The digitalization journey of product information management

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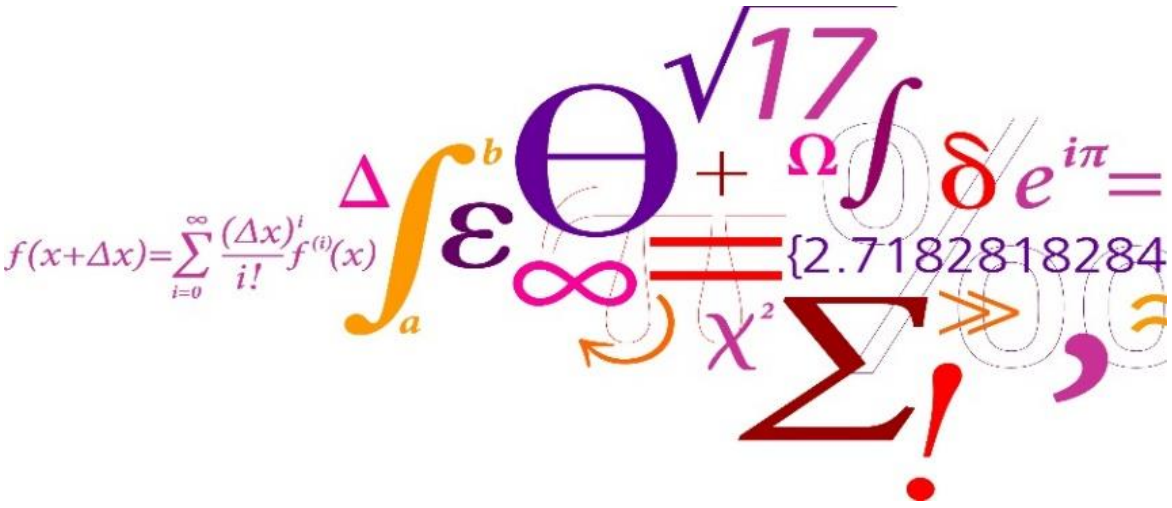

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SUMMARY

Customers nowadays gather information about products online, regardless of whether they will ultimately purchase the product online or in-store, expecting to find high-quality information that helps them select the products that meet their requirements. Following this trend, companies are digitalising their marketing processes so as to provide consistent and accurate product information in the form of technical specifications, images, videos and so on. Such product information is offered via a variety of channels, such as webpages, mobiles/cell phones, online stores and printed catalogues. In this context, ensuring information quality, and more specifically, its consistency across such systems, can be challenging. In fact, a 2018 survey conducted by Ventana revealed that only 16 percent of organisations trust their existing product information. To deal with the challenges of managing product information meant for a variety of sales channels, companies are increasingly turning to product information management systems (PIMSs). A PIMS is an IT system designed for the central management of product information across different departments, such as sales, marketing and product development—in short, customer-oriented product information. Responding to the pressing needs from practice and building a theoretical understanding, this thesis explores how manufacturers can manage their product information by providing a proposal framework for digitalisation and central management of product information, which is tested through a study of the digital transformation process of a multinational company. The results show that companies can centralise the management of digital product information through three sequential phases: simplification, preparation and implementation. First, and following the logic of 'simplify before automating', companies need to consider their product variety and implement product description standards; second, they need to prepare the organisation for the digital transformation process in which product information management becomes centralised; and third, the central management of digital product information should be accomplished with the implementation of an IT system like a PIMS. Each phase involves a number of challenges, which have only received limited attention the in the literature. The overall purpose of this thesis is to provide a better understanding of such challenges and offer some guidelines for addressing them. Thereby, this thesis provides insights that are relevant for both academics and practitioners. For future product information management research, the thesis offers an overview of the processes and challenges involved in the three phases and lays a foundation for future studies. For practice, the thesis provides guidelines for how to implement centralised product information management and an overview of the pitfalls to avoid.

RESUMÉ (DANISH)

Forbrugere søger tit efter information om produkter online, uanset om de i sidste ende vil købe produktet online eller i en fysisk butik. De forventer at finde information af høj kvalitet, der kan hjælpe med at se om produktet lever op til de krav de har behov for. Grundet dette er virksomheder begyndt at digitalisere deres markedsføringsproces, for at sikre, at informationen om produktet er konsekvent og præcist, der gør de ved at bruge tekniske specifikationer, billeder, video, etc. Informationen om produktet er tilgængeligt fra forskellige kanaler, så som hjemmesider, mobiltelefoner, online butikker og fysiske kataloger. Det kan være svært at sikre informationskvaliteten- mere præcist, det kan være svært at sikre, at informationen er konsekvent over de forskellige kanaler. Ventana lavede i 2018 en undersøgelse, som viste, at kun 16% af organisationer stoler på deres daværende produktinformation. For at løse dette problem, for at kunne sikre produktinformationen mellem diverse kanaler, er virksomheder begyndt at udnytte produkt informationssystemer (PIMSs). PIMS er et IT-system som er designet til at kunne styre produktinformationen på tværs af forskellige afdelinger, såsom salg, marketing og produktudvikling- kort sagt skal informationen af produktet være kunde orienteret. For at kunne svare på de opstående praktiske nødvendigheder, og for at få en teoretisk forståelse- vil denne afhandling undersøge hvordan producenter kan styre produktinformationen ved at give rammer for at digitalisere og centralisere produktinformationen, som afprøves gennem en undersøgelse af den digitale transformationsproces i en international virksomhed. Undersøgelsen viser, at virksomheder kan centralisere styringen af produktinformationen gennem tre sekventielle trin: simplifikation, forberedelse og implementeringen. Først, og ved at følge 'simplify before automating' (forenkle inden automatisering), bør virksomhederne tage i betragtning variationerne af produkterne samt tilføje en standard produkt deskription; dernæst skal de forberede digitaliseringen hvor styringen af informationen om produktet bliver centraliseret; tredje, og sidste trin, den centrale styring af digital produktinformation bør gøres ved implementeringen af et IT-system så som PIMS. Hvert trin har sine udfordringer, hvilket den nuværende litteratur ikke har udforsket i særlig høj grad. Det overordnede formål med denne afhandling, er at belyse disse udfordringer og yde bidrag til at møde dem. Derved vil denne afhandling give indsigter der både er relevant for akademikere og praktikere. For fremtidig forskning om styring af produktinformation, kan denne afhandling give et overblik om processen og over de udfordringer der er opstået i de tre faser, og give basis for videre forskning indenfor PIM systemer. Rent praktisk, kan denne artikel give retningslinjer til at implementere centralisering af produktinformation og give et overblik over, hvilke faldgruber man skal undgå.

LIST OF PUBLICATIONS

The list below provides a full overview of the research activities. Only the journal articles are included in the present thesis.

Journal Articles in Progress

Battistello, L., Trattner, A., Hvam, L., Haug, A. (2020). "A CLASSIFICATION OF BARRIERS TO PRODUCT VARIETY REDUCTION", *CIRP Journal of Manufacturing Science and Technology* (Under Review)

Battistello, L., Haug, A., Suzic, N., Hvam, L. (2020). "Implementation of product information management systems: Identifying the challenges of the scoping phase", *Computers in Industry* (Under Review)

Battistello, L., Haug, A., Hvam, L. (2020). "The Challenges of Implementing Product Information Managements Systems: A Case Study of a Construction Materials Manufacturer", *Industrial Management & Data Systems* (Under Review)

Conference Articles

Battistello, L., Trattner, A., Hvam, L. (2019), *Why Your Product Variety Management Strategy May Fail: Barriers in the Reduction of the Product Variety*. Paper presented at 9th International Conference on Operations and Supply Chain Management, RMIT University, Vietnam.

Battistello, L., Kristjansdottir, K., Hvam, L. (2019), *Scoping a PIM System: A Supporting Framework*. Paper presented at 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bangkok, Thailand.

Kristjansdottir, K., Ghosh, A., Battistello, L., Hvam, L. (2019), *Time Estimation for Product Configuration Systems Projects*. Paper presented at 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bangkok, Thailand.

Shafiee, S., Kristjansdottir, K., Hvam, L., Battistello, L., Sandrin, E. (2017), *Usage Frequency of Product Configuration Systems Relative to Integrations and Fields of Application*. Paper presented at 2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Singapore.

Kristjansdottir, K., Shafiee, S., Battistello, L., Hvam, L., Forza, C. (2017), *Complexity of Configurators Relative to Integrations and Field of Application*. Paper presented at 19th International Configuration Workshop. Paris, France.

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List of Abbreviations

Compound Annual Growth Rate (CAGR)

Customer Relationship Management (CRM)

Digital Asset Management (DAM)

Digital transformation (DT)

Enterprise Resource Planning (ERP)

Information Systems (IS)

Information Technology (IT)

Master Data Management (MDM)

Product Data Management (PDM)

Product Information Management (PIM)

Product Information Management System (PIMS)

Product Lifecycle Management (PLM)

Product Variety (PV)

Product Variety Management (PVM)

Product Variety Reduction (PVR)

Research question (RQ)

1. INTRODUCTION

The fourth industrial revolution, namely, Industry 4.0, is becoming one of the most popular subjects among researchers and practitioners worldwide. It is considered the new fundamental step in industrial production (Chiarello et al., 2018). Industry 4.0 is based on the adoption of techniques and processes allowed by digitisation, cloud computing, the internet and big data to gain competitive advantages in domestic and global markets (Castelo-Branco et al., 2019; Chiarello et al., 2018; Ustundag and Cevikcan, 2018; Lasi et al., 2014). This digital transformation era differs from the previous industrial revolution because, besides providing the change in primary business processes, it also reveals the concepts of smart and connected products by presenting service-driven business models (Ustundag and Cevikcan, 2018; Figure 1).

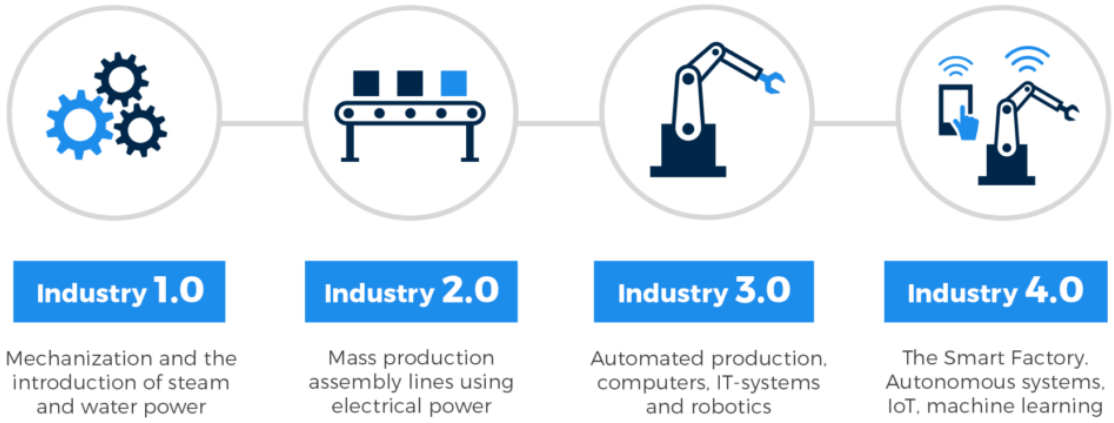

Figure 1. The four industrial revolutions (Spectral Engines, 2018)

Digital transformation (DT) has emerged as an important phenomenon in strategic Information Systems (IS) research (Castelo-Branco et al., 2019; Vial, 2019; Hagberg et al., 2016). However, clearly defining it may not be so easy. Vial (2019) identified 23 unique definitions of digital transformation, with differences related to the types of technologies involved and the nature of the transformation, and later defined DT as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication and connectivity technologies". In line with this definition, recent research showed that DT is not only limited to technology but is also the result of the combination of several elements (Castelo-Branco et al., 2019; Vial, 2019): corporate strategy (Castelo-Branco et al., 2019; Bharadwaj et al., 2013; Matt et al., 2015), organisational structure (Selander and

Jarvenpaa, 2016), organisational and production processes (Castelo-Branco et al., 2019; Carlo et al., 2012), and culture (Karimi and Walter, 2015).

Although DT involves several types of digital technologies (Vial, 2019; Hagberg et al., 2016), this thesis focusses on the digitalisation of customer-oriented product information and the technologies that support this process. Companies are offering more and more products online to their customers, which increases the need for providing accurate product information in the form of technical specifications, images, videos and so on (Abraham, 2010; Sheldon and Goetz, 2014). Such product information is offered via a variety of channels, such as webpages, mobiles/cell phones, tablets, online stores and printed catalogues (Vial, 2019; Hagberg et al., 2016). Companies often use different IT systems to provide information for different sales channels; thus, product information is often registered in a variety of IT systems managed by different departments, which can lead to information inconsistency across such systems (Abraham, 2010; Ventana Research, 2017). Information inconsistency is critical to an organizations ability to adopt digitalization strategies (Ventana Research, 2018a).

1.1 Research focus

The rapid growth of e-commerce and online stores obligated that companies established an online presence and moved core business operations online. To support product development and new product introduction in this digital environment, companies must be able to efficiently synchronise, manage, and share product data across the organisation and supply chain (Dury et al, 2012). With digital transformation, companies face a significant growth in data volumes, a change in the business models, and an introduction of new sales channels (Informatica, 2019). Accordingly, having trusted product data becomes pivotal (Boyd, 2006). While there are multiple systems containing product data, such as ERP, CRM, PLM, MDM, etc., ensuring information quality and, more specifically, its consistency across such systems can be challenging (Ventana Research, 2017; Ventana Research, 2018a). Industries, companies and, even, functional groups within the same organisation frequently use different names and attributes to describe the same products (Ventana Research, 2017). In fact, a 2018 survey conducted by Ventana revealed that only 16% of organisations trust their product information (Ventana Research, 2018a). Recent academical studies highlighted the necessity of developing strategies and supporting tools to "transform" the physical products into their digital version in a structured way (Kärkkäinen et al., 2003; Brunner et al., 2007; Power, 2010), and emphasised the lack of standards and guideline to support this transformation process (Boyd, 2006).

Due to the pressing needs from practice, and the lack of theoretical investigation this thesis investigates the following overarching research question (RQ):

RQ: How can companies manage the digitalisation of product information?

The RQ reflects the overlap of the practical needs of an industrial collaboration partner (Section 3.4) and relevant gaps in the academic literature (Section 2).

A step that facilitates the creation of reliable customer-driven product data is to have a single, consistent source of product information; this enables companies to standardise data (Boyd, 2006). However, before a single version of product information can be maintained, it must first be created. Product information is rich with meaning, which needs to be comprehended. There is no single, valid way to describe products and no standards to use as a guide (Boyd, 2006). To address the challenges that impede the adoption of a single version of product information, an increasing number of companies have implemented product information management systems (PIMSs; Abraham, 2010; Grizaut, 2018). The PIMS is a category of IS focused on centrally managing product information that supports product processes and departments, with a focus on customer-oriented product information (Ventana Research, 2018a; Dury et al, 2012; Abraham, 2010). The global PIMS market size is poised to continue its growth from USD 7.0 billion in 2019 to USD 11.4 billion by 2024, at a compound annual growth rate (CAGR) of 10.2% during the forecast period (Product Information Management Market). Multinational companies such as Samsonite, Heineken, Pandora, Carrefour Market, Nikon Europe, etc. (Eppinger, 2017; Abraham, 2010) have implemented PIMSs in the last decade. Similarly, major IT software companies like IBM, Informatica, SAP, Oracle, etc. are offering a PIMS solution in their portfolios.

The initiative to enact a product information management (PIM) strategy is not taken by the IT department only (Informatica, 2019); other departments such as Marketing, Sales, R&D and Procurement expect updated and synchronised product information to deliver a single version of the truth. The factors prompting companies to implement a PIMS are: number (n.) of products, n. of users, product complexity, data quality, n. of sources, n. of customer segments, n. of channels, n. of countries and languages (Abraham, 2014). Therefore, the company's complexity, the complexity of managing product information, and the complexity of implementing a PIMS are all dynamically evolving. For example, implementing a PIMS in an

organisation with a high product variety (PV) portfolio requires more resources, time and data storage compared to an organisation characterised by low PV.

1.2 Research questions

The development of the research questions was guided by the longitudinal field study approach (Åhlström and Karlsson, 2009). In a longitudinal field study approach, the research questions aim to describe and explain temporal sequences of events that narrate as an organisational change occurs (Åhlström and Karlsson, 2009); for instance, the implementation of new technology (Leonard-Barton, 1988). The thesis analyses the process of digitalisation of product information in a multinational company over 3 years. The digitalization of product data is genuinely distinguished into two central steps. First, a simplification of the volume of data/information that need to be managed and stored and second, the actual digitalization of the information (Abraham, 2014). Following this logic, this thesis thus investigates the overarching research question in two steps, the preparation phase and the digitalization phase. First, the company invested in a product variety reduction (PVR) strategy to improve profitability of its sales. Obviously, this had a significant impact on the product information digitalisation because it allowed the digitalisation, storage and exportation of only the essential products and product information. In that respect, this first RQ follows the guideline of 'simplify before automate,' a guideline that should always considered in order to digitalise, store and export only the essentials. Second, the company implemented a PIMS as a support for the DT. The challenges and factors that occurred during the digitalisation process have been identified and analysed in the thesis.

1.2.1 Product Variety Reduction (PVR) strategy

The progress of Industry 4.0 and the recently common practice of embedding software into products highlights the need for manufacturers to manage and reduce product variety (Aljorephani et al., 2016; Closs et al., 2008). The digitalisation of unsold, unprofitable, or obsolete products leads to an increase in complexity and cost of the DT process. Therefore, the optimisation of the product portfolio is a prerequisite for an efficient PIM strategy. The study began with the analysis of the PVR strategy applied in the case company. The company pursued a PVR program in 2015 with the aim of reducing unprofitable and low-volume stock keeping units (SKUs). Product proliferation was increasing as new product variants were added to the existing portfolio upon customer request, and a process for removing SKUs from the assortment was not implemented. As product variety management (PVM) literature

inadequately describe the cost and value of PVM and PVR (ElMaraghy et al., 2013), RQ1 was used to guide the review of the literature and the case study to identify the barriers that companies meet while pursuing a PVR program.

RQ1: What barriers do companies encounter during product variety reduction projects?

1.2.2 PIMS implementation

Once the PVR strategy was realised, with a 51% reduction in the number of SKUs, the optimised product portfolio was ready to be digitalised for the e-commerce. The company decided to invest in a PIMS and evaluated the PIM project as a primary task within the organisation.

The research focus shifted to the implementation of the PIMS, specifically to the challenges and the factors affecting the implementation of the system. The second and third research questions intended to contribute new knowledge on PIMS implementation. In order to avoid a broad focus, RQ2 focuses on understanding the challenges related to the successful completion of the scoping phase. The decisions made in the early phases of IS projects are very important for the success of the entire project (Shafiee et al., 2014; Meredith and Mantel, 2002). An unclear scope is one of the major causes of failure in IS projects (Haug et al., 2019; Whitney and Daniels, 2013; Ewusi-Mensah, 2003; Lyytinen and Hirschheim, 1987).

RQ2: What challenges do companies encounter in PIMS implementation regarding the scoping phase?

The third research question broadened the research focus of RQ2 by exploring the reason why the implementation of a PIMS is very challenging. The findings based on RQ2 helped pinpoint the challenges and their causes in the first phase of the implementation. Using this knowledge and the literature on IS implementation, RQ3 broadens the focus on the other phases of the PIM implementation, namely, elaboration, realisation and in service (Abraham, 2010).

RQ3: What challenges do companies encounter in the PIMS implementation phase?

Figure 1 reassumes the three phases of the digitalisation of product information in the longitudinal field study and the relative research questions. The three research questions cover the full scope of DT, analysing the implementation of the system in support of the digitalisation process (RQ2; RQ3) and the strategy adopted as a preparation for the digitalisation of product information (RQ1).

