing capabilities of all products in the portfolio. Moreover, the study will also provide information regarding the amount of working time the different departments in the organisation spend on these activities each year. In this context, this study also highlights which departments are particularly affected by the size of the portfolio in terms of the amount of time spent on these activities. This also means that it is possible to understand how the knowingly large portfolio of the case company is reflected in practice from a maintenance point of view.

On a practical level, this research will help the case company to understand what are the characteristics that should be taken into account when considering the profitability of product sustainment. Typically, it was felt that products that both lack demand and are special designs, meaning that they are manufactured using special components, add excess maintenance effort. Thus, this study is able to provide the company with a clear list of products, from the scoped product families, that fit this description. The results of the study indicate that, especially for the larger product families, the number of such products is also higher.

The results of the study suggest that the case company could consider a critical review of which products really deserve an active position in the product portfolio and which ones could move into passive status or be removed from the portfolio altogether. Optimisation of the product portfolio could have the potential to free up resources from maintenance for other areas. This could be particularly useful precisely because in most considered departments maintenance activities are not the main responsibility of the team rather, they are involved in maintenance more indirectly. By optimising product families, resources could therefore be used more efficiently by departments for their main area of responsibility.

However, it should be noted that case company in question is a large global organisation, where causal relationships are often complex and layered. Meaning that implementing changes does not happen overnight, as there are usually many aspects to consider. In this context, it should also be noted that the reasons behind certain choices are often multidimensional, making it challenging to draw direct conclusions. With this in mind, the case company could possibly investigate, as a smaller scale measure, whether products sustaining activities could be implemented more efficiently. A good example of such an activity, where there is certainly room for improvement, is the updating of products' rating plates, which in some product families currently has to be done separately for each product in that family. Therefore, in terms of optimising operations and ensuring a more efficient utilisation of resources, it could be worthwhile to explore whether such repetitive and single-product tasks could be centralised and performed on a mass or, alternatively, automated. In both cases, the need for manual work would certainly be reduced.

5.4 Limitations and suggestions for future research

Although this study was able to provide valuable insights into product sustaining activities and portfolio maintenance in manufacturing company, it has its own limitations that should be recognised. First of all, this study has used only literature published in English or Finnish, which presents limitations to the theoretical framework of the study. In the future, the inclusion of literature published in other languages could enhance the comprehensiveness of the theoretical overview.

Secondly, this study was conducted as single case study focusing on assessing certain company’s operations. The single case study design allowed a more precise focus on the activities of this particular company, but at the same time this limitation means that results cannot be directly generalised outside this company. A future study could investigate the implementation of product sustaining activities across a larger sample of companies in the same sector, providing a more comprehensive picture of the maintenance activities and associated resource requirements in the sector.

Finally, this research was also limited with its resources. Due to resource constraints data related to product sustaining activities was gathered with semi-structured interviews. In the future research, data collection could be carried out by observing the operations of different departments over a longer period of time. In this way, a more accurate understanding of the types of actions carried out by the different departments and the variables involved in the implementation of these activities, which lead to situational variation, could be obtained. At the same time, it would probably give a more accurate estimate of the time taken to implement these activities. This would also make it possible to estimate the time taken to implement individual actions. Thus, such an approach would also allow a more comprehensive use of TDABC and thus provide a more accurate estimate of the costs associated with the time spent by resources. Also, it might be possible to gain comprehensive understanding how differences between product families are reflected in the maintenance activities. Which would allow even better identification, within each product family, of those products that may not be worth keeping alive.

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Appendices

Appendix 1. Interview guide

Role & Responsibilities

1. Can you briefly describe your role and main responsibilities in the company?

Product Sustaining Activities

2. Do you or your team carry out any product sustaining activities, and if so, what are these activities?
3. Could you please explain what are the key tasks involved in these activities?
4. Will it affect the implementation of these activities if the product is not sold or produced at all?

Time Allocation

5. Could you estimate approximately how much time (in hours) each product sustaining activity requires annually. Or, alternatively, estimate what percentage of your working time is spent on activities related to product sustainment.
6. Does the time needed for the same action vary from one situation or implementation to another? If yes, what do you think is the reason?
7. Does the size of the product families and the amount of variation in the end products have an impact on the time/effort required for sustainment/maintenance? How can this be seen in practice?
8. Are these activities scheduled according to a specific timetable, or are they performed as needed?
9. Do the product-sustaining activities involve so-called "idle time" and/or unnecessary waiting?