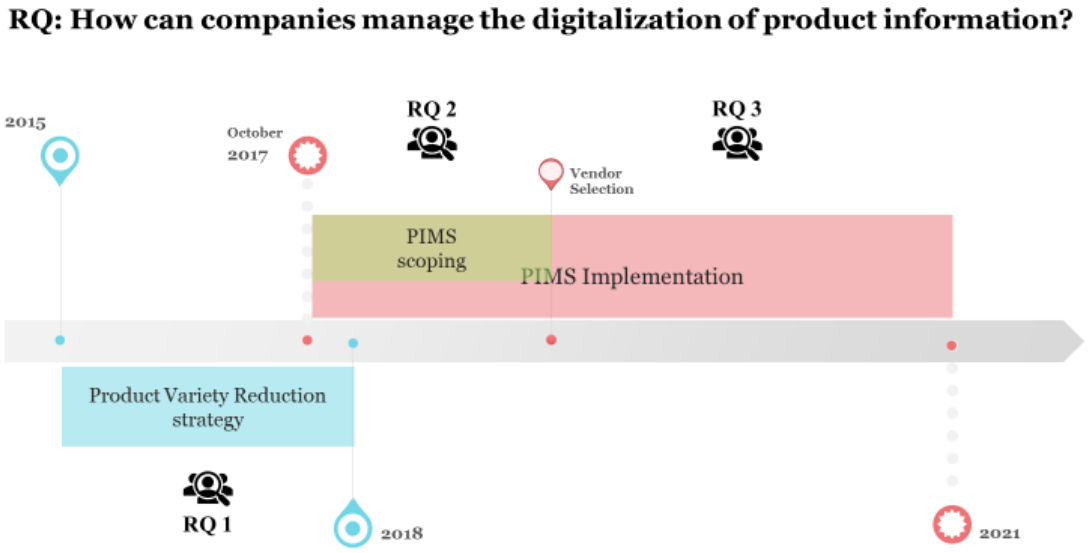

Figure 2. Research questions in the digitalization of product information

1.3 Structure of the thesis

This thesis consists of eight chapters. Chapter 1 presented the focus of the research and the research questions. Chapter 2 provides a deeper theoretical understanding and defines the research gaps. Chapter 3 discusses the research design of the study. It describes the philosophical standpoint underlying the present thesis and the implications for research methodology, that is, longitudinal field study. Chapters 4-6 present the three articles that investigate the research gaps. Lastly, Chapters 7 and 8 present the discussion and conclusions, respectively.

2. THEORETICAL BACKGROUND

This chapter presents the theoretical background of the thesis. It follows the timeline presented in the RQs (Section 1.2) and identifies the gaps in existing research. The topics discussed include product variety management (PVM), product information management system (PIMS) and the implementation of information systems (ISs). Section 2.1 presents the market-facing perspectives of PVM, with a focus on product variety reduction (PVR) strategies. Section 2.2 defines and positions PIMS in relation to similar ISs, discusses the challenges related to the implementation of PIMS and the factors influencing IS implementation failures.

2.1 Product Variety Management

The advancement of technology and the practice of embedding software into products in Industry 4.0 have given rise to the need for managing and controlling product variety (Aljorephani et al., 2016; Closs et al., 2008). The increase in product variety entails corresponding increasing costs, poor delivery performance and quality problems (ElMaraghy et al., 2013; Hu et al., 2008; Mariotti, 2008; Ramdas, 2003; MacDuffie et al., 1996). Thus, many companies attempt to reduce their product variety (Bortolini et al., 2018; ElMaraghy, 2005). However, some fail to implement programs that effectively carry out this thrust in their organisation or they encounter difficulties in implementing the reduction of PV at the pace and degree they desire. This section starts with a general definition of complexity management and product variety, as well as an analysis of the methods used for managing PV. This is followed by the presentation of PVR and the identification of the first research gap.

2.1.1 Complexity Management and Product Variety

The first question that needs to be answered is the following: What is complexity? Different interpretations of complexity can be found in the literature on operation management (Maylor & Turner, 2017; Wilson & Perumal, 2009; Marti, 2007; George & Wilson, 2004; Perona & Miragliotta, 2004). The present thesis adopted the cube model of Wilson and Perumal (2009) for describing complexity (Figure 3). The authors divided complexity into three interacting dimensions, namely, product complexity, process complexity and organisational complexity, which are interconnected and interdependent.

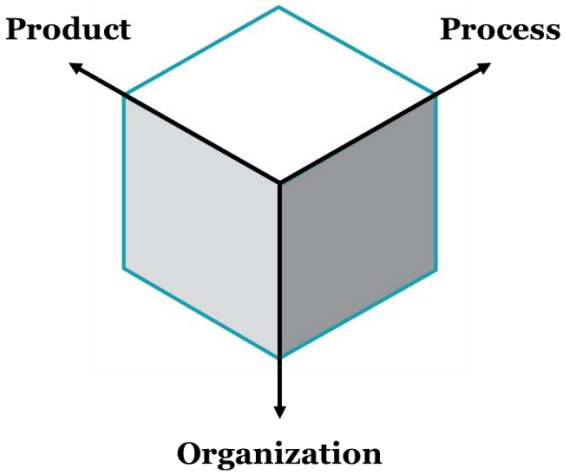

Figure 3. Complexity cube model (*adapted from:* Wilson and Perumal, 2009)

Product complexity represents the variety of products and/or services that a company is offering to customers. Process complexity describes the number of process steps involved in executing and delivering the products. Meanwhile, organisational complexity constitutes the demands on the organisational structures, such as facilities, systems and functional entities, that are involved in executing the processes of a company (Wilson & Perumal, 2009). This study focuses on the product aspect of the complexity and its interaction with the organisational aspect.

Despite the description presented by Wilson and Perumal (2009), product complexity has no consistent definition in management and engineering literature (Lindemann et al., 2010). The number of components, modules and finished good variants in a portfolio and the interrelations between the components all describe product complexity (Lindemann et al., 2010; Jacobs & Swink, 2011). In other words, product complexity can be defined as a measure of the sophistication of a product in terms of the number of components, level of interaction between the components and the degree of product novelty (Ding et al., 2007; Novak & Eppinger, 2001). One of the main elements of product complexity is product variety (PV) (Trattner, 2019). PV is defined as the number of finished goods produced by a firm (Wan et al., 2012; Pil & Holweg, 2004; Berry & Cooper, 1999; Mapes et al., 1997; Pine, 1993). Some authors have divided PV into external and internal varieties, where external variety refers to the amount of different products offered in the market while internal variety comprises the requirements for manufacturing and processing the products (Stäblein et al., 2011; Pil & Holweg, 2004). In the present study, PV is defined as external variety.

While good and bad product complexities can be easily distinguished in theory, determining the degree by which product variety affects organisations in practice is very challenging (Wilson & Perumal, 2009). High product variety implies important trade-offs (Wilson & Perumal, 2009; Ramdas, 2003; Ramdas & Sawhney, 2001). On the positive side, the image of the firm is boosted, demand may become more stable and there is a potential to expand to other markets and increase sales volume and revenue (ElMaraghy et al., 2013; Xia & Rajagopalan, 2009; Ramdas, 2003; Green & Krieger, 1989). On the negative side, high product variety may cause problems with excessive setups and over-inventories, as well as increase the complexity and costs of the supply chain processes (Ramdas, 2003; ElMaraghy et al., 2013; Xia & Rajagopalan, 2009; Hu et al., 2008). Moreover, customers might be confused by the differentiation among the product variants and experience long lead times before making a choice (Huffman & Kahn, 1998). An effective management of the PV helps maintain balance between costs and the benefits of variety in decision making (Lancaster, 1990). Product variety management (PVM) is the process of making decisions that are related to the product offerings of a firm, with the main goal of reducing variety-induced complexity and its associated costs (Ramdas, 2003).

2.1.2 Product Variety Reduction

A variety of methods and strategies for analysing and managing existing product portfolios have been introduced in the literature. However, a leading strategy for determining how to effectively manage PV has not been defined (Ulrich, 2006). Theoretical frameworks for the management of product variety have been provided in academic and practitioner literature incorporating both marketing and operational perspectives (Hvam et al., 2019; Perumal & Wilson, 2017; Wilson & Perumal, 2009; Mariotti, 2008; Silveira, 1998). The majority of PVM strategies aim to optimise PV in order to improve supply chain performance (Scavarda et al., 2010; Pil & Holweg, 2004; Silveira, 1998). They are also implemented to achieve profit (ElMaraghy et al., 2013). PVM strategies can be grouped into product-based and process-based strategies (Um et al., 2017). In product-based strategy, the initiatives are related to the product and product portfolio, such as product modularisation (Kaski & Heikkila, 2002; Salvador et al., 2002; Kim & Chhajed, 2000), substitution (Ye, 2014; Dixit & Stiglitz, 1977), and stock-keeping unit (SKU) rationalisation (Enz et al., 2019; Malinowski et al., 2018; Alfaro & Corbett, 2003). Process-based strategy is concerned with making changes to production and distribution processes, such as process modularity (Erlicher & Massone, 2005), cellular manufacturing (Selim & Muge, 2006; McCutcheon et al., 1994; Yeh & Chu, 1991) and postponement (Davila

& Wouters, 2007; Blecker & Abdelkafi, 2006; van Hoek, 1999). The amount of literature regarding the difficulties and challenges encountered during the application of a PVM strategy is very limited. The sample articles on the barriers to implementing a PVM strategy are presented in Table 1.

Table 1. Papers identified in the literature

Research Design	References	Total
Conceptual	ElMaraghy et al. (2013), Berman (2011), George and Wilson (2004), Byrne (2007)	4
Case study	Bech et al. (2019), Enz et al. (2019), Sloot et al. (2006), Appelqvist & Gubi (2005), George and Wilson (2004)	5
Literature Review	Ferreira & Correia-Stein (2017)	1

A discussion of the contents of these articles is presented in Section 4 (Article 1, Sec. 2.2). The reasons why a company decides to initiate a PVM program, the methods applied, the business context and the barriers to implementation are described. A central element of PVM strategies is product variety reduction (PVR) strategy (ElMaraghy et al., 2013). PVR, also called SKU rationalisation, is an approach for managing PV through the reduction of the number of products or SKUs (Alfaro & Corbett, 2003). PVR strategies can be applied using different approaches (Malinowski et al., 2018), including product substitution (Malinowski et al., 2018; Shin et al., 2015; Yücel et al., 2009), pooling (Alfaro & Corbett, 2003), ABC analysis (Hvam et al., 2019; Millstein et al., 2014) and complexity cost (Hvam et al., 2019; Hansen et al., 2012). These approaches come with a series of benefits, such as lower production costs, inventory simplification and maintenance of current customer service at a lower cost (Malinowski et al., 2018; Alfaro & Corbett, 2003). The need for PVR strategies arises from the fact that 80% of business revenue is derived from 20% of the product offerings, which means that several product offerings contribute very little, if any, to total revenue (Gilliland, 2011).

Major contributions have been made on the effects and value of a PVR strategy (Enz et al., 2019; Malinowski et al., 2018; Bermann, 2011; Alfaro & Corbett, 2003). However, to date, no study has investigated the barriers that organisations face during the implementation of these strategies. As such, the previous research contributions serve as valuable inspiration and inform the present thesis. In order to further develop PVM approaches or study the causes of problems in such projects, it is necessary to understand the issues that companies encounter. Without a

complete account of these PVM barriers, obtaining an in-depth understanding of this field is not possible. With regards to practice, an overview of the possible barriers may help companies avoid potential issues by adopting a proactive approach. This constitutes the first research gap that this thesis aims to address:

Research Gap 1: *Lack of identification of the relevant barrier types in product variety reduction strategies*

2.2 Product Information Management System (PIMS)

There is a dearth of literature on PIMSs, and a unique definition for this term is not available to date. Several recent white papers have demonstrated the importance of this system in the global market. The necessity of having a system that could manage product information in a centralised manner was anticipated by Kärkkäinen et al. (2003), Brunner et al. (2007) and Power (2010) before the development of the "modern" PIMS. Kärkkäinen et al. (2003) proposed an approach and a system called product-centric information management for centralising information about individual products. Brunner et al. (2007) developed a semantic PIMS with the goal of improving the flexibility and scalability of the existing systems. Meanwhile, Power (2010) predicted the benefits of creating a single product information hub across the enterprise. Boyd (2006) stated that the challenges involved in managing product information are much tougher compared to other types of product data, as there are no standards and no single valid way to describe products.

However, a clear explanation of PIMS, including its functionality, benefits and implementation, was presented by Abraham (2014) less than a decade ago. To provide a better overview of PIMS, this section first collates the different definitions of PIMS and attempts to describe its role in the organisation, after which it positions PIMS in relation to similar IT systems.

2.2.1 PIMS definition and scope

Table 2. PIMS definitions

Definition	**Reference**
"A centralized software platform used to store, manage, and deliver product data such as descriptions, SKU numbers, pricing, images, and more to a variety of different channels"	Plytix, 2020, p.4

"A business application that centralizes the management of product data and digital assets and streamlines collaborative data enrichment"	Informatica, 2019, p.5
"A category of dedicated applications that support product processes as well as the departments that contribute to and use product information for their business needs"	Ventana Research, 2018a, p.3
"Software that enables organizations to manage product information efficiently in a unified way, supporting business processes and the interconnected customer-to-supply-chain network"	Ventana Research, 2018b, p.2
"A set of business practices and a category of business applications focused on managing product information for use across an organization from the supply chain to commerce to customers"	Grizaut, 2018, p.4
"An enterprise application enabling an organization to identify or derive trusted product data across heterogeneous data environments, enabling transactional, bidirectional synchronization across upstream production sources, downstream analytical target systems, and external trading communities and data sync networks"	Sheldon and Goetz, 2014, p.5
"Processes and technologies focused on centrally managing information about products, with a focus on the data required to market and sell the products through one or more distribution channels"	Abraham, 2014, p.3

Table 2 presents the definitions of PIMS found in the literature. The terms appearing more often in the definitions are "central", "managing" and "product information". Based on the previous definitions, it is possible to describe PIMS as an IS that supports business processes across the organisation by centrally storing, enriching, managing and delivering customer-oriented product information. Even if the system supports different departments that are using product information, PIMS is a sales/marketing tool (Informatica, 2019). The central concept of PIMS is that product information is entered and stored once, and from there, that information is distributed without being re-entered manually into a different system. This facilitates the standardisation of the increasingly complex demands of product content and the distribution of high-quality product information to different distribution channels, such as e-commerce, websites, mobile apps, etc. (Grizaut, 2018; Informatica, 2019).

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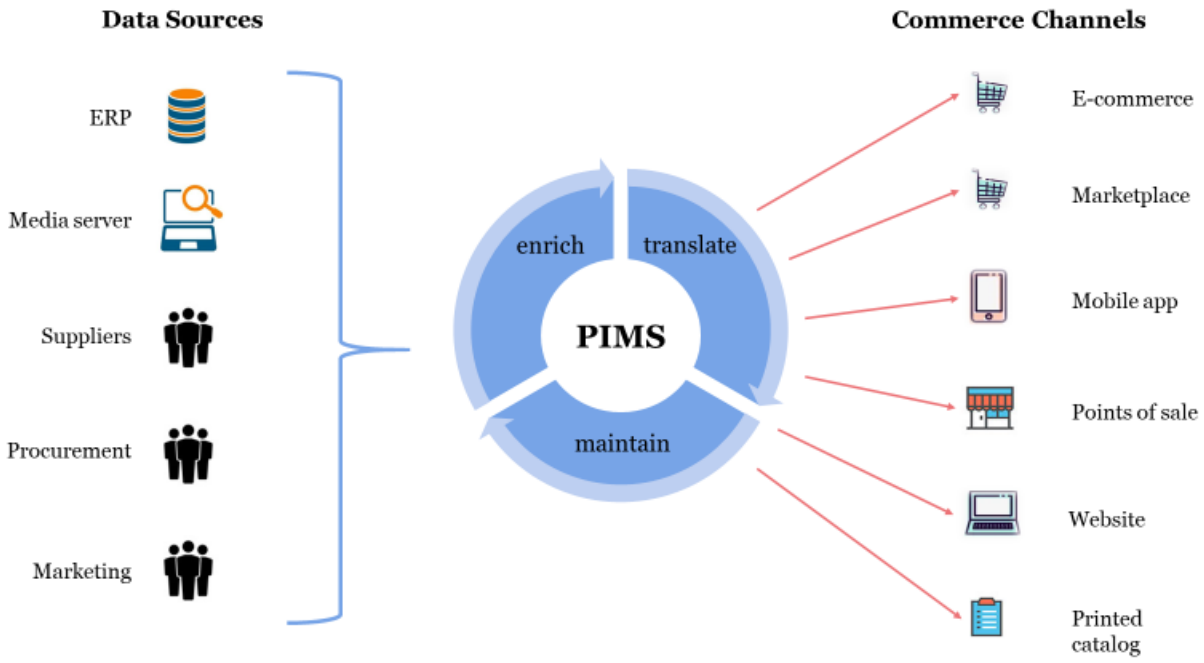

Figure 4. PIMS data sources and outbound channels (*adapted from Grizaut, 2018*)

The advantages of implementing PIMS in the organisation can be divided into strategic, tactical and operational benefits (Abraham, 2014). Table 3 displays the benefits of implementing a PIMS.

Table 3. Benefits of implementing a PIMS

Type of benefit	Benefits	References
Strategic	Assortment Expansion	Grizaut, 2018; Abraham, 2014
	Shorten Time to Market	Informatica, 2019; Grizaut, 2018; Abraham, 2014

	Uniform Customer Experience Across All Channels	Informatica, 2019; Grizaut, 2018; Ventana Research, 2018a; Abraham, 2014
	Improving customer experience	Grizaut, 2018; Ventana Research, 2018a
Tactical	Manage Complexity	Abraham, 2014
	Controlled Content Distribution (consistent, relevant, and localized)	Abraham, 2014
	Legal Compliance	Abraham, 2014
	Supporting retail chatbots	Grizaut, 2018
Operational	Improve Marketing productivity	Grizaut, 2018; Abraham, 2014
	Improve data quality	Informatica, 2019; Grizaut, 2018; Ventana Research, 2018a; Abraham, 2014
	Fewer information enquiries	Abraham, 2014
	Automate product information management and approval workflows	Informatica, 2019
	Fewer product returns	Grizaut, 2018; Abraham, 2014

2.2.2 PIMS positioning

Several systems are comparable to or overlap with PIMS. For example, PDM, PLM and MDM are all ISs that manage product/process data. Therefore, it can be difficult to distinguish the differences among the systems. This section positions PIMS in relation to similar IT systems. Product data management (PDM) systems (Do, 2018) and product lifecycle management (PLM) systems (David & Rowe, 2016) are more similar ISs compared with PIMSs. A major difference is that PIMSs mainly focus on sales and marketing, whereas PDM/PLM systems focus on data related to product development and manufacturing (Abraham, 2014; Dury et al., 2012). PLM addresses the entire lifecycle of a product—from the conceptualisation up to the moment of service and support— and the associated information is still provided after the product is no longer being sold; it is focused on internal stakeholders without containing customer-facing information (Grizaut, 2018; Abraham, 2014; Dury et al., 2012). Meanwhile, PDM aims to support the development and manufacturing of products (Abraham, 2014).

From a process perspective, PIMS and master data management (MDM) system are similar. However their focuses are very different: PIMS is intended for business while MDM is for

technology management. Whereas MDM aims to harmonise the core data of the company, including customer and supplier data, PIMS aims to extend and enhance product data with commercial information (Grizaut, 2018; Abraham, 2014; Sheldon & Goetz, 2014; Dury et al., 2012). In other words, PIMS is a subset of an MDM that deals with product-related information and is mostly used to support merchandising and marketing (Grizaut, 2018; Dury et al., 2012).

With regards to the differences among customer relationship management (CRM), ERP and PIMS, the first two are designed for conducting transactions and supporting operational processes like logistics and finance rather than managing product information (Ventana Research, 2018a; Abraham, 2014).

PIMS and product configurators differ in relation to their purpose, architecture and use. Specifically, PIMS is intended for documenting and sharing product information, while product configurators are expert systems that identify product specifications based on user inputs (Haug et al., 2019; Forza & Salvador, 2002).

2.2.3 PIMS implementation

For all software applications, the implementation process of PIMS is crucial. Abraham (2014) divided PIMS implementation into four phases: (1) scoping, (2) elaboration, (3) realisation and (4) in-service (Figure 2).

Although the implementation process presented in Figure 5 is relatively similar to that of other ISs, the implementation of PIMSs differs from most other systems, as some information cannot readily be implemented but, to a large extent, need to be constructed. Some of the most demanding aspects of implementing a PIMS involve populating the system with information. The reason is that PIMSs include generic product information models that are typically not available in companies (Abraham, 2014).

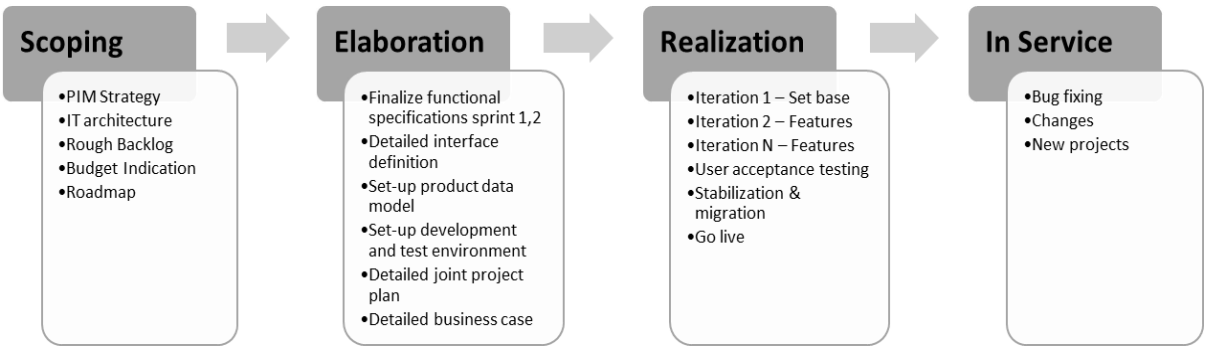

Figure 5. Phased implementation of a PIMS (adapted from Abraham, 2014)

In the companies analysed by Abraham (2014), the most common challenge during the implementation of PIMSs proved to be the shared product data model. Often, the complexity and time needed to develop the model were underestimated. The other challenges identified ERP to the PIMS, underestimating the storage space needed and the belief that the old solution was better, easier and more complete.

Given the lack of literature on PIMSs, we turn the focus towards general IT and PLM literature to lay the foundations for understanding the challenges and the success factors associated with the implementation of PIMSs. Several causes and factors of IS implementation failures were identified in the literature and summarised in table 4.

Table 4: Causes and factors of IS implementation failures

Causes of IS implementation failures	**Reference**
Not meeting the defined schedule	Whitney & Daniels, 2013
Not achieving cost objectives	
Not conforming to the defined project scope	
Correspondence failure: design objectives or specifications of system not met	Lyytien & Hirchheim, 1987
Process failure: unable to develop the system within the defined budget or schedule	
Interaction failure: Lack of correspondence between user satisfaction, attitude, and use frequency and system usage level	
Expectation failure: system is unable to meet stakeholder expectations, requirements, or values	
Technology newness	Barki et al., 2001
Application size	
Application complexity	
Experience shortcomings	
Organizational environment	
Project goals and objectives	Ewusi-Mensah, 2003
Project team, management, and control issues	
Lack of technical expertise and technology problems	
Inadequate executive support and commitment	
Change requirements	
Cost overruns and delays in schedule	

The literature review by Singh et al. (2020) has identified the following 17 PLM implementation success factors organised according to three themes, as shown in Table 5.

Table 5. Success factors in PLM implementation

Business processes and practices	S1 Business-process re-engineering S2 Information sharing or communication S3 Risk management S4 Clear business goals and objectives S5 PLM system evaluation and selection S6 Selection of PLM systems solution provider S7 Implementation budget S8 Implementation methodology S9 PLM project monitoring
People	S10 Leadership and commitment S11 Training and education S12 Knowledge sharing from previous experiences S13 Organisational culture
Technology	S14 Project team spirit and commitment S15 IT infrastructure S16 Interoperability among all systems S17 Data security and user authentication

In sum, the distinct challenges encountered in implementing a PIMS call for the investigation of management practices. This is particularly motivated by the high failure rates of IS implementation in practice (Flyvbjerg & Budzier, 2011), as well as a lack of theory development on PIMS implementation processes. The IS literature highlights the relevance of longitudinal field studies addressing the challenges to the implementation of IS (Pan et al., 2008). The lack of management practices for implementing PIMSs constitutes the second gap that this thesis aims to address.

***Research Gap 2**: Lack of management practices for implementing product information management systems (PIMSs)*

The decisions made in the early phases of IS projects are very important for the success of the entire project (Shafiee et al., 2014; Meredith and Mantel, 2002). An unclear scope is one of the major causes of failure in IS projects (Haug et al., 2019; Whitney and Daniels, 2013; Ewusi-Mensah, 2003; Lyytinen and Hirschheim, 1987). Therefore, the second gap was re-defined into two parts: (2.1) the *lack of understanding of the challenges affecting the scoping of a PIMS* and (2.2) the *lack of understanding of the factors influencing the implementation of a PIMS*.

3. METHODOLOGY

Research can be defined as "something that people undertake in order to find out things in a systematic way, thereby increasing their knowledge" (Saunders *et al.*, 2012). "In a systematic way" suggests that the research includes an explanation of the methodology used for conducting the study. Therefore, this chapter aims to provide an overview of the philosophy of science guiding this thesis, as well as its overarching methodology. The chapter begins by introducing the ontological and epistemological views underlying the research. This is followed by the presentation of the research methodology, specifically explaining the data collection as well as the data analysis process. This is followed by a presentation of the case company. The chapter closes with a short summary.

3.1 Philosophy of science

Research philosophy can be viewed as a researcher's assumptions about the way in which he/she views the world, where these assumptions support the research strategy and the methods chosen as part of the strategy (Saunders *et al.*, 2012). The philosophy of science is described by the combination of ontology (the nature of reality) and epistemology (the nature of knowledge). Ontology refers to the researcher's assumptions about the nature of reality. There are several ontological views, where the two extremes are objectivism and subjectivism. Objectivism asserts that social entities exist as a reality external to social actors (Saunders *et al.*, 2012). In contrast, subjectivism claims that social phenomena are shaped by the perceptions and consequent actions of social actors (Saunders *et al.*, 2012). This thesis adopted the objectivist view, defining reality as something concrete that can be observed.

Epistemology regards what is considered acceptable knowledge for the researcher in a field of study (Saunders et al., 2012). Several research paradigms have been discussed in the literature. The two extremes research paradigms are positivism, where only law-like generalisations based on data and facts are acceptable, and interpretivism, which focuses on the details of a situation, the reality behind the details, and the subjective meanings motivating actions (Saunders et al., 2012). The paradigms of positivism and interpretivism suffers from theory-practice inconsistencies across IS research (Smith, 2006) and social science research (Fleetwood, 2001; Ron, 2002). The inconsistencies emerge between theory, the researchers' assumption, and empirical evidence, the actual practice of science (Bhaskar, 2002; Smith, 2006). The theory-practice inconsistencies in positivist and interpretivist paradigms led to the

development of critical realism by Bhaskar (1978). The critical realism paradigm shifts the attention to the real analysed problem and its original causes, instead of focusing on the research data and methods (Mingers *et al.*, 2013). Critical realism has been promoted (Dobson, 2002; Carlsson, 2003; Mingers, 2004; Allen *et al.*, 2013) and adopted (Henfridsson and Bygstad, 2013; Williams and Karahanna, 2013) within the IS research.

The present research adopts a critical realist paradigm. For a more extensive discussion of how the critical realism paradigm corresponds to the research approach employed by the author's research group at DTU Management, see the discussion by Haug (2008, p. 47). The three RQs attempt to elucidate the challenges and their underlying causes in the implementation of strategies (RQ1) and IS (RQ2, RQ3) for the digitalisation of product information. The implementation of a PIMS is characterised by a sociotechnical environment, where continued interactions between social structure (e.g. individuals) and organisations, technological artefacts and sociocultural aspects are occurring following a set of rules and practices.

3.2 Research process

The existence of different types of objects of knowledge (physical, social and conceptual) with different ontological and epistemological characteristics is accepted in critical realism (Mingers *et al.*, 2013). Different research methods, based on the nature of the object of study, can be used to conduct the research (Easton, 2010). However, numerous researchers encouraged the use of a case study methodology for critical realist studies (Wynn and Williams, 2012). This thesis adopted as its main research method a special type of case study, the longitudinal field study. Given the limited and scant literature on the implementation of PIMS and the general challenges of digitalizing product information, longitudinal field study has been used for exploration and theory building (Åhlström and Karlsson, 2009). Contrary to cross-sectional research, which analyses a phenomenon at a specific point in time, longitudinal research studies a phenomenon over time. Moreover, longitudinal field study is a real-time study. This allows the avoidance of issues related to retrospective research, such as reinterpretation of past events and difficulties in determining causes/effects from recreated events (Becker and Geer, 1957; Leonard-Barton, 1990; Åhlström and Karlsson, 2009). In summary, longitudinal field study can be defined as a methodology suitable for generating theory (Miller and Friesen, 1982; Åhlström and Karlsson, 2009), where the researcher is studying, in real-time, the process of chance in organisations (Barley, 1990; Van de Ven, 1993). The researcher is close enough to the studied phenomena to discover the forces most crucial to

the object of inquiry and present for long enough to determine the causal links among events and constructs (Åhlström and Karlsson, 2009).

The use of longitudinal field study has been used in operations management to analyse and describe organisational changes, like the adoption of lean production (Åhlström, 1997) and the implementation of new technology (Leonard-Barton, 1988; Myrodia *et al.*, 2017). Due to the substantial researcher commitment and the organisational access required to conduct a longitudinal field study, this methodology is not frequently used in operations management literature (Van de Ven, 1993; Åhlström and Karlsson, 2009). In the present thesis, the process of digitalisation of product information was observed in real-time and in-depth over a 3-year period, including the implementation of a PIMS and the application of a PVM strategy. The researcher started the study when the PVR project was concluding and before the implementation of the PIMS. However, a collaboration with a researcher who performed a longitudinal field study during the PVR strategy (Trattner, 2019) was made, allowing the extension of the study period to the whole digitalisation process.

The main pressures for conducting a longitudinal field study are related to the timeframe, size and unit of analysis of the process to be studied (Åhlström and Karlsson, 2009). As illustrated in section 1.2, to conduct the study in reasonable timeframes, the DT process was divided in two steps: the execution of the PVR strategy and the implementation of a PIMS. To have a better understanding of the change processes, the implementation of the system was divided in two parts: first, the researcher scrutinised the initial phase of the implementation, namely the scoping phase; second, the study was extended to the all-implementation phase. The second demand is associated to the observability of the process. In other words, the smaller the size of the organisation, the easier the observation of the change process (Åhlström and Karlsson, 2009). The company studied in this thesis, illustrated in section 3.3, is a multinational company consisting of 18 individual business units (BUs) and operating in 39 countries. Hence, to avoid an overly broad study, the unit of analysis was restricted to the corporate level of the organisation.

3.2.1 Data collection

Longitudinal field studies and ethnography, the study of cultures, have various characteristics in common (Åhlström and Karlsson, 2009). One of them is the use of participant observation as a method of data collection. Adopting participant observation allows the ethnographer to become part of the everyday life of the observed people for a prolonged period, utilizing the

opportunity to acquire the knowledge needed for the analysis and interpretation of the collected data (Becker and Geer, 1957; Van Maanen, 1979; Barley, 1990). Similarly, in operations management studies, the researcher copiously takes part in the daily activities of an organisation, such as meetings, workshops, etc., becoming a member of the studied group and allowing him/her to not only observe the process but also experience the emotional involvement (Gill and Johnson, 2010).

There are four types of participant observation, divided by the identity of the researcher (revealed or concealed) and the interaction of the researcher with the organisation he/she is observing (Saunders *et al.*, 2012). The four types of PO are *complete participant*, *complete observer*, *observer as participant*, *participant as observer* (Figure 6; Gill and Johnson, 2010).

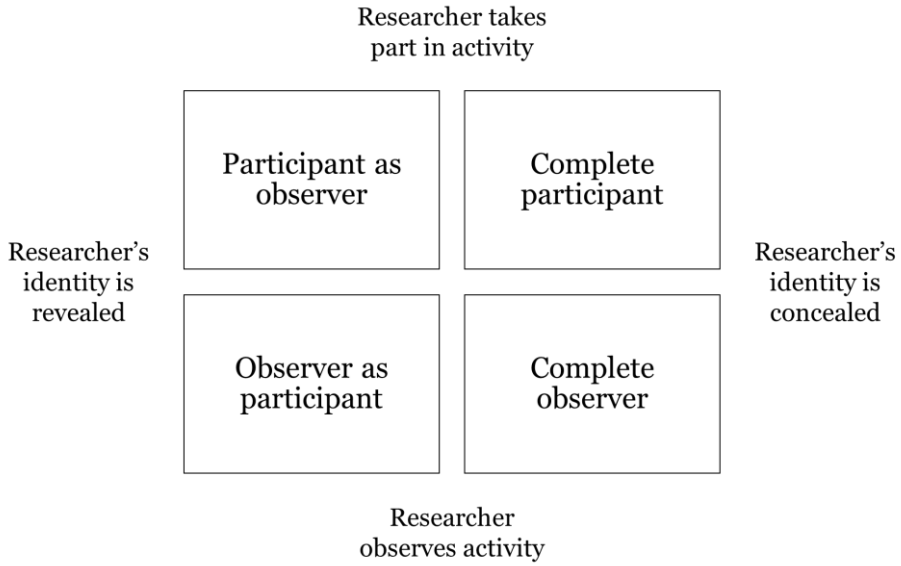

Figure 6. Typology of participant observation (*adapted from* Saunders *et al.*, 2012)

During the overall study the researcher adopted both observer-as-participant and participant-as-observer roles. In detail, the observer-as-participant role was adopted in order to study RQ1 and RQ3, and the participant-as-observer role was used to answer RQ2. The people involved in the projects were concerned with the purpose and research identity of the researcher. In the scoping phase of the PIMS (RQ2), the researcher had the opportunity to actively participate in the evolvement of the project. This choice was made for three reasons: first, it allowed the researcher to experience the emotional involvement and similar feelings as the employees involved in the project; second, the scoping phase was completed in a short-time period,

allowing the full participation of the research; third, it helped gain the trust and the support of the organisation, all essential factors for gaining access to the organisation and its data.

While adopting participant observation as the method for collecting data, the researcher risks becoming completely immersed in the organisation and, ultimately, losing the research perspective and some critical incidents (Scott, 1965). In order to avoid this risk, the researcher alternated between the research fields (the case company) and the academic environment. The time spent at university was used to analyse and improve the notes, research relevant literature, and discuss with colleagues, raising the level of abstraction on the observations (Åhlström and Karlsson, 2009).

Informal interviews, semi-structured interviews and studies of documents were adopted as secondary methods of data collection. The use of these methods, combined with participial observation, allowed the triangulation of data and evidence (Jick, 1979; Miles *et al.*,2014). Informal interviews, such as chats with group members and stakeholders, helped in understanding the feelings of people in certain instances of the change process (Zelditch, 1962; Åhlström and Karlsson, 2009). Semi-structured interviews, based on the critical incident technique by Flanagan (1954), were used to collect relevant facts about people's behaviour in well-defined situations (Flanagan, 1954) and to also collect data from the periods the researcher was not present at the company (Åhlström and Karlsson, 2009). Documents, such as meeting protocols, business cases and official reports were used to analyse events that the researcher was not able to observe or took place before the start of the research project. The time between meetings was used to transcribe the field notes, enrich them with additional observations, and cross-check the collected data with informant interviews.

3.2.2 Data analysis

The The data analysis in the longitudinal field is a complex process, where a big amount of descriptive data needs to be ordered and analysed (Huberman and Miles, 1983; Barley, 1990; Åhlström and Karlsson, 2009). The data analysis starts when the fieldwork is completed and consists of data reduction methods (Miles and Huberman, 1984; Åhlström and Karlsson, 2009). The researcher needs to avoid the oversimplification of the data and maintain different opportunities of analysis approach when conducting the reduction (Huberman and Miles, 1983). Åhlström and Karlsson (2009) proposed a five-step approach for analysing data in a longitudinal field study, consisting of:

- Narrating the sequence of events in the change process

- Dividing the narrative to define the incidents
- Coding the incidents into qualitative event constructs
- Sorting the list of incidents in order to separate the important events
- Searching for sequences and patterns

The researcher repeated the presented approach for each RQ, adapting the execution of the steps to the change processes analysed. The approach was also adapted at the end of the study in order to answer the overreaching RQ. After collecting and narrating the sequence of events in a unique document, one key aspect was to develop a definition of the incident. Different definitions of incidents are used in the literature (Van de Ven and Poole, 1990; Åhlström, 1997; Flanagan, 1954; Pan *et al.*, 2008). In the present thesis, an incident was defined as *an occurrence that either facilitated or impeded the digitalisation process of product information, particularly, the factors and the challenges influencing the execution of a PVR strategy and the implementation of a PIMS*. In the following step, coding the incidents, the codes could either be derived from the data or from the theory. In this study, the researcher adopted a combination of the data and theory to create codes (Åhlström and Karlsson, 2009). In the research of sequences and patterns, the researcher compared the findings with the existing literature (Eisenhardt, 1989).

The analysis of data gathered from semi-structured interviews was conducted by adopting the thematic analysis method. Thematic analysis is a methodology for identifying, analysing and reporting patterns within qualitative data (Braun and Clarke, 2006). This method helps the researcher organise and describe the data set as well as interpret different aspects of the research topic (Braun and Clarke, 2006; Boyatzis, 1998). The researcher followed the six-phase recursive process proposed by Braun and Clarke (2006) in conducting the analysis. The six phases of this process are:

- Familiarising with the data
- Generating initial codes
- Searching for themes
- Reviewing themes
- Defining and naming themes
- Producing the report

3.2.3 Theory evaluation

Quantitative studies differ from qualitative studies in the methods used for collecting and analysing the data. The contribution to knowledge of a quantitative research is evaluated on the base of four main factors: reliability, validity, objectivity and accurate measurement (Daft, 1983; Kirk and Miller, 1986; Åhlström and Karlsson, 2009). In quantitative studies, Yin (1989) defined reliability as the ability to obtain the same result if another researcher replicates the study, and validity as the accuracy of the measurement. However, judging qualitative research in the same manner as quantitative research is inappropriate (Agar, 1986), as qualitative studies are more interested in the meaning of organisational phenomena, rather than the measurement (Daft, 1983). Therefore, the notion of validity and reliability need to be redefined to fit qualitative research (Kirk and Miller, 1986).

Replicating the findings is very challenging in a longitudinal field study (Åhlström and Karlsson, 2009). Nonetheless, the researcher increased the reliability of the longitudinal field study by: during the fieldwork, trusting the information provided by the most knowledgeable members of the organisation and distinguishing between observational and presentational data (Van Maanen, 1979); during data collection, separating the observations themselves from the interpretation of the observations (Van Maanen, 1979); during the data analysis, separating the interpretation of the coded incidents from the observation (Van Maanen, 1979).

The validity of the research was enabled by the triangulation of data and findings, adopting different sources of data and methods (Silverman, 1993). Moreover, when compared to retrospective research, real-time observations raise the validity of the study (Leonard- Barton, 1990).

To ensure theoretical generalisation, the research compared the findings with other theoretical frameworks identified in the existing theory (Berg, 1981). Longitudinal case study conducted in a single organisation cannot be generalised in a statistical sense. However, from a practical point of view, it is the person who receives the information that can determine whether or not it applies to their own circumstances (Kennedy, 1979).

3.3 Case company

For the setting of the present thesis, the researchers sought a company that was embracing a digitalisation journey, where the change process would be transparently observable during the entire period (Åhlström and Karlsson, 2009). Moreover, the company was interested in obtaining several benefits from the collaboration with the researcher, such as investigating

current practices, inputting knowledge from literature into the digitalisation process, and obtaining support for the change process. The practical needs of the company fit the overreaching RQ, making the company the best choice for conducting the study.

The company is a mineral wool production enterprise located in Europe. It has a market-leading position in the building materials industry and operates over 20 global production facilities with over 11,000 employees. It is composed of 18 individual business units (BUs) selling products in 39 countries, with each BU managing its own assortment. These type of enterprises, distributed in space and composed of different co-operating units, have been defined as virtual extended enterprises (Kovács and Paganelli, 2003). Virtual extended enterprises have similar basic functionalities, goals, and challenges of large, distributed, complex organisations (Kovács and Paganelli, 2003), which are the targets of the thesis.

The company faced product variety (PV) issues as new variants were added to the portfolio upon customer request, with no methods in place for eliminating unsold and unprofitable SKUs from the assortment. The negative effects of this strategy were seen from an organisational perspective, with a lack of clarity in the portfolio strategy of the company, and from a production perspective, with a higher number of product changeovers and constraints on capacity. Therefore, in 2015, the company started a global programme to develop methods to address increasing PV, which led to the PVR strategy implementation. Between 2015 and 2018, the company reduced the number of SKUs by 51% (Figure 7) and improved their portfolio by removing unprofitable SKUs and adjusting prices. This had a significant impact on the product information digitalisation as it allowed the digitalisation, storage and exportation of only the essential products and product information. It was at this point that the researcher was contacted to support the digitalisation of products and product information.

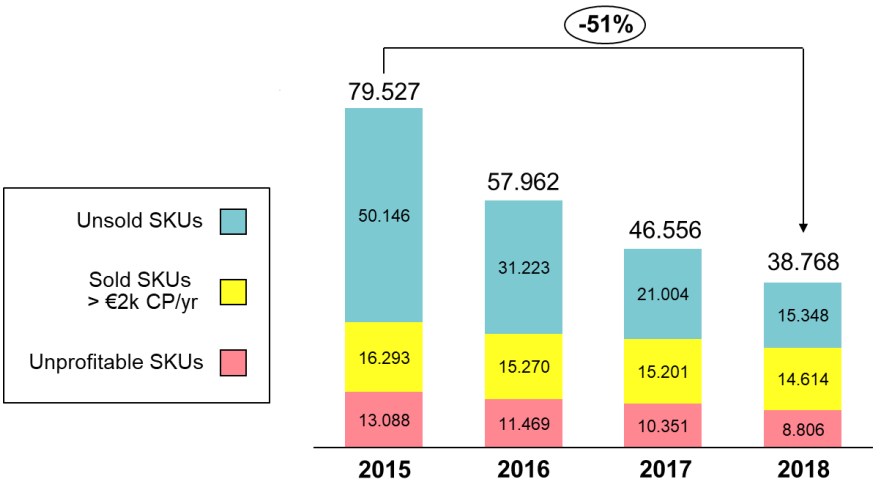

Figure 7. SKUs reductions from 2015 to 2018

In the beginning of 2017, the company launched a product digitalisation initiative, with the goal of being represented across digital channels (e-commerce, mobile apps, retailer websites, etc.). However, before being represented across online channels, the company needed the creation of a central hub to collaboratively manage product information. Subsequently, the company decided to implement a PIMS as a supporting tool for gathering, managing and delivering product information. The implementation of the PIMS started in October 2017 with the scoping phase. This was followed by a vendor selection phase and concluded with the technical implementation of the system in three BUs. The implementation of the PIMS is still ongoing, but the research was limited to the first three BUs due to time limitations.

3.4 Summary

Chapter 3 explained the overall research strategy of the present study. This thesis is based on an objectivist ontology and a critical realist epistemology. The main research method is a longitudinal field study in a multinational company, where the data were primarily collected through participant observation. Other research methods, explained in the following chapters, were adopted to obtain data and findings triangulation. RQ1 was studied following the structured literature review method and enriched with a longitudinal field study. In conducting RQ2, the researcher adopted a participant-as-observer role within the longitudinal study. For answering RQ3, longitudinal field study was complemented with semi-structured interviews. Figure 8 shows the different method used for conducting the present thesis.

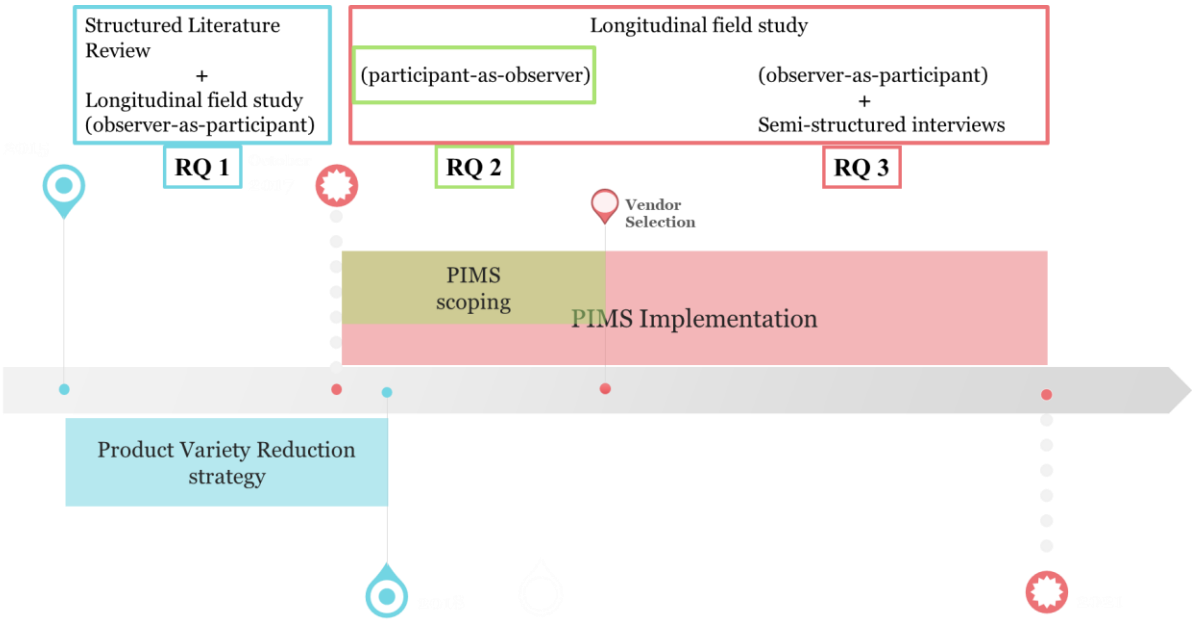

Figure 8. Methods adopted for answering the RQs

4. A CLASSIFICATION OF BARRIERS TO PRODUCT VARIETY REDUCTION

This chapter presents Article 1:

Battistello, L., Trattner, A., Hvam, L., Haug, A. (2020), 'A CLASSIFICATION OF BARRIERS TO PRODUCT VARIETY REDUCTION', CIRP Journal of Manufacturing Science and Technology (Under review)

The presented research in Article 1 is targeted to build theory corresponding to the research Gap 1.

A CLASSIFICATION OF BARRIERS TO PRODUCT VARIETY REDUCTION

ABSTRACT

Many industrial companies face a demand for a steady increase in product variety in order to accommodate customers' requirements for more individual products. With this increasing product variety also come increasing costs, poor delivery performance and quality problems. Thus, many companies attempt to reduce their product variety; however, they often fail to do so. To understand the causes of this problem, this paper aims to identify and classify the most important barriers companies meet when trying to reduce their product variety. We present an overview of barriers identified from the literature and from a case study. The case study identified a type of barrier not identified in the existing literature, namely a barrier related to the culture and the personality of the people involved. The paper adds to the literature by providing a more extensive and well-organized perspective on barriers to product variety reduction. The overview of barriers to product variety reduction may help managers in focusing their attention and resources.

Keywords: Product Variety Reduction, SKU Rationalization, Barriers, Product Variety Management.

1. INTRODUCTION

Complexity management and product variety management (PVM) are fields of increasing interest for both researchers and practitioners. A 2010 survey conducted by IBM in over 1500 companies representing different sizes of organizations in 60 countries and 33 industries revealed that more than half of CEOs doubt their ability to manage complexity. Seventy-nine percent of CEOs anticipated even greater complexity ahead (IBM, 2010). Almost a decade later, in 2017, surveys have revealed that manufacturing companies are still struggling with increasing product variety, as they have realised that, on average, 75% of their revenue comes from 13% of their portfolio (Hirose *et al*., 2017; Rigby, 2013). Offering greater product variety is supposed to create a competitive advantage (Da Silveira, 1998), but only to a certain extent, as the actual variety demanded from customers differs from the theoretical variety (i.e. the greatest variety possible to offer) (Stäblein *et al.*, 2011). In this context, a recent report by McKinsey & Company indicates that companies are struggling to distinguish between good and bad product variety, and reducing unneeded product variety is a subject of great interest (Adams *et al*., 2016).

Practitioners are increasingly concerned about the cost of increasing product variety (Bannasch and Bouche, 2019; MacDuffie et al., 1996). Specifically, increasing complexity is considered a major cause of the rising costs and deterioration of operational performance, leading to decreased quality, long delivery times, delayed deliveries and low process flexibility (Mariotti, 2008). The need to manage and control product variety is also apparent in the concept of Industry 4.0, the rapid progress of technology and the recently common practice of embedding software into products (Aljorephani *et al*., 2016; Closs *et al*., 2008). These factors highlight the need for manufacturers to manage and reduce the product variety of highly customised products in a more efficient manner (Bortolini *et al*., 2018; ElMaraghy, 2005).

For the reasons discussed above, many CEOs would like to reduce their product variety (PV), but fail to implement programs to do so in their organization or meet difficulties in implementing the reduction of PV at the pace and to the degree they desire. Researchers define PV as the number of finished goods produced by a firm (Trattner *et al*., 2019). High product variety implies important trade-offs. On the positive side, the image of the firm is improved, demand may be more stable, and there is the potential to expand markets and increase sales volume and revenue (ElMaraghy *et al*., 2013; Ton and Raman, 2010; Ramdas, 2003). On the negative side, high product variety may cause problems with excessive setups and over-inventories, and it may increase the complexity of the supply chain processes. Moreover,

customers might be confused by the differentiation among product variants and experience long lead times before making a choice (Ramdas, 2003; ElMaraghy *et al*., 2013; Hu *et al*., 2008). Product Variety Management is the process of making decisions related to the product offering of a firm. These decisions are made at different times and in different functions of the business (Ramdas, 2003). The main goal of PVM is to reduce variety-induced complexity and its associated costs. A variety of methods and strategies of analysing and managing existing product portfolios have been introduced. Examples of such methods and strategies are product ABC classification, pooling, modular product architectures, product family design and delayed differentiation (Bech et al., 2019; Hvam *et al*., 2019; ElMaraghy *et al*., 2013; Alfaro and Corbett, 2003; Graman and Magazine, 2002).

As indicated by ElMaraghy *et al*. (2013), PVM literature inadequately explains and predicts the cost and value of PVM. Moreover, the literature regarding the difficulties and challenges met during the application of a PVM strategy is very limited. This is problematic from both a research and practice perspective. Specifically, in order to further develop PVM approaches or study the causes of problems in such projects, there is a need to understand which issues companies encounter. Without a complete account of these PVM barriers, this is not possible. With regard to practice, an overview of possible barriers may help companies avoid potential issues through a pro-active approach. To avoid having too overall a focus, the focus of the paper is delimited to a central part of PVM, namely product variety reduction (PVR) (ElMaraghy *et al*., 2013).

Based on the discussion above, the research question addressed in this paper may be formulated as follows:

Which barriers do companies encounter in product variety reduction projects?

To address the research question, we first conduct a systematic literature review (SLR) to identify existing knowledge on the barriers to implementing a PVR strategy. In order to make the research clearer and more complete, we reported, when possible, the reasons why a company decided to initiate a PVR program, the methods applied and the business context. As the literature resulting from the SLR was limited, we decided to enrich the research by analysing other publications related to variety management. At this point, a case study research methodology was adopted to understand the challenges of applying a portfolio rationalization in a real case company. The purpose of the case study was to verify if the case company had met the same challenges in implementing a PVR program previously discovered in the SLR,

to enrich the list of barriers with new challenges and to test the completeness and the accuracy of the classification. Figure 1 shows the steps taken by the researchers in conducting the study. The remainder of the paper is structured according to these four steps, followed by a discussion and conclusion section.

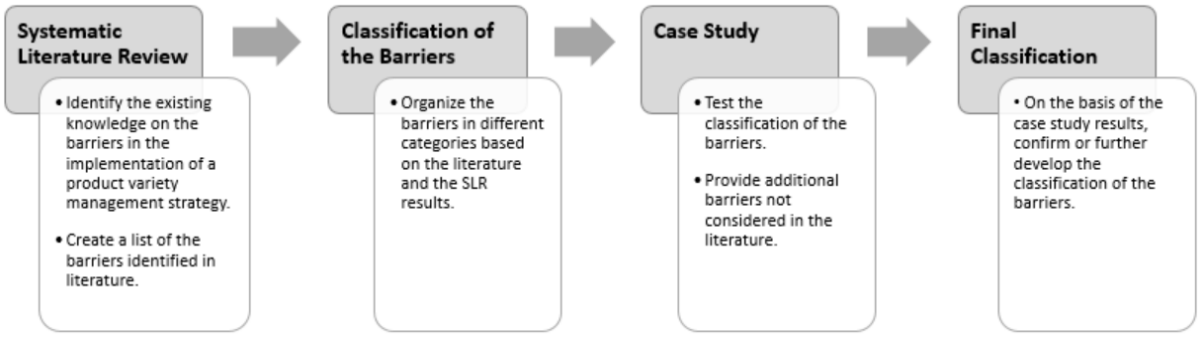

Figure 1. Research approach.

2. SYSTEMATIC LITERATURE REVIEW

2.1 Review process

The purpose of the review was to identify barriers to PVR described in the literature. To do so, a systematic literature review was carried out. Following the approach proposed by Tranfield *et al.* (2003), we divided the SLR into three phases: planning, conducting and reporting. In the first phase, a search string was developed to explore the literature for the challenges of portfolio rationalization. Keywords were chosen to balance precision and specificity, being sufficiently broad so as not to artificially restrict the number of studies but specific enough to find only the studies related to the topic (Cooper, 2010). The initial search string was developed in collaboration with other researchers to guarantee a complete overview and reduce the risk of omitting keywords and synonyms. Two literature databases, Scopus and Web of Science, which cover relevant management and engineering journals, were selected to conduct the research. Using the advanced search in both databases and limiting the search to English-language papers only, we collected and stored 69 articles. The search string used for the Scopus (Elsevier) database was:

> *TITLE-ABS-KEY ("product complexity reduction" OR "product vari* reduction" OR "sku rationalization" OR "product vari* management" OR "product portfolio rationalization" OR "product portfolio reduction") AND TITLE-ABS-KEY ("barrier*" OR "challenge*" OR "problem*" OR "issue*") AND LANGUAGE (English).*

The search string used for Web of Science (Thomson Reuters) database was*:*

> *TS= ("product complexity reduction" OR "product vari* reduction" OR "sku rationalization" OR "product vari* management" OR "product portfolio rationalization" OR "product portfolio reduction") AND TS= ("barrier*" OR "challenge* OR "problem*" OR "issue*"); additional filters applied: LANGUAGE: (English).*

The search results, after removing duplicates arising in both WOS and Scopus, yielded 45 papers. Hereafter, criteria were applied to the abstracts of the remaining articles. Articles that discussed the application of PVM methods or the impacts of PVR strategy in the abstract were assessed for full-text reading. The abstract screening resulted in a sample of 23 articles. The text of one article was not accessible. A full-text screening was then performed, and a sample of five articles was identified as the core of this SLR. Understanding that there may be some related works which were not retrieved with this keyword structure, the researchers decided to expand the analysis to other works found in the SLR papers' references and in the identified papers. As a result, a final sample of nine articles was identified as the core of this literature review (Figure 2).

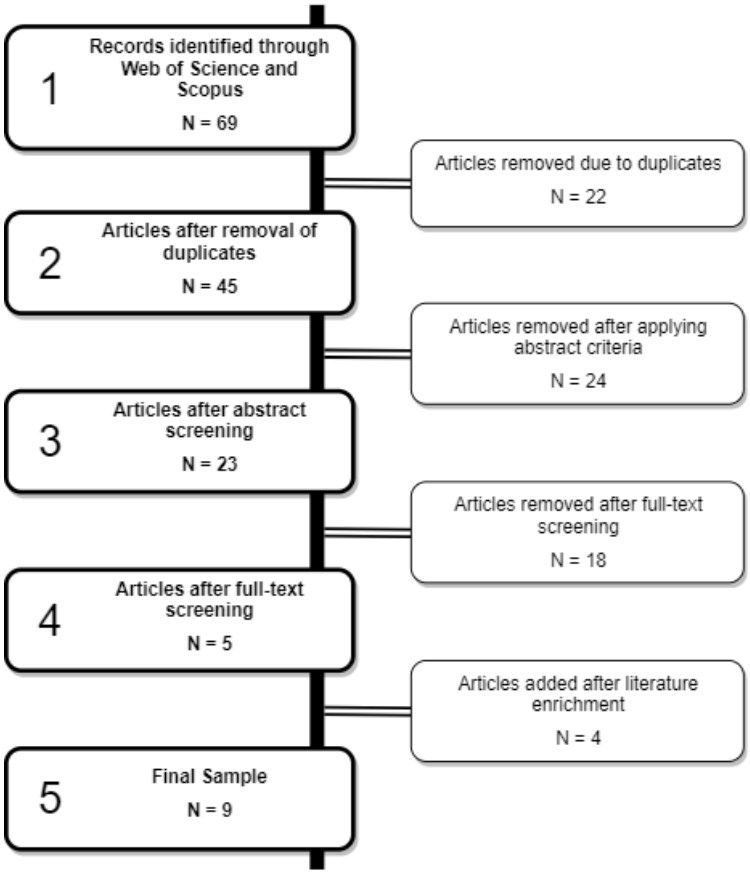

Figure 2. Steps in the literature review

The methods of the nine papers are shown in Table I.

Table I. Identified papers

No.	Authors	Method
1	Bech et al. (2019)	Case study
2	Enz et al. (2019)	Case study
3	Ferreira & Correia-Stein (2017)	Literature review
4	ElMaraghy et al. (2013),	Conceptual
5	Berman (2011),	Conceptual
6	Byrne (2007)	Conceptual
7	Sloot et al. (2006)	Case study
8	Appelqvist & Gubi (2005)	Case study
9	George and Wilson (2004),	Conceptual, Case Study

2.2 Identified PVR barriers

PVM is the topic of a large number of research papers and recent books. However, the interdependencies across themes that make variety management so challenging have received little attention in the research literature (Ramdass, 2003). When narrowing the focus to papers with an explicit focus on barriers to implementing a PVR strategy, the literature is even sparser. For this reason, we include literature on PVM, while delimiting our analysis to the parts of these papers that deals with PVR-related issues. On this basis, in the following, we discuss identified reasons why a company decided to initiate a PVM or PVR program, the methods applied, the business context and the barriers to implementation.

Bech *et al*. (2019) conducted a case study within a Danish manufacturer of breads and pastries with the goal of investigating challenges and experiences of product and process variety management in the process industry. The reasons for adopting initiatives of product and process variety management are related to the long development phase of new products, which involves high costs related to product development, prototyping and pilot production, increasing time-to-market. The authors identified seven main challenges regarding variety management: (1) Difficulties in delaying the point of product differentiation due to the nature of the process utilized in the food industry; delaying the point of product differentiation represents an effective means of addressing product variety. (2) Difficulties in product testing and

determining the effects of the tests; knowledge of the production process and the products was lacking, and the effects of the tests were not documented. (3) No standard interfaces between the parts of the product; the product cannot be viewed as a mechanical assembly of parts. (4) Lack of waste transparency, which results in not knowing the product's cost to produce. (5) Cognitive complexity in the production setup. (6) Due to the lack of examples from the process industry, the company has not prioritized the analysis of the benefits of having a product family. (7) Challenges in translating customer requests to parameters of the product and process; the process and product variety are not closely linked with customer wishes.

Enz *et al*. (2019) conducted a single case study to analyse the implementation of a SKU rationalization project by a restaurant chain and its food distributor. The authors explored the factors that favour the success of a SKU rationalization project and provided seven propositions that help to achieve an efficacious and sustainable SKU rationalization. The case company owned and operated more than 500 stores, and it decided to use a single food distributor to achieve economies of scale. The restaurant chain implemented a portfolio reduction strategy with the aim of substituting some of the proprietary SKUs with customer items. The proprietary SKUs were increasing costs and complexity for both the restaurant chain and the food distributor. The authors recognised five main barriers during the implementation of the strategy. First, marketing, sales, R&D, manufacturing, procurement and finance assessed the importance of a given SKU differently. The different departments had conflicting goals that affected and were affected by the decision to add or eliminate SKUs. Second, if the executive team did not define strategic guidelines for SKU rationalization, communicate the guidelines across the organization and enforce their implementation, functional managers may inadvertently or purposely try to influence the results of the SKU rationalization project to favour the objectives of their function. Third, different interpretations of the financial impact of SKU proliferation were shaped by the positions held in the organization. This was due to a lack of information about all the factors that influenced the results and the overall picture. Fourth, the lack of a formal implementation framework contributed to the failure to solve the problem of SKU proliferation. Fifth, the first-year savings were the lowest because the team needed to identify the information requirements, generate reports and analyse the data. Without senior management support, there may have been pressure to drop the effort after year one on the grounds that the savings were not worth the effort.

Ferreira and Correia-Stein (2017) presented a systematic literature review concerning the impact of product variety on operations management, concluding that product variety has been

one of the key conflicts between manufacturing and sales departments. However, they did not go into detail about particular types of barriers.

ElMaraghy *et al*. (2013) presented the drivers of product variety – a product's benefits, associated complexity and cost – throughout the product's entire life cycle. The authors indicated that product variety creates both challenges and opportunities for firms and highlighted how product variety leads to conflict between supply chain managers and marketing managers. While marketing managers are rewarded with higher revenue when they increase product variety to satisfy customer request, supply chain managers prefer less product variety to increase efficiency.

Sloot *et al*. (2006) evaluated the short- and long-term effects of a 25% item reduction on category sales. The case study was conducted in collaboration with a Dutch retailer. The retailer's aim was to save costs in the supply chain and to reduce complexity by decreasing the number of items in various categories. The original plan was a major assortment reduction, with an estimated cost savings higher than four million euro per year. However, the company feared that a big assortment reduction might affect its category sales. Therefore, the researchers conducted a pilot project in one category. Regarding the execution of the assortment reduction, the authors highlighted a significant potential barrier: an exclusive focus on short-term sales effects that leads to an incorrect conclusion. The time span for analysing the effect of an assortment rationalization should be long enough to include long-term effects.

We identified other research projects in which a product variety management approach was adopted. However, the challenges met by the authors during the PVM approach were not indicated in the papers. As these projects might be interesting for the reader, we briefly cite them here. Alfaro and Corbett (2003) analysed the pooling effect under suboptimal inventory policies and nonnormally distributed demand. Escobar-Saldìvar *et al*. (2007) adopted a product variety management approach in the painted sheet metal industry. Ding and Sun (2007) applied Data Envelopment Analysis (DEA) models to analyse product complexity related to product variety and tested these tools in a US automobile plant. Malinowski *et al*. (2018) applied SKU rationalization in the form of a variant of product substitution to an industrial packaged supply chain problem.

Berman (2011) described how a firm can limit product proliferation without incurring reduced sales or lowering consumer loyalty. He identified five main barriers to an effective product proliferation reduction program: (1) An all-things-to-all-people orientation – many managers keep excessive assortments of poorly-selling products out of concern for losing customers to

competitors; (2) product proliferation as part of a barrier to entry strategy – major brands can attempt to control shelf space such that third-tier brands are precluded from entering the market due to an absence of available sales surface; (3) product proliferation as a low-risk strategy to increase sales – a product manager may be more highly regarded in his company if he develops new products that are redundant rather than increasing profits by reducing SKUs; (4) improper management of product life cycles – firms add new products without removing existing products in the life stage of maturity or decline; (5) reluctance of managers to prune products due to the fear of harming positive relationships with customers.

Byrne (2007) presented a different and truly strategic approach to SKU optimization designed to eliminate high-volume but unnecessary SKUs. The author states that companies usually cut 30 percent of slow-moving, low-volume SKUs. This approach is necessary and commendable, but not strategic. To get the full benefits of a SKU optimization, companies need to focus on the high-volume SKUs. The author identified two entry barriers to the rationalization approach presented: (1) SKU optimization is often run by the supply chain department with the goal of reducing operational costs and complexity, while marketing and sales departments complain that eliminating the latest promotion pack will negatively affect brand equity; (2) a lot of SKUs are not created for the consumer, but for retailers – manufacturers invent numerous new SKUs and special packs to keep all customers happy. When eliminating higher volume SKUs, there will be a backlash from the customers.

Appelqvist and Gubi (2005) used simulation tools to evaluate and quantify the benefits of postponement for a consumer electronics company. In the case study, the benefit of postponement is first evaluated qualitatively through interviews, followed by a quantitative study using discrete-event simulation. The authors identified two barriers. First, they described that the idea of applying a postponement approach had been suggested for some time but never implemented due to a lack of quantitative evidence. Second, showing a potential for savings raises the question of who will benefit from the savings. The case company bears the cost of developing and manufacturing products while savings occur at the retail outlets.

George and Wilson (2004) discuss how portfolio simplification (rationalization) is a key aspect for managing complexity in a company. The authors state that, with the elimination of low economic profit products and services, a company can free up resources to provide better services to the customer and to allow them to focus more on the remaining (profitable) products/services. In this chapter, we identified four barriers that may arise when adopting a rationalization strategy: (1) while most companies understand the dynamic of the

product/service life cycle, very few companies have methodologies in place for managing the end of a life cycle, and consequently, functional groups in the organization tend to blame each other for the creation of complexity; (2) companies may believe that their products and services represent significant diversification and stability of revenues and that a reduction of the portfolio's breadth would mean a permanent reduction in revenue; (3) if the product/service rationalization includes a large section of the portfolio, managers and staff responsible for that segment of products may think they will lose their job; (4) the 'core competencies' (what the company does well) can constrain a company to a market where it cannot earn positive economic profits and become an obstacle to portfolio simplification.

The authors also introduce the case of Intel, a multinational semiconductor manufactory company. Intel was well known as a producer of computer memories, and that was their core business. The company was also developing microprocessors for specific customers. When the memory market started to become more capital-intensive, with tighter margins, the CEO decided to apply a portfolio simplification strategy with the intent of focusing on microprocessors and scuttling memory. During the rationalization process, the CEO met two main challenges: (1) the majority of Intel managers and executives who had memory as a core competence didn't support the transition and became obstructive for the process – their internal competency represented Intel's main barrier to taking the rationalization action; (2) concern over what the company's customers would think.

3. CLASSIFICATION OF BARRIERS IDENTIFIED IN THE LITERATURE

The identified papers included different ways of organizing barriers to PVR. In this context, Enz *et al*. (2019) explored the factors that favour the success of SKU rationalization projects and provided seven propositions that help to achieve an efficacious and sustainable SKU rationalization. We used these seven propositions as a basis for building the classification system for the barriers. In fact, the propositions are the enablers that favour the success of SKU rationalization projects, and we used the categories made by the authors as an inspiration for our classification. The seven propositions are related to the following topics: executive sponsorship, organizational alignment, cross-functional integration, financial information, collaboration, implementation framework and long-term focus (Enz *et al*., 2019). Those categories, however, only partially reflect the barriers found in the literature.

Ramdas (2003) organized variety creation decisions into four key decision themes: dimensions of variety, product architecture, degree of customization and timing. Similarly, he sorted

variety implementation decisions into three key decision themes: process and organizational capabilities, points of variegation and day-to-day decisions. By process capabilities, the author means manufacturing/service process flexibility and technology; organizational capability comprises ease of interaction between organizational entities, ease of interaction across functions and across development projects and the firm's ability to measure the revenue and cost implications of its variety-related decisions.

It is easy to see how organizational capability, as described by Ramdas (2003), includes organizational alignment, cross-functional integration and financial information presented by Enz *et al*., (2019). The PVR project should be aligned with corporate goals and strategies, and its support for the company strategy should be clearly communicated across the organization (Enz *et al*., 2019). However, the strategy of the company can contrast with the goals of PVR. For example, at the retail store level, product proliferation is used as part of a barrier to entry strategy, with the goal being to preclude third-tier brands from entering the market (Berman, 2011). A lot of SKUs are not created for the consumer, but for retailers. Manufacturers invent numerous new SKUs and special packs to fulfil the unique needs of different classes of trade. Moreover, product managers are usually more highly regarded for developing new products rather than increasing profits by reducing SKUs. The barriers related to the company strategy are grouped in the category *strategy and organizational alignment*. We used the category *data/information quality* in our classification, which includes not only financial information but also quantitative data, misinterpretation of data, and lack of data and information.

Conflict between departments was indicated as a barrier in four articles. Ferreira & Correia-Stein (2017), ElMaraghy *et al*. (2013) and Byrne (2007) identified the same cause of the conflict: product variety creates both opportunities and challenges for firms and it requires a trade-off between balancing the increase of revenue and the corresponding costs. While marketing managers are rewarded with greater revenue when they increase product variety, supply chain managers prefer less product variety to increase efficiency and decrease operational costs. The conflict between marketing and manufacturing has gone on for many decades (Shapiro, 1977), and firms face this conflict when they implement a PVM strategy. Enz *et al*., (2019) extend the tensions between functions to marketing, sales, R&D, manufacturing, procurement and finance. The functions assess the importance of a given SKU differently and have conflicting goals that affect and are affected by the decision to add or eliminate SKUs. These barriers are grouped in the category *cross-functional integration*. The causes of the resistance of top management are varied. In the Intel case study, for example,

George and Wilson (2004) indicated the internal competency of the managers as Intel's main barrier for taking the rationalization action. The core competence of the managers was computer memory. When the CEO decided to cut memory products and focus on microprocessors, most of Intel's managers and executives would not make the transition and became obstructive to the simplification strategy. Berman (2011) observed that the reluctance of managers to prune products is particularly applicable in a business-to-business environment. The category *executive sponsorship* collects the above-mentioned barriers.

Inspired by Ramdas (2003), we introduced *product architecture* and *manufacturing process* as categories in the classification system. Product architecture comprises the barriers to a PVM strategy related to the nature and the architecture of the products. Manufacturing process comprises the barriers related to technologies, decoupling point, logistics and supply chain elements. Companies do not usually have methodologies in place for systematically managing the end of a life cycle (Berman, 2011; George and Wilson, 2004). PVR strategy requires a formal *implementation framework* that helps to implement the strategy in a structured manner (Enz *et al*., 2019). The implementation framework supports the resolution of the conflicts, the achievement of consensus within the team, the analysis of the existing portfolio and the creation of a new SKU methodology. Collaboration with the main customers and suppliers during the PVR strategy can provide the opportunity to obtain bigger benefits (Enz *et al*., 2019). In this way, the company can satisfy the suppliers/customers without creating a new SKU and come to an agreement on which SKU they should discard. The lack of *customer/supplier collaboration* during the PVR strategy will lead to a disappointing customer experience and is a sure way to hurt the company's brand image.

Another barrier we identified is related to *fears and negative beliefs* that companies and employees have in the early stages of a PVR strategy. Examples of these common beliefs are given in the literature by George and Wilson (2004), Sloot *et al*. (2006) and Berman (2011): concern about what the client will think, fear that significant assortment reduction might affect the category sales, the belief that a reduction of portfolios means a reduction in revenue, fear of losing an important client to a competitor for even one item and, for the staff responsible for the products affected by rationalization, fear of losing their job. This category is not highlighted in the literature analysed, but it has a big impact on the implementation of a PVR strategy. For this reason, we decided to include this topic in the final classification system.

In the end, we identified the following nine categories for the classification of the barriers:

1. Cross-functional integration
2. Strategy and organizational alignment
3. Executive sponsorship
4. Fears and negative beliefs
5. Data/information quality
6. Implementation framework
7. Product architecture
8. Customer/supplier collaboration
9. Manufacturing process

Using these nine categories, the barriers described in the previous subsections may be categorized as shown in Table II.

Table II. Barriers identified in the literature

	Barriers	Category	Reference
1	The nature of the process utilized in the case company results in difficulty in delaying the point of product differentiation. The task is difficult because the differentiation happens in the mixing process, before the process becomes discrete. The semi-manufactured products cannot be kept in stock in order to make the customization later, since the products decay.	Manufacturing process / product architecture	Bech *et al*. (2019)
2	Knowledge of the production processes and the correlation with the ingredients in the dough is lacking, and tests have to be performed in the production setup. The effects of the tests are not documented, which results in significant testing.	Data/information quality	
3	There are no standard interfaces between the parts of the product (a dough, a shape with a filling and a topping). The product cannot be viewed as a mechanical assembly of parts.	Product architecture	
4	The case company experiences challenges with the cost of products due to lack of waste transparency. The physical waste is not logged per product, which results in not knowing the product's cost to produce. In conclusion, the company is lacking information on the product's performance in production.	Data/information quality	
5	The production process is, today, solely operator-driven. Thereby, cognitive complexity exists in the case company.	Manufacturing process	
6	Even though the durable goods industry has seen good results, exploring the benefits of applying a product family has not been prioritized. One of the reasons for this lack of prioritization is the lack of examples from the process industry.	Data/information quality	

7	It has been a challenge to translate customer requests to parameters of the product and process. As a result, the process variety and the product variety are not closely linked with customer wishes. Finding a systematic way of establishing the product and process variety which encompasses customer requests has not been in focus at the case company.	Customer/supplier collaboration	
8	The importance of a specific SKU is likely to be viewed differently by marketing, sales, R&D, manufacturing, procurement and finance, which usually have conflicting goals that affect and are affected by the decision to add or eliminate SKUs. There is tension between functions in the area of SKU rationalization.	Cross-functional integration	Enz *et al.* (2019)
9	It is necessary to align SKU rationalization objectives with the organization's goals and strategies. If the executive team does not define strategic guidelines for SKU rationalization, communicate the guidelines across the organization and enforce their implementation, functional managers may inadvertently or purposely try to influence the results of the SKU rationalization project to favour the objectives of their function.	Strategy & organizational alignment	
10	Due to a lack of information about all the factors that influenced the results and the overall picture, different interpretations of the financial impact of SKU proliferation were shaped by the positions held in the organization.	Data/information quality	
11	Lack of a formal implementation framework contributed to the failure to solve the problem of SKU proliferation.	Implementation framework	
12	The first-year savings were the lowest because the team needed to identify the information requirements, generate reports and analyse the data. Without senior management support, there may have been pressure to drop the effort after year one on the grounds that the savings were not worth the effort.	Strategy & organizational alignment / executive sponsorship	
13	Product variety has been one of the key conflicts between manufacturing and sales departments.	Cross-functional integration	Ferreira and Correia-Stein (2017)
14	Customers prefer broad product lines, and therefore, marketing managers are rewarded with greater revenue when they increase product variety. Supply chain managers, on the other hand, prefer less product variety to increase efficiency, which may reduce revenues and profits. Unfortunately, firms face this product variety conflict between supply chain managers and marketers with limited predictive ability.	Cross-functional integration	ElMaraghy *et al.* (2013)

15	An all-things-to-all-people orientation: many managers keep excessive assortments of poorly-selling products out of concern for losing customers to competitors. They fear losing an important client to a competitor for even one item.	Fears and negative beliefs	Berman (2011)
16	Product proliferation as part of a barrier to entry strategy: at the retail store level, major brands can attempt to control shelf space such that third-tier brands are precluded from entering the market due to an absence of available sales surface.	Strategy & organizational alignment	
17	Product proliferation as a low-risk strategy to increase sales: in many cases, a product manager may be more highly regarded in his/her company for developing new products that are redundant with existing ones rather than increasing profits by reducing SKUs.	Strategy & organizational alignment	
18	Improper management of product life cycles: firms add new products without removing existing products that are in the life stage of maturity or decline.	Implementation framework	
19	Reluctance of managers to prune products: part of this reluctance may be due to the fear of harming positive relationships with customers. This concern is particularly applicable in a business-to-business environment.	Executive sponsorship / fears and negative beliefs	
20	Attacks on the lowest-volume SKUs are usually run as supply chain initiatives aimed at cutting operating costs by reducing product-line complexity. Often, marketing and sales people complain that eliminating the latest promotion pack will negatively affect brand equity.	Cross-functional integration	Byrne (2007)
21	When eliminating higher-volume SKUs, or trying to eliminate them, be prepared for a backlash. A lot of SKUs are not created for the consumer, but for retailers. Companies don't create five sizes of spicy tomato sauce because they think the consumer wants them but because they have to fulfil the unique needs of different classes of trade. Thus, manufacturers invent numerous new SKUs and special packs to keep all channels happy.	Strategy & organizational alignment	
22	The company feared that a big assortment reduction might affect its category sales.	Fears and negative beliefs	Sloot *et al*. (2006)
23	The collaborative research project provides some information for the retailer regarding the execution of assortment reduction projects. One key lesson is that an exclusive focus on short-term sales effects leads to incorrect conclusions. Instead, the time span for analysing these effects must be long enough to include long-term effects.	Strategy & organizational alignment / implementation framework	
24	The simulation project was a success that triggered implementation of a new delivery concept. The idea had been suggested for some time but never implemented due to a lack of quantitative evidence.	Data/information quality	Appelqvist and Gubi (2005)

25	Showing a potential for savings raises the question of who will benefit from the savings. In the described setting, the case company bears the cost of developing and manufacturing products while savings occur at the retail outlets.	Customer/supplier collaboration / strategy & organizational alignment	
26	While most companies understand the dynamic of product/service life cycles, very few companies have methodologies in place for systematically managing the end of a life cycle.	Implementation framework / cross-functional integration	George and Wilson (2004)
27	Functional groups in the organization tend to blame each other for the creation of complexity.	Cross-functional integration	
28	Companies may believe that a reduction of the portfolio's breadth means a permanent reduction in revenue.	Fears and negative beliefs	
29	Managers and staff responsible for the segment of products affected by rationalization may think they will lose their job.	Fears and negative beliefs	
30	Core competency as an obstacle to create shareholder value: most companies are stuck in a paradigm where strategic decisions are based on what the company does well (its core competencies) instead of what customers value.	Strategy & organizational alignment	
31	A concern over what the company's customers would think. The company believes that customers will react negatively to the portfolio simplification.	Fears and negative beliefs	
32	Managers and executives with a core competency in the 'rationalized' products don't support the transition and become obsolete and obstructive to the process. This represented Intel's greatest barrier to taking the necessary action for survival.	Executive sponsorship	

4. CASE STUDY

4.1 Research method

The case study research methodology was adopted to investigate the proposed classification of PVR barriers and, possibly, to identify additional ones. A case study is defined as 'a study that investigates a contemporary phenomenon (the 'case') in depth and in its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident' (Yin, 2018). This is especially meaningful for the present study, as the barriers in a PVR implementation strategy are not evident or predictable and might be influenced by the market context.

Gammelgaard (2017) describes three types of case studies. First, case studies are often applied to generate theory through inductive exploration of unknown phenomena. Second, case studies

are used for deductive theory testing, as described by, for example, Yin (2018). Third, case studies can used for theory elaboration by utilizing through the use of both inductive and deductive reasoning, as proposed by Ketokivi and Choi, 2014. The present study may be categorized as such a case study, as it both tests the relevance of the PVR barriers identified in the literature (i.e., deductive theory testing) and conduct an inductive exploration to identify additional barriers.

For the setting of the case study, the researchers sought a company that felt the need to implement a PVR strategy and, consequently, had already made the choice to invest in this project. Furthermore, other companies with the same characteristics (worldwide presence, extended enterprise, composed of different business units) can be represented by the chosen case company. The company selected for the case study is a mineral wool production company located in Europe. The company has a market-leading position in the building materials industry and operates over 20 global production facilities with over 10,000 employees. It is composed of 18 individual business units (BU) operating in different markets, with each BU managing its own assortment. Led by the CEO, the company pursued a PVR program in 2015 and achieved operational and financial benefits across multiple factories and sales units. At the beginning of the project, product proliferation was increasing as new variants were added to existing product lines upon customer request. The sales department was not applying any process for removing stock keeping units (SKUs) from the assortment, and in the production, the negative effects of additional product variants were evident.

Multiple investigators were used to enhance the creative potential of the study and to enhance confidence in the findings (Eisenhardt, 1989). One of the researchers collaborated with the supply chain team between two and four days per week during the entire project period (four years). The main role of the researcher was observing the project team in the SKU rationalization tasks: development of the program, methodology, quantification of the impact and reports to the management. During the PVR program, the researcher had full access to the financial and operational data of the company. A second researcher used qualitative data analysis techniques to understand the managers' perceptions and identify the challenges that influenced the execution of the SKU rationalization strategy. The researcher involved in this phase did not participate in the SKU reduction project and thus was not influenced by participation in the company's PVR strategy. The first step was to interview supply chain managers and portfolio managers responsible at the cooperate level. The semi-structured

interviews contained questions about the timeline of the strategy, the execution of the project and the barriers encountered.

4.2 Case study results

Led by the CEO, the case company set the reduction of product portfolio complexity as a top priority in 2015 and initiated a program to develop methods to address increasing product variety. As mentioned in Section 2.2, the company consists of 18 individual BUs operating in different markets, with each BU managing its own assortment. Fifteen of the BUs participated in the SKU rationalization project. The main goal of the SKU reduction was to create additional throughput on the production lines and thereby reduce product cost. Unprofitable and low-volume SKUs were targeted for rationalization so that more profitable SKUs could be sold in their place. In order to determine if a SKU was profitable or unprofitable, a threshold of 2000 EUR in contribution margin (CM) per year per SKU was established. Reductions in operational costs resulting from the project were sought by some BUs, but this was not the primary objective of the rationalization.

Full-time collaboration with the company allowed the researcher to observe first-hand the challenges of implementing a portfolio reduction program within an international organization. A number of challenges were observed during the SKU rationalization. First, in the building materials business, some products are sold primarily to building project contractors, and, to win a project bid, the company must be able to provide all requested products, including the low-volume SKUs with low profitability. Thus, the potential revenue of high-volume SKUs is linked to the availability of the low-volume SKUs. Therefore, the company-wide approach to assess profitability at the SKU level couldn't be applied for certain low-volume product segments. Second, the threshold for unprofitable products was heavily critiqued by top managers as being too high for special products that are produced to satisfy large customers. While many of the managing directors of the BUs thought the CM threshold was too high, the CEO thought it was too low, favouring a threshold value closer to 5000 EUR in CM per SKU. Third, not all of the BUs implemented a cross-functional portfolio review to drive assortment changes. To prevent an immediate impact on the customer base, some BUs focused on the simpler task of closing unsold SKUs. In other words, instead of rationalizing the sold SKUs, they simply removed the SKUs that had not been produced or sold in over one or two years. Fourth, the change management process in an organization with distributed decision-making power was quite complex. In the first year of the project, the BUs often questioned and criticized the methods for managing the SKUs and for evaluating the BUs' results. In the first

year, some training was needed to explain the expectation of SKU rationalization to the BUs' management. Fifth, the importance of clearly communicating the expected business benefits of the portfolio simplification to all stakeholders was clearly seen in the project. The managing directors who clearly saw how the SKU rationalization would help them meet their financial and operational performance goals were more motivated to execute the project. During the first two years of the project, the expected business benefits didn't permeate the top management, and resistance to the project was evident. Sixth, a further challenge to SKU rationalization was the complex production network setup and the lack of global product management across the BUs. Some BUs operated as production BUs, offering their standard product line and managing the production equipment. Other BUs operated as sales BUs, offering specialized product lines but not directly managing production, instead sourcing the products from the production BUs. These interdependencies between BUs introduced complications into the SKU rationalization process for both sales BUs and production BUs. For example, if a sales BU wanted to close a SKU, they could close the SKU for sale from their organization but could not close it for production themselves; for that, they also needed to coordinate with the production BU to close the SKU. Seventh, another issue related to the production network arose when a certain production BU tried to simplify the products it produced on the manufacturing equipment. During their analysis, the team at the production BU found that their own product lines accounted for a fraction of the SKUs produced while the remainder of the SKUs produced were managed by sales BUs that were unwilling to reduce the product assortments. This complication limited the amount of operational benefits the production BU could achieve and also seemed to dampen their motivation to pursue the project further. Eight, there seemed to be some cultural and personality factors which affected the execution of the SKU rationalization initiatives across the BUs. Regarding personality factors, the North American team was headed by a very driven supply chain director who was able to persuade the BU's management team to commit to a drastic SKU reduction (> 50%) at the very onset of the cross-company SKU rationalization initiative. His drive and character were seen across the company as key factors that led to their first mover status in the company and the success of the project in their BU. Regarding cultural factors, there was a clear difference in the initiative shown by the Polish and Russian BUs compared to the German and Dutch BUs. The Polish and Russian BUs appeared to be much more execution-oriented, implementing the guidelines from headquarters with rigor and little resistance. The German and Dutch organizations, however, delayed in execution and required multiple visits and conference calls from the researchers to explain the SKU rationalization methods and potential improvements to be gained. The German and Dutch

BUs did not make significant changes until the last year of the project, being two of the last BUs to take action.

The managers interviewed had been aware of the problem of SKU proliferation for a long time, and a few isolated portfolio simplification initiatives were carried out some years before the main project. Five years before the group SKU rationalization, the supply chain department of one BU started a SKU reduction initiative with the goal of improving the efficiency of production. At the same time, the marketing department of another BU ran a similar project with the purpose of increasing capacity in the production site. Slowly, other BUs started to see the operational benefits of these initiatives and began to support the project. The former CEO understood that product complexity was a problem for the company and started focusing a bit more on the rationalization projects. However, he was not persistent, and he did not set the portfolio simplification as a priority for the company. The BU initiatives remained local projects, and the overall project didn't start until the arrival of the new CEO. In 2015, the new CEO saw the big potential of the SKU rationalization strategy, set it as a top priority of the overall company and established the direction to address the product variety reduction. The operations and production manager highlighted how the sponsorship and the directions of the new CEO were relevant to the success of the PVR strategy. To determine the threshold between unprofitable and profitable products, an activity-based costing analysis was performed for a generic, low-volume product that was most representative of the products made by the company. The analysis incorporated existing cost of goods sold figures with analyses of inventory costs, extra waste and manning required for small batches, sales order handling costs and a desired CM. The researchers, together with the company's supply chain team, discovered that 2000 EUR in CM per year was the threshold between profitable and unprofitable products. Initially, the methods of the strategy were not clearly communicated to the BUs, and the top managers heavily critiqued the threshold for unprofitable products. There was a crucial misunderstanding in the communication of the threshold: the BUs were under the impression that all products with a contribution margin below 2000 EUR must be removed. The real goal of the methods was to start analysing those products and take some action to remove/substitute the products or raise their contribution margin (pricing, changing volume, etc.). One more barrier identified by the managers is related to the fear of applying the portfolio rationalization within BUs in which sales were declining. The operations managers of these BUs were afraid to lose more volume in the production line and were reluctant to remove unprofitable products. They would have preferred to keep producing those products in order to run the production

lines at full capacity. The managers observed that these fears and the economic factors were related to each other: BUs with good financial conditions were more confident in starting a PVR strategy compared to BUs that had financial issues. Finally, an interesting observation was made by the operations and production manager: '*No matter how you approach a PVR strategy, there will be always some reluctance in the beginning due to the change management. You have to consider the change management factor and that it will decrease over the time'*.

Table III summarizes the barriers to PVR identified in the case study.

Table III. Barriers identified in the case study

	Barriers	Category	Reference
1	In the construction business, the company must be able to provide all requested products – both high-volume SKUs and low-volume SKUs. Therefore, the company-wide approach to assess profitability at the SKU level couldn't be applied for this product segment.	Product architecture	Case Study
2	Top managers heavily critiqued the threshold for unprofitable products, which they considered to be too high for special products that are produced to satisfy large customers.	Executive sponsorship	
3	To prevent an immediate impact on the customer base, some BUs, instead of rationalizing the sold SKUs, simply removed the SKUs that had not been produced or sold in over two years.	Implementation framework	
4	The BUs often questioned and criticized the methods for managing the SKUs and for evaluating the BUs' results. Some trainings were needed to explain the expectation and the benefit of SKU rationalization.	Information quality/ Implementation framework	
5	During the first two years of the project, the expected business benefits didn't permeate the top management, and resistance to the project was evident.	Information quality/ Executive sponsorship	
6	The production network and lack of global product management across the BUs created many interdependencies in the SKU rationalization that limited the reductions for some BUs.	Process capabilities	
7	The former CEO was not persistent, and he did not set the portfolio simplification as a priority for the company. The BU initiatives remained local projects, and the overall project didn't start before the arrival of the new CEO.	Executive sponsorship	

8	Initially, the methods of the strategy were not clearly communicated to the BUs, and there was a crucial misunderstanding in the communication of the threshold.	Information quality/ Implementation framework	
9	There was some fear of applying the portfolio rationalization in BUs in which sales were declining. The operations mangers of these BUs were afraid to lose more volume in the production line and were reluctant to remove unprofitable products.	Fears and negative beliefs	
10	There seemed to be some cultural and personality factors which affected the execution of the SKU rationalization initiatives across the BUs	**?**	

5. A CLASSIFICATION OF BARRIERS TO PRODUCT VARIETY REDUCTION

Based on the review of the literature and the case study, a final classification of barriers was created. In this context, the barriers identified in the literature and the ones identified in the case study differ in some respects. Specifically, some of the barriers identified in the literature were not identified in the case study. This is not surprising; it can be explained by differences across contexts. In other words, it can be expected that some barriers would only be found in certain cases. Conversely, we could not allocate the tenth barrier found in the case study to any of the classifications derived from the literature. Thus, we propose an extension of the barriers identified in the literature: namely, the category 'socio-cultural factors'. Socio-cultural factors are one of the main environmental factors that significantly affect the economic activity of multinational companies and their performance (Masovic, 2018). The socio-cultural factors that impact the operations of multinational companies are culture, language, religion, level of education, customer preferences and the attitude of the society towards foreign goods and services (Trehan and Trehan, 2009). Multinational companies should be aware of predominant attitudes, values and beliefs in each host country when deciding to implement a PVR strategy and should anticipate the impact of all socio-cultural factors. The researchers agreed that this new barrier needs its own category in the classification. Therefore, we propose a final classification of the barriers as shown in Table IV.

Table IV. Barrier Categorization

CROSS-FUNCTIONAL INTEGRATION	PVR strategies must have cross-functional involvement so that functional biases are understood and addressed. Ease of interaction across functions enhances a firm's ability to quickly introduce new products.

STRATEGY and ORGANIZATIONAL ALIGNMENT	The way in which the objectives for the PVR project are aligned with corporate goals and strategies should be clearly communicated throughout the organization.
EXECUTIVE SPONSORSHIP	PVR strategy requires executive sponsorship in order to overcome strongly competing functional priorities. The initial phase of the project involves the creation of awareness that SKU proliferation is a priority problem.
FEARS and NEGATIVE BELIEFS	A PVR strategy can scare both management and staff inside an organization. Before the implementation, companies tend to be concerned about losing customers and revenue. During the implementation, the staff may be scared about the changes required by the initiative.
DATA/INFORMATION QUALITY	PVR strategy decisions require the availability of data, revenue and cost information that managers from different functions understand and can trust. This information must be disseminated throughout the organization to build support for the project as well as an understanding of its benefits.
IMPLEMENTATION FRAMEWORK	PVR strategy requires a formal implementation framework. It helps to implement the strategy in a structured manner (resolve conflicts, achieve consensus within the team, analyse the existing portfolio, create new SKU methodology, etc.).
PRODUCT ARCHITECTURE	Architecture is a mayor determinant of how a firm can differentiate and variegates its products. The product architecture can influence the selection of a PVR strategy and its implementation.
CUSTOMER/SUPPLIER COLLABORATION	The benefits of a PVR strategy are greater with key customer/supplier collaboration.
MANUFACTURING PROCESS	Manufacturing process flexibility is a key capability in order to manage the implementation of a variety strategy. Flexible technologies, point of variegation (decoupling point), logistics and supply chain elements can influence the application of a PVR strategy.
SOCIO-CULTURAL FACTORS	Society and culture have an impact on every aspect of the overseas business of multinational companies. Although they are not directly included in business operations, they indirectly appear as key elements in shaping how the business is managed. The key socio-cultural factors that have a major impact on the operation of the multinational companies are culture, language, religion, level of education, customer preferences and the attitude of the society towards foreign goods and services.

6. DISCUSSION AND CONCLUSIONS

In this paper, we investigated the barriers to the implementation of a PVR strategy by analysing and classifying the barriers found in the literature and then further exploring these through a case study. The case study partially confirmed the barriers identified in the literature, and it enriched these by introducing a new category of barriers.

6.1 Implications for research

As demonstrated by the literature review, the PVR literature involves different organizations of PVR barriers. This is problematic, from at least three perspectives. First, to further develop PVR approaches, there is a need to understand the issues that companies encounter when engaging in PVR programs so that PVR approaches can provide means for avoiding such issues. Second, research employing a hypothetical-deductive method for exploring characteristics of barriers, such as frequency of occurrence and barrier strength, will not provide full accounts of PVR barriers if leaning on incomplete classifications. Finally, for research discussing PVR barriers, the lack of agreement on PVR barriers makes cross-study comparisons difficult.

This paper addressed these issues by providing a more complete classification of barriers to PVR. Specifically, this study makes three contributions to the research. First, it identifies barriers to the implementation of PVR strategies described in the scholarly literature. Second, it provides a classification system for these barriers. Third, through a case study, an additional category of barriers was identified. Hereby, the paper provides an important contribution to the PVM literature.

6.2 Implications for practice

Practitioners may utilize the PVR barrier classification to anticipate the barriers they will meet while pursuing a PVR program. Such an overview would reveal where the management should focus attention and resources in order to overcome scepticism and even resistance in the implementation of the strategy. In other words, an overview of possible barriers may help companies avoid them through pro-active effort.

6.3 Research limitations and further research

This study has some limitations that may provide worthwhile opportunities for further research. First, the final sample of nine articles identified as the core of the systematic literature review is limited. Additional studies should include the use of new keywords to enrich the search string

in order to discover more literature about the challenges facing PVR strategies. Second, the case study research methodology was applied at the aggregated level. This study considered the barriers met during the reduction of product portfolio complexity at the company level. The firm consists of 18 individual BUs operating in different markets, with each BU managing its own assortment. Additional research should study the effects and the challenges of a SKU rationalization at the BU level. It might be interesting to see the difference between the barriers met by the same company at the aggregated and disaggregated levels. However, more research is required, both at the aggregated and disaggregated levels, because the number of studies on the barriers to implementing a PVR strategy is still limited.

The proposed method, a systematic literature review followed by a case study, is useful to obtain an overview of the existing knowledge in the recent literature and to verify and enrich it with a more qualitative study. Using this project as a starting point, additional research should confirm and develop the categorization of the barriers presented in this paper. Case studies of companies that want to apply a PVR strategy might enrich the list of barriers with some real-world examples.

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5. IMPLEMENTATION OF PRODUCT INFORMATION MANAGEMENT SYSTEM: IDENTIFYING THE CHALLENGES OF THE SCOPING PHASE

The PIM system is a relatively new type of software (Abraham, 2014) that is rarely studied in the literature; furthermore, there are no previous indications on how to do the scoping of the project. It must be recalled, that decisions taken in the early stages of a PIM project are very important for the success of the entire project, significantly affecting the successive stages. A major cause of failure of IT implementation projects concerns planning-related problems because of an unclear scope (Meredith and Mantel, 2002). The existing literature suggests a theory about the selection phase of a PIMS (Abraham, 2014), the implementation phases of a PIMS (Abraham, 2014), and the scoping phase of other IT systems (Shafiee et al., 2014; Shafiee et al., 2018; Saaksvuori and Immonen, 2008). However, the implementation of PIMS differs from most IT systems, as some information cannot relatively readily be implemented, but, to a large extent, needs to be constructed. Specifically, PIMS include generic product information models, which typically are not available in companies. In the companies that Abraham (2014) analysed, the main challenge during the PIM implementation proved to be the shared product data model. In many cases, the companies had underestimated the complexity and the time needed to develop this model. The creation of the data model requires a close cooperation between departments, external data provider(s), and implementation partner(s), as well as a know-how on product structures and processes and an understanding of the PIMS functionalities. These requirements need to be established from the beginning of the project, specifically in the scoping phase. For this reason, a framework designed to support the scoping phase of a PIMS was developed. The framework was applied to the case company and the results observed through participant observation (Åhlström & Karlsson, 2009; Sanday, 1979).

The remainder of the section is structured as follows. Section 5.1 describes the framework and its different steps (Battistello et al., (2019), "*Scoping a PIM System: A Supporting Framework"*). Section 5.2 provides the results of the framework application and explores the challenges of PIMS implementation in relation to the scoping phase (Article 2).

1.1 Scoping a Product Information Management System: A Supporting Framework

The development of the framework is based on the related literature review and on industrial experience. A combination of IT project frameworks and case studies were used. With specific regard to general theories about project (Pryke and Smyth, 2016; Dvir et al., 2003) and information (Forza and Salvador, 2007) managements, general theory on scoping IT systems (Sulgrove, 1996), frameworks for implementing IT systems based on the Rational Unified Process (RUP) (Kruchten, 1998), and case studies on scoping product configuration systems (Shafiee et al., 2014; Shafiee et al., 2018). The framework was developed in collaboration with practitioners, PIM consultants and professors with a research background in product information management and product modelling.

The proposed framework for scoping PIMS includes the following four macro-activities:

- Stakeholders' identification
- As-Is analysis
- To-Be proposal
- Sharing results and system selection preparation

The macro-activities should be followed in sequence because it facilitates the gradual and harmonic development of the project (Figure 9). Every step has well-defined purposes and deliverables.

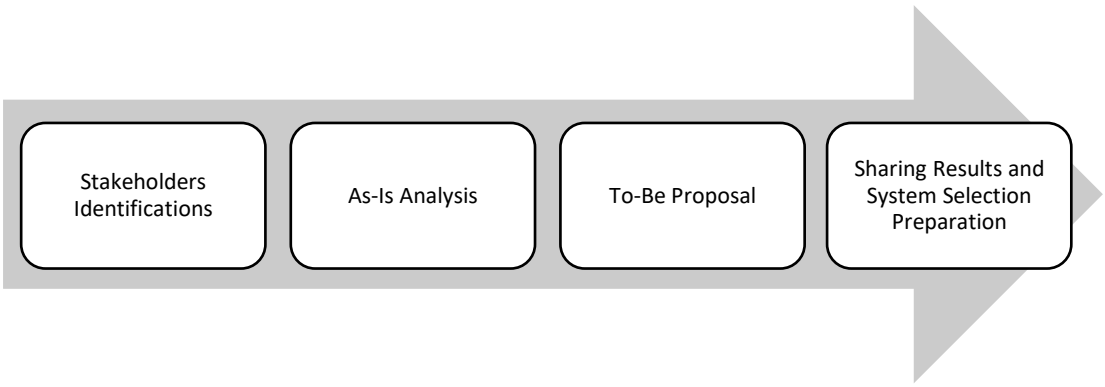

Figure 9. Macro activities of the framework.

1.3.1 Stakeholders Identification

A PIM system has many different users, and it can be used by the entire value chain. In the scoping phase, it is important to include the representatives of all the stakeholders. The aims of the stakeholders' identification are:

- Define the project organisational structure and the main responsibilities

- Create an overview of who is involved in the project and the impact across the company
- Define a group of people who provides guidance, direction and control of the project
- Establish an base-knowledge of PIM

The first step consists of the identification of the PIM project team, the "PIM specialist" and the steering committee (Abraham, 2014). The PIM project team is the core group that manage the full scoping phase. It should comprise at least the project manager, the PIM specialist and the business owner of the project. The PIM specialist supports the project manager and the business owner during the scoping phase. He/she should have a base-knowledge of PIMS and experience in the implementation of IT systems. He/she can be internal or external. The steering committee should be composed of decision-makers with financial and managerial authority. The following activity is to identify all the possible stakeholders of the PIMS (Dvir et al., 2003; Shafiee et al., 2014; Abraham, 2014). To have a clear overview, a classification of the stakeholders may be done; for example, stakeholders can be divided in core stakeholders and secondary stakeholders. In a multinational company, the stakeholders can be classified by divisions, departments and markets. Once the classes of the stakeholders are identified, the representatives for each class need to be defined. Due to the nature of PIMS, marketing representatives should be considered as stakeholders for divisions and markets. The first macro-activity ends with a kick-off meeting: the first formal workshop with the project team and the main stakeholders of the project. This step is crucial for establishing a common knowledge of PIMS and for gathering the general problems that the company is facing in managing product information. Examples of how other companies are preventing similar issues with the use of a PIMS include simplifying the learning process for the stakeholders. Additionally, the kick-off meeting is used to inform and educate stakeholders about their role in the project, explain the purpose and approach of the project, establish communication protocols and communicate the target timelines for the implementation. (Wright, 2009)

The deliverability of the stakeholders' identification phase is a well-defined project organisational scope and structure, where the organisational units, and members who represent them, are stated for the project realisation.

1.3.2 As-Is Analysis

The *As-Is* analysis aims to give an understanding of the current working processes (Shafiee et al., 2014) and is divided in four steps:

- Organisational business introduction
- Identification of the stakeholders' requirements
- Data localisation and ownership
- Product model identification

The four steps mentioned above consist of one or more direct interviews with all the stakeholders. The duration of the interviews may vary across stakeholders. The organisational business introduction aims to understand how marketing information was managed across the company and identify the main digital and physical touchpoints of product information.

In the second step, identification of the stakeholders' requirements, the project team has to identify the problems and the unmet needs of the stakeholders regarding product information management. Understanding the needs of the stakeholders is the first step to identify the functionalities of the PIM system that are relevant for the company (Dvir et al., 2003).

The data localisation and ownership step has the goal of analysing the currently IT architecture involved in the product information processes. Particularly, understanding where product data are stored, how they are currently managed, and who has ownership to them. An overview of the current IT architecture becomes essential because it helps to understand the data ownership and systems integration (Kruchten, 1998; Shafiee et al., 2014).

In product model identification, the main objective is the identification/collection of the existing product taxonomy and product models of the different divisions of the company (Abraham, 2014). Nevertheless, not all the divisions may have their own product models. In this case, it is important to build a draft of the product model with the collaboration of the stakeholders. By taxonomy, we mean classifications of the products in a structured and hierarchical way (Hung, 2005).

The deliverables expected for the as-is analysis: a collection of the stakeholders' needs, divided into common and conflicting requirements; a list of PIMS functionalities that the stakeholders expect; a product data-flow diagram representing the overview of the systems involved in the product information management; for each division, a product data model with the attributes representing the product.

1.3.3 To-Be Proposal

The *To-be* proposal aims to identify the impact of any future process changes before making them. It is divided into three steps:

- Identification of the stakeholders' common needs and mediation of conflicts of interest among stakeholders
- Development of a proposal for a future IT architecture with PIMS implementation
- Development of the frame of a single product model representing the full organisation

This phase is conducted by the project team, with some interaction with the stakeholders when some clarifications are needed. The first action is to identify the needs, from among those that arose from the dialogues with stakeholders, that are possible to satisfy. Some trade-off between different needs are necessary, taking into consideration that different stakeholders have different requirements. While in certain cases it is easy to solve these trade-offs, in others, there are a conflicts to resolve. The difference between this step and the identification of the stakeholders' requirements in the as-is analysis is: while in the as-is analysis, all the possible needs and opportunities of each stakeholders are listed; in the to-be proposal it must be understood which of those are important to satisfy from an organisational prospective.

The second step consists of developing a future IT architecture with the implementation of a PIMS (Saaksvuori and Immonen, 2008; Shafiee *et al.*, 2014). In the scoping phase, it is better to evaluate the introduction of a general PIM system, without considering special functionalities of a specific system. The proposal architecture shows how the product information data will be exchanged between systems after the implementation of the PIMS. In other words, the new process flow and integrations between PIMS and other systems are defined in this step.

The last step is the development of a single product model frame. Starting from the product models collected in the as-is analysis, it is relevant to find and/or develop the frame of a single product model that can represent all the products of the company. It is possible to choose one of the existing product models, if it fits all the divisions, or develop a new one. The result of this activity is a frame and not the final product model version, which will be developed after the vendor selection phase. The shared product data model has proved to be one of the most common challenges during the implementation of PIMSs in the case studies presented by Abraham (2014). In many cases, the companies underestimated the complexity and time needed to develop the model, resulting in significant delays to the implementation process. For this reason, a first draft of the model should be developed during the scoping phase. A PIMS requires structured and attribute-based information (Boyd, 2006; Abraham, 2014), therefore,

the only way to reliably understand and describe a product in a PIMS is to isolate and extract its attributes (Boyd, 2006).

The deliverables of the to-be proposal: a classification in order of importance of the stakeholders' requirements from an organisational perspective; a proposal of the future IT architecture after the PIMS implementation; a frame of the shared product data model.

1.3.4 Sharing Results and System Selection Preparation

The last macro-activity aims to communicate to the stakeholders the work that has been done in the previous steps (As-Is Analysis and To-Be Proposal) and prepares them for next phase, vendor selection. A new workshop with all the stakeholders is suggested for conducting this phase. This macro-activity is divided in three steps:

- Sharing the results of the previous macro-activity
- Preparing an ideal roadmap for PIMS implementation and a risk-management assessment
- Training for the vendor selection phase

The scoping phase is reaching its completion, and it is relevant that all the stakeholders know and agree with the outputs of the to-be proposal activity.

The PIMS implementation's roadmap should be developed and discussed with the stakeholders. The implementation of a PIMS often uses agile methods (Abraham, 2014); therefore, there is a need to understand which of the stakeholders are ready, in term of resources and knowledge, for the pilot test and first onboarding. A risk assessment, with the identification of any risks that could impede the project, should be conducted at this stage. Detecting emerging problems at the earliest possible moment, while there is still time to take corrective action, is fundamental to IS implementation projects (Sulgrove, 1996).

Finally, to introduce the stakeholders to the vendor selection phase, a training session on how to evaluate a PIMS (interface, implementation, IT performance, PIM functionalities, etc.) should be conducted. The stakeholders must be prepared to ask the appropriate questions during the meetings with the vendors and to understand if the functionalities of the different systems can fit their requirements.

The deliverability of this last macro-activity: a shared agreement between stakeholders and the PIMS project team about the requirements to satisfy concerning the implementation of the PIMS; an ideal roadmap for the implementation of the system; a risk assessment.

1.2 Implementation of product information management system: Identifying the challenges of the scoping phase

This session presents Article 2:

Battistello, L., Haug, A., Suzic, N., Hvam, L. (2020), 'Implementation of product information management systems: Identifying the challenges of the scoping phase', ***Computers in Industry*** **(Under Review)**

The presented research in Article 2 is targeted to build theory corresponding to the Sub-research Gap 2.1.

Implementation of product information management systems: Identifying the challenges of the scoping phase

Loris Battistello, Anders Haug, Nikola Suzic, and Lars Hvam

Abstract

In the digitalization era, companies are offering more and more products online to their customers, increasing the need to provide accurate product descriptions in the form of technical specifications, images, videos, and so on. Such product information is offered via a variety of channels, such as web pages, mobile phones, tablets, stores, and printed catalogs. Sometimes, different IT systems are used to provide information for different sale channels, potentially leading to inconsistency of information across these systems. To address this issue, an increasing number of companies engage in the use of product information management systems (PIMSs), which are systems focused on centrally managing customer-oriented product information. Although such systems are being increasingly used by companies, the academic literature on the topic is sparse. Moreover, the challenges companies face when implementing PIMS have hardly been addressed. To contribute to this area, the present paper explores the challenges that arise during the scoping phase of PIMS projects through a case study of a multinational company. Eighteen main challenges and their causes were identified.

Keywords: *Product Information, Product Information Management Systems, Scoping Phase, Industry 4.0.*

1. Introduction

In the digitalization era, companies are offering more and more products online to their customers, increasing the need to provide accurate product descriptions in the form of technical specifications, images, videos, and similar information [1]. Aside from the need to manage product information internally within companies, there is also an increasing information demand from customers. Because of the rapid growth of e-commerce and online stores, companies have to collect and manage clear, basic product information that customers can understand [1,2]. Customers expect product information that is comprehensive, complete, and accurate; therefore, the quality and completeness of product information are of primary importance [3]. Product information can be offered through a variety of channels, such as web pages, mobile phones, tablets, stores, and printed catalogs [4]. However, companies often use different IT systems to provide information for different sale channels. Thus, product information is often registered in a variety of IT systems managed by different departments, which can lead to information inconsistency across these systems [1].

In this context, ensuring information quality, and more specifically its consistency across such systems, can be challenging. In fact, a 2018 survey conducted by Ventana revealed that only 16 percent of organizations trust their product information [5]. The challenges that impede the adoption of a single version of product information are typically related to incompatible data integration, data quality, and data tools [5].

To address the barriers that impede the adoption of a single version of product information, an increasing number of companies are implementing product information management systems (PIMSs). PIMs are a category of dedicated applications focused on centrally managing product information in support of product processes and departments, with a focus on customer-oriented product information (i.e., the data required to market) [1,5,6]. The global PIMS market size is expected to grow from USD 7.0 billion in 2019 to USD 11.4 billion by 2024 at a compound annual growth rate of 10.2% during the forecast period [7]. Multinational companies such as Samsonite, Heineken, Pandora, Carrefour Market, Nikon Europe, etc. [1,8], have implemented a PIMS in the last decade, and major IT software companies like IBM, Informatica, SAP, Oracle, etc. [1,7,8], are offering a PIMS solution in their portfolio. Although the theoretical benefits of PIMS are numerous, building a business case to implement PIMS proves to be more difficult in practice, which is the primary reason why PIMS projects fail to start at all [1].

To contribute to the knowledge of PIMSs while avoiding too broad a focus, this paper focuses on understanding the challenges related to the successful completion of the initial phases of such projects. Specifically, this paper explores the challenges of PIMS implementation in relation to the scoping phase. This enables greater knowledge of PIMSs and their implementation to be contributed to the literature.

The remainder of this paper is structured as follows: Section 2 summarizes the relevant literature. Section 3 describes the case study research method. Section 4 describes the findings of the case study. Section 5 discusses these findings and, finally, Section 6 provides the final conclusions.

2. Literature review

This section first defines and positions PIMSs in relation to IT systems. As the literature on PIMSs is limited and sparse, we draw on the general IT literature to provide a foundation for understanding the challenges of implementing PIMSs.

PIMSs are IT systems for the management of customer-oriented product information by unifying and synchronizing disparate product information [1,9,10]. The main idea is that product information can be stored in PIMS, from which it can be subsequently distributed without the need to manually re-enter information in different systems. The benefits of implementing PIMS include shorter time to market, expanded product assortment, uniform customer experience across channels, better managing complexity, controlled content distribution, and legal compliance in addition to reduced costs, speed of information retrieval, data cleaning, and logistical errors as well as fewer returns and information enquiries [1,3,10].

PIMSs, although closely related to product data management systems (PDM) [11] and product lifecycle management systems (PLM) [12] systems, differ by mainly focusing on sales and marketing, as compared to the product development focus of PDM and PLM [1,6]. For this reason, PDM and PLM systems typically include data related to the manufacturing and development of a product, while PIMSs include sales and marketing information not included in the former [6,13].

For PIMS, as for all software applications in fact, the implementation process is crucial. Abraham [1] described PIMS implementation in four phases: (1) scoping, (2) elaboration, (3) realization, and (4) in-service (Figure 2).

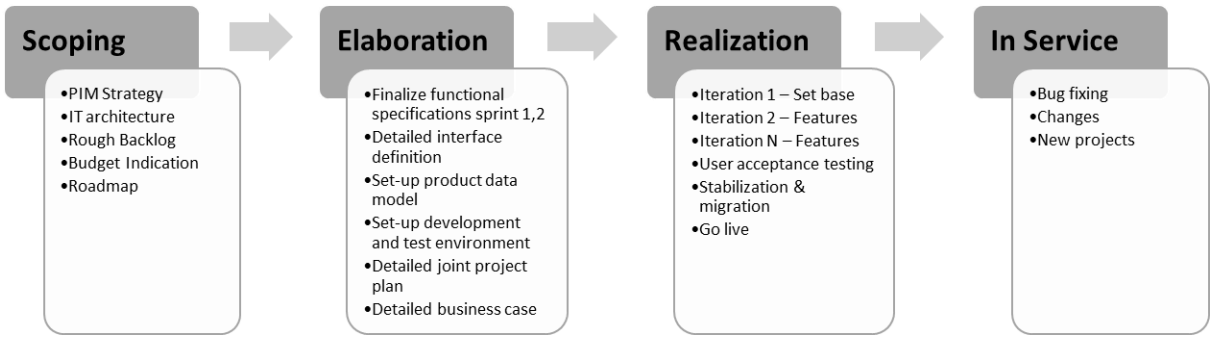

Figure 2. Phased implementation of a PIMS (*Source*: [1])

Although the implementation process presented in Figure 2 is relatively similar to the one for other IT systems, the implementation of PIMSs differs from most other IT systems, as some information cannot readily be implemented but, to a large extent, needs to be constructed. Also, some of the most demanding aspects of implementing a PIMS do not concern integration and customization of the system but rather populating the PIMS with information [1]. The reason is that PIMSs include generic product information models that typically are not available in companies [1]. This implies some special challenges in relation to scoping and other implementation phases. The comparison between the implementation of typical IT and PIMS projects is illustrated in Figure 3.

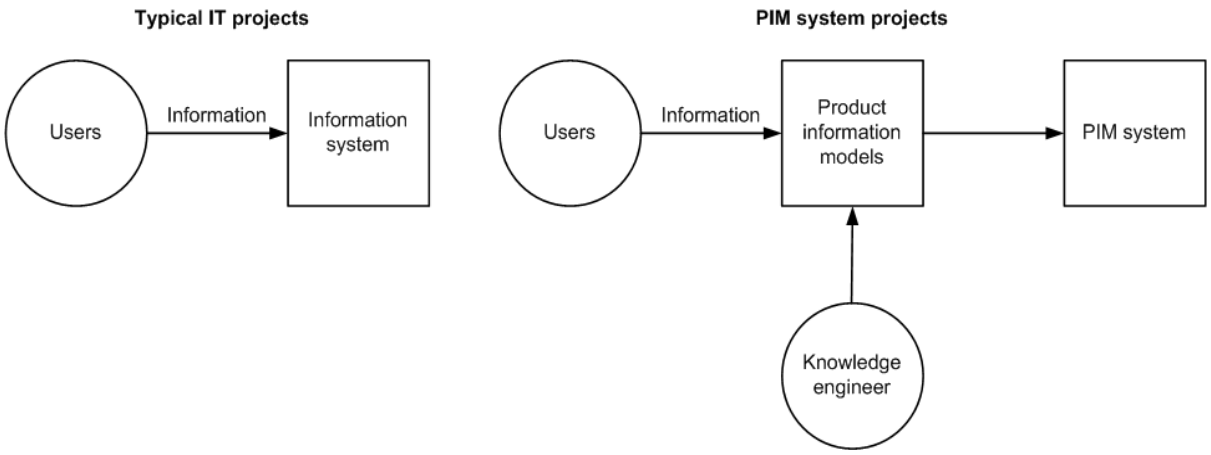

Figure 3. Information system implementation

The challenges associated with the creation of generic product information models have also been identified in product configurator projects [14,15]. There are, however, major differences between PIMS and product configurators in relation to their purpose and use. Specifically, while PIMS aim at documenting and sharing product information, product configurators are expert systems that identify product specifications based on user inputs [15,16].

Given the lack of literature on PIMSs, we turn the focus toward the IT literature to lay the foundations for understanding the challenges associated with the implementation of PIMSs. Generally, in IT projects, project failures can typically be placed into one of the following categories [17]:

1) Not meeting the defined schedule
2) Not achieving cost objectives
3) Not conforming to the defined project scope

Lyytien and Hirchheim [18] also offer a classification of the reasons why such failures occur:

4) Correspondence failure: design objectives or specifications of system not met
5) Process failure: unable to develop the system within the defined budget or schedule
6) Interaction failure: Lack of correspondence between user satisfaction, attitude, and use frequency and system usage level
7) Expectation failure: system is unable to meet stakeholder expectations, requirements, or values

Meanwhile, Barki et al. [19] classified the causes of IT project failure into the following:

8) Technology newness
9) Application size
10) Application complexity
11) Experience shortcomings
12) Organizational environment

With a focus on risk, Ewusi-Mensah [20] described some factors related to the abandonment of software projects:

13) Project goals and objectives
14) Project team, management, and control issues
15) Lack of technical expertise and technology problems
16) Inadequate executive support and commitment
17) Change requirements
18) Cost overruns and delays in schedule

In the companies analyzed by Abraham [1], the most common challenge during the implementation of PIMSs proved to be the shared product data model. In many cases, the companies underestimated the complexity and time needed to develop the model. The other

challenges identified were underestimating the time needed to collect all product data, connecting the enterprise resource planning system (ERP) to the PIMS, underestimating the storage space needed, and the belief that the old solution was better, easier, and more complete.

Challenges such as those described above seem likely to be found during the PIMS scoping phase as well. However, as previously mentioned, we expect PIMS projects to involve some particular challenges.

3. Research Method

Given that the literature does not provide much insight into the implementation of PIMSs, an explorative approach was used. Such an approach is generally considered appropriate when constructs for a phenomenon have yet to be clearly identified and delineated [21,22]. More specifically, a longitudinal field study was selected as the research method. In this type of study, the researcher is able to gain insight into the studied phenomena and to discover the most crucial aspects affecting the object of inquiry. Also, the study is carried out for long enough to gain an understanding of the causal links among events and constructs [23], for instance, in relation to the implementation of new technology [24]. In this case, the process of scoping a PIMS was observed real-time and in-depth over a 3-month period.

For the setting of this study, the researchers sought a company that had made the choice to invest in a PIMS project where the process of interest would be transparently observable during the entire implementation period [25]. The selected company was a mineral wool production company located in Europe. The company had not yet started the scoping phase and had only made a preliminary analysis, determining the PIMS project as a task of primary importance. It has a market-leading position in the building materials industry and operates over 20 global production facilities with over 10,000 employees. It is composed of 18 individual business units (BUs) operating in different markets, with each BU managing its own assortment.

Due to the nature of the research approach, the main method for collecting data was participant observation [23,25]. The researchers participated in all the meetings of the project, taking notes on relevant aspects, such as the challenges, limitations, needs, results, etc. In this way, the researchers had the opportunity to learn the language of the group under study and acquire the necessary know-how, giving a foundation for the interpretation and analysis of the collected data [26]. Participant observation was complemented with informal interviews and studies of documents. While interviews helped to obtain a deeper understanding of the process being studied, documents such as business cases, meeting protocols, and official reports were used

to keep track of events taking place before the start of the study and events that the researchers were not able to observe. The time between the meetings was used by the researchers to understand and note the challenges of the scoping phase and to write down whatever impressions occurred [27,28]. The participant observation was carried out over a period of three months, during which 33 meetings were conducted: 2 workshops with all the stakeholders, 10 weekly catch-up meetings with the project team, 2 steering group meetings with the steering committee, and 19 meetings with individual stakeholders.

The collected notes from the observations and transcriptions of interviews were analyzed. The data analysis was conducted in three different stages: data reduction, incident identification, and incident coding [23]. Multiple investigators were involved in these steps to enhance the creative potential of the study and to enhance confidence in the findings [28].

4. Case Study

The process used for scoping a PIMS in the case study was based on the general theory on implementing IT systems [29,30,31] and scoping product configuration systems [32,33] as well as industry experience. The process included the following four macro activities:

1) Stakeholder identification
2) As-is analysis
3) To-be proposal
4) Sharing results and system selection

4.1 Stakeholder Identification

A PIMS has many different users and can be used by the entire value chain. Thus, in the scoping phase, it was important to include representatives of all the stakeholders. The aims of this macro activity were to (1) define the group of people who would provide guidance, direction, and control of the project; (2) define the project organizational structure and main responsibilities within the project; (3) create an overview of who is involved in the project and the impacts across the company; and (4) create awareness-based knowledge of PIMSs.

The PIMS project team was the core group that managed the full scoping phase. It was composed of the project manager, the PIMS specialist, and the project business owner. An external consultant was hired for the role of PIMS specialist. He had a knowledge base of PIMS and experience in the implementation of IT systems. The steering committee was composed of

five people: the Group Marketing Senior Vice president, a business units' representative, the Chief Information Officer, the Chief Financial Officer, and the Product Management Director. Four different classes of stakeholders were identified (Figure 3).

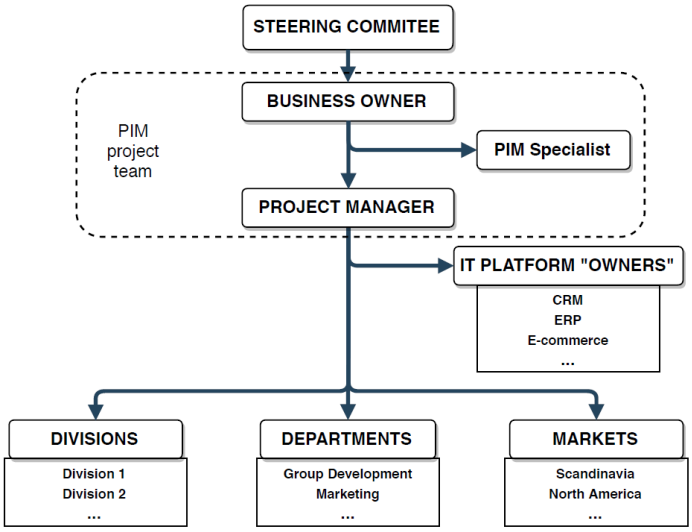

Figure 3. Project organizational structure

Once the classes of stakeholders were identified, questions were directed to the project team, including the following: What are the different types of information that a PIMS is supposed to store? Who are the (internal) stakeholders of the digital platform? How is product information related to the stakeholders? To face these challenges, a tool was developed to relate the types of stakeholders to the types of information (Table 1). We identified three groups of stakeholders: 1) those who use the information (output, O), 2) those who produce the information (input, I), and 3) those who provide support for managing the information (support, S).

Table 1. Types of stakeholders/types of information

		TYPE of STAKEHOLDER			
		Product Manager	Sales Manager	ERP Specialist	…
TYPE of INFORMATION	Master Data	O		I	
	Price	S	O	I	
	Marketing Data	I/O	O		
	…				

Eighteen different stakeholders were identified, namely the product managers of the six divisions, the product managers of the three markets selected for the pilot test, the specialists of the software to be integrated to the PIMS (such as BIM, e-commerce, ERP, and DAM), and a representative from each department (i.e., finance, group development, operations, digital, and marketing). Due to the nature of the information, Table 1 confirmed the necessity of having marketing representatives from the different divisions and markets.

At following, a 5-hour workshop with the project team and main stakeholders, called the kick-off meeting, was conducted. The PIMS project team explained the organizational structure, roles of each member, and functionalities and limitations of PIMSs. It was crucial to establish a common understanding of the benefits and limits of PIMSs and to gather the general problems that the company was facing in managing product information. To simplify the learning process, the project team presented some examples of how other companies were addressing similar issues through the use of a PIMS. The kick-off meeting helped the project team to engage in individual dialogs with the stakeholders in the next phase. Managing the different backgrounds and levels of understanding, along with ensuring that each stakeholder could contribute and be integrated in the overall scheme, was very challenging. Another challenge during this phase was the planning of the kick-off meeting: The different stakeholders were based in different areas of the world, although most were able to physically participate in the workshop.

4.2 As-Is Analysis

The as-is analysis was aimed at providing a better understanding of the current working processes. It was divided into four steps:

1) Organizational business introduction
2) Identification of stakeholders' requirements
3) Data localization and ownership
4) Product model identification

The four steps listed consisted in one or more direct interviews with the stakeholders. The duration of the interviews varied among the stakeholders. The first aim was to understand how marketing information was managed across the company. The company is organized into individual BUs, which have independent ownership of both global and localized product assortments. The product assortments have individual information models and cater to local requirements for product information. Each BU has siloed marketing operations and largely relies on manual processes or steps.

During the identification of the stakeholders' requirements, the PIMS project team first collected the issues and unmet needs of the stakeholders regarding product information management and, second, identified the functionalities of the PIMS relevant to them. The main problems that the stakeholders were facing in managing product information were related to customer experience, marketing process, digital transformation, and market development (Table 2).

Table 2. Issues in managing product information and consequences

Area	Problems	Consequence
Customer experience	The customer experience was challenged due to inconsistency in product information and access to relevant product documentation. Product information was not updated and did not include a full range of relevant data.	Could potentially endanger the company position as a premium brand
Marketing process	The marketing enrichment of product information was not efficiently supported and relied on manual services. Marketing was prone to redundant processes using local Excels and repositories to comply with growing needs for enrichment and documentation.	Could reduce capabilities to scale and improve synergies between the individual business units
Digital transformation	The digital roadmap was not sufficiently supported by a service architecture to provide enriched and structured product information. The individual touchpoints were supported by individual repositories with limited integrations and governance on data distribution.	Could slow the digital transformation and result in broken services
Market development	There was no shared customer information model to guide product positioning or ambitions to deliver solution selling. Limited capabilities for supporting transition in the dealer market and the growing scope of relevant market services.	Could reduce agility and readiness to adapt to new changes in customer behaviour

The collected requirements for the PIMS varied across stakeholders. However, the common needs were identified: having access to updated product information; having a shared product information HUB; sharing information across the company in order to maximize content use in other areas, such as certificates and test results; and defining a clear ownership and governance of product information across divisions and markets. During the identification of

the stakeholders' requirements, the MoSCoW (must have, should have, could have, won't have this time) prioritization technique was used. Based on the collected data, the project team created a list of the stakeholders' needs, which is summarized in Table 3.

Table 3. Common needs of the stakeholders

Area	Need description
Enrichment of products	General capabilities to provide each BU and local market with a predefined product information structure: • centralized access, overview, and organization of all areas of product information customized to the individual product categories • empowering marketing to enrich product information to comply with local requirements, digital channel consumption, and customer focus • full support of localization and translation needs
Sourcing and integrations	PIMS must be based on a flexible platform that enables full connectivity of key product information areas through an upstream enrichment process: • sourcing of product data from ERP to create and populate products in individual business units and markets • access and availability to all relevant digital assets in both PIMS and other repositories • open service architecture with capabilities to provide a shared information model across systems
Marketing process support	Integrated tools for better process support of marketing enrichment, automation, and tooling of marketing product ownership: • process support of production of marketing materials and campaigns • overview on general completeness and quality of product information • distribution of tasks and personalized workspaces • support of marketing PLM responsibilities
Distribution & governance	Services to provide the company channels with relevant and updated product information: • integrated tools to produce and distribute localized marketing catalogs • standardized methods to distribute structured information to standard service-interfaces • integrated governance services to insure compliancy with role-based rights, internal controls, and reporting

The challenges in identifying the stakeholders' requirements were related to the timing and organizational complexity of the company. A limited amount of time was available for this step, forcing the project team to quickly establish the level of detail achievable in a short timeframe. However, the company wanted to select a system that could be uniformly accepted and utilized across the group. Thus, the project team built a user-case contemplating the

company as a whole; otherwise, a sharing agreement would not be reached. Ultimately, the complexity of the organization was reflected in the as-is analysis: All the BUs and local markets had different requirements, steering the focus in different directions.

The data localization and ownership step had the goal of analyzing the current IT architecture involved in the product information processes. Particularly, understanding where product data are stored, how they are currently managed, and who owns them. To have a comprehensive overview of the current situation, a flow diagram was derived from the information gathered in the interviews (Figure 4). The product data enrichment was, to a large extent, based on a manual ad-hoc process with multiple market localizations and limited support of digital touchpoints. Consequently, there was inconsistency in product information and documentation, and marketing was prone to redundant processes, using local Excel sheets to comply with growing needs for enrichment and documentation. Also, the individual touchpoints were supported by individual repositories with limited integrations and governance on data distribution.

The main challenge here was the fact that the same information could be either stored in the same IT system but with different tags in different countries or even stored in two different systems. Once again, the lack of consistency and a harmonized approach was evident.

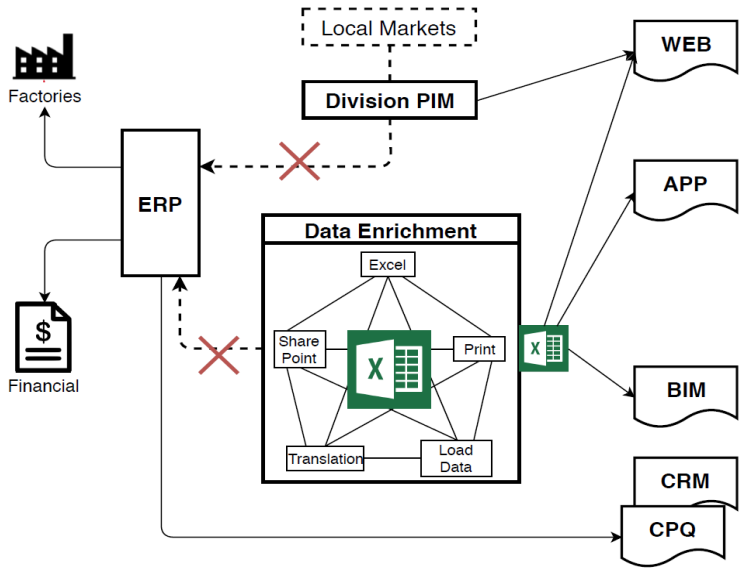

Figure 4. As-is product information data flow

In the product model identification, the goal was the identification/creation of the existing product models of the different divisions/segments. During the interviews, a collection of 502 different product attributes was gathered. This assortment was the starting point to estimate the

size of the PIMS to be implemented. The main challenge was to detect and solve repetition. The attributes were collected in English and, for this reason, stakeholders tended to add new ones without realizing that the attributes already existed under a different tag. These problems were even more exacerbated during the mature phases of the project, mainly due to the lack of an underlying master data management (MDM) system and official dictionary defining the attributes. Also, employees struggled to understand which attributes they had to list as part of the data model. Moreover, some BUs delayed the process because they did not have time to share data, as they were busy with their ordinary workload. In this regard, PIMSs are a new type of software that the stakeholders did not have experience in, and providing the requirements and data for an application unfamiliar to them was complex and time consuming.

4.3 To-Be Proposal

The to-be phase was conducted by the project team with some interaction with stakeholders when clarification was needed. It was divided into the following three steps:

1) Mediation of conflicts of interest among stakeholders
2) Development of a proposal for a future IT architecture for PIMS implementation
3) Development of the frame of a single product model

While the stakeholders' common needs were previously collected (Table 3), the project team had to mediate the conflicts of interest in this step. Some trade-offs were necessary taking into consideration the needs prioritized by different stakeholders. Smaller divisions were more focused on automatizing printing processes, such as the printing of technical datasheets or brochures (processes that are normally managed internally), while larger divisions were more focused on prioritizing the means of distributing relevant attributes to a client PIMS solution. Local BUs aimed to control the delivery of product information to individual markets, while global divisions were oriented toward a standardized and uniform solution. Moreover, the BUs were in a different position to start the implementation. For example, one BU already had a local PIMS solution. They saw the implementation of a new PIMS as a problem and would have preferred to improve their existing solution. As mentioned, the main challenge here was trying to find a common solution between numerous stakeholders that essentially had conflicting requirements.

The second step consisted in the development of a future IT architecture for the implementation of a PIMS. Considering stakeholders' needs, the project team suggested a to-be IT architecture

where the PIMS would function as a centralized product marketing HUB, distributing product catalogs to the individual digital touchpoints through standard publishing services (Figure 5).

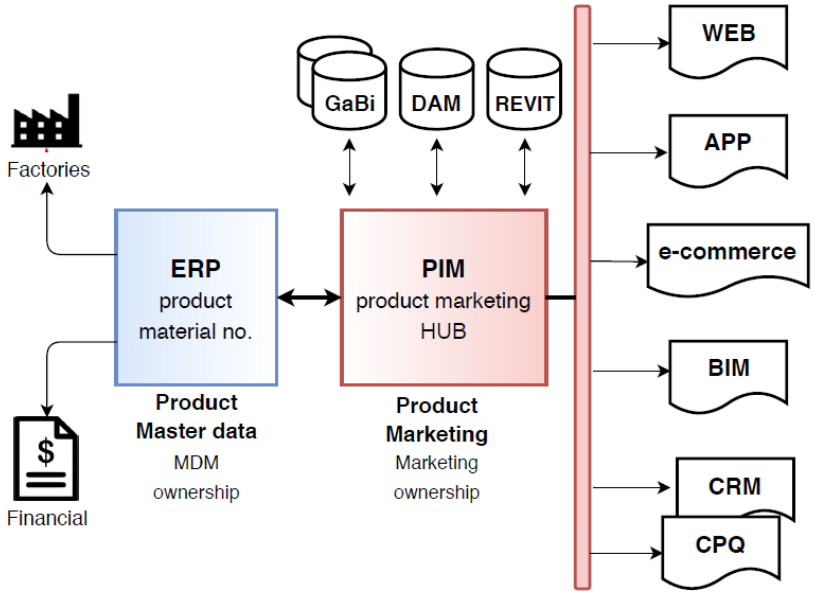

Figure 5. To-be product information data flow proposal

The proposal shows how the product information data can be exchanged between systems and applications after the implementation of the PIMS: Specifically, PIMS sources master data from the ERP system, such as material number, product characteristics (dimension, properties, etc.), performance values, sales data, logistic data, and digital assets from other systems, such as DAM and Revit. It is built on an upstream-sourced data model, in which the ERP owns the product entity and PIMS owns the further enrichment in a federated model. Part of the data enrichment will be done through manual processes, although systematically. To ensure that only good, properly structured data can be entered into the system, best practices for governance will be adopted. PIMS will deliver process support and tools to produce product marketing information on an aggregated level. It will be responsible for a collective and role-based overview and the publishing of consistent product information across the digital touchpoints in each market. The main challenge in this step is related to governance. As mentioned, some data will belong to the ERP system and other data to the PIMS, but everything will be connected to avoid redundancy. The digital department seemed to lack a governance process in the ERP system and did not fully trust their data. However, this department was also averse to being depended on for data that they did not fully control.

The next step was to frame a centralized product model with the flexibility to embrace the full range of BUs and divisions within the company. The product model was designed to organize the multiple levels needed to logically enrich and manage product variations for a related range of products. It was composed of six levels: business unit/division, product line, product family, product, product variation, and material number (Figure 6). Each level was composed of several attributes that define its characteristics. The attributes were divided into different categories, for example, dimensions, thermal properties, product advantages, etc. After analyzing and screening the collected data, the number of attributes were reduced from 503 to 350. The project team spent a lot of time on the screening process because of the poor quality of the attribute data. Several clarifications with the stakeholders were necessary. The main challenges relative to the data were language issues, ambiguous data, and incorrect data. Duplicate, mistranslated, and incomplete data were often found in the material provided by the stakeholders.

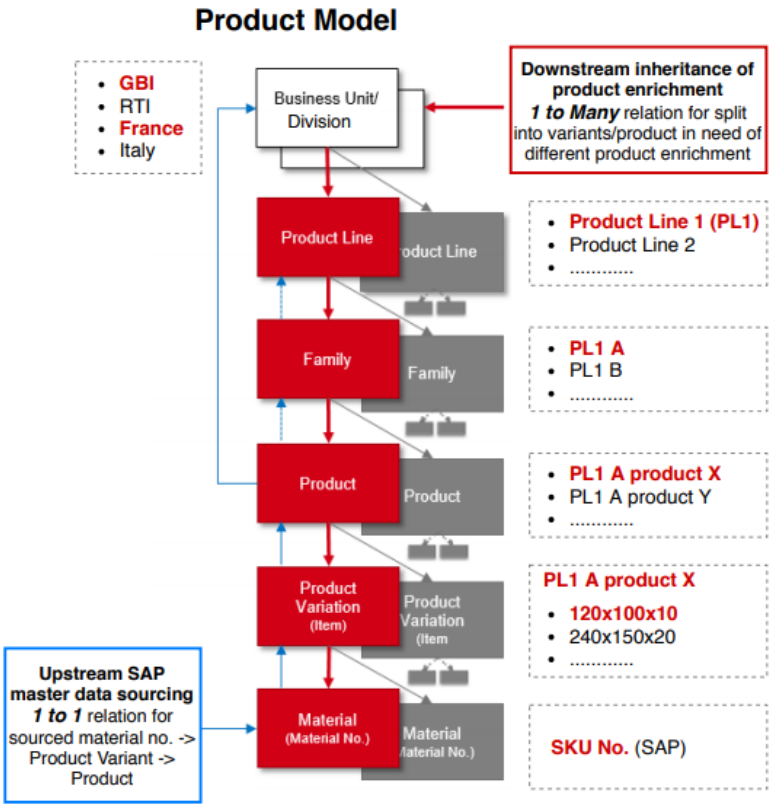

Figure 6. Centralized product information model

4.4 Sharing Results and System Selection

The last macro activity aimed to communicate to the stakeholders the work done in the previous activities (as-is analysis and to-be proposal) and introduce them to next phase: system selection.

A new workshop with all the stakeholders was conducted to share the results. As the scoping phase was reaching the end, it was considered relevant that all stakeholders agree upon the outputs of the to-be proposal.

During the workshop, a final list of functional requirements from a business and IT architectural perspective was presented by the project team. A long discussion between the Marketing and IT Departments arose, and a mutual agreement was difficult to establish. The Marketing Department clearly favored user friendliness and experience more than advanced IT features, whereas the IT Department preferred more advanced technical solutions, to the detriment of user friendliness.

To complete the scoping phase, an ideal roadmap of the PIMS implementation was made, and the system selection phase was introduced to the stakeholders. Finally, a 3-hour training session on how to evaluate a PIMS was conducted by the project team (interface, implementation, IT performance, PIMS functionalities, etc.).

5. Discussion

As the case showed, the implementation of PIMS projects can be complicated from the start, with several challenges being identified during the scoping phase. Table 4 summarizes the challenges identified during the four macro activities.

Table 4. Challenges and causes identified in the scoping phase.

Phase	**Identified challenge**	**Cause of challenge**
1. Stakeholder identification	Lack of clarity of the information the PIMS should store	Unclear organization process/structure
	Lack of clarity of who the internal stakeholders are	
	Lack of clarity of how product information relates to stakeholders	
	Difficulties in achieving a common understanding of the project	Different backgrounds and levels of understanding of the stakeholders
	Difficulties in defining stakeholders' roles	
	Difficulties in the organization/planning of the physical kick-off meeting	Stakeholders based in different parts of the world
2. As-is analysis	Too little time to conduct the project	Overly ambitious planning
	Same information stored with different identifiers in same or different systems	Lack of consistency and a harmonized approach
	Attributes exist multiple times in different languages	Language issues

	Employees struggled to understand which attributes they had to list as part of the data model	Problems understanding the PIMS
	BUs delayed the process because they did not have time to share data	Failure to reserve BU resources
	Not knowing which data to supply	Lack of system understanding
3. To-be proposal	Global markets and local markets had different or even conflicting requirements	Differences between local and global markets
	Different BUs were in a different position to start the digitalization journey	Differences between BUs
	Deciding if data should be native of PIMS or other systems	Lack of data governance and data structure
	Same product attributes with different names in existing systems	Lack of data structure and language issues
	Information quality problems	Lack of focus on information quality
4. Sharing results	Marketing department favored user friendliness, while IT department favored advanced features	Different needs of the departments

The causes of the challenges seem to be related to each other and to affect the whole scoping phase rather than a single activity. Implementing a software in a company is always challenging, and the complexity of implementing a completely new type of software in an extended enterprise is even higher. However, when comparing the challenges described in Table 4 with the general challenges of IT projects [18,19,20], it is evident that there are also several challenges particular to PIMSs. Specifically, there are several challenges related to populating these systems with information, i.e., information can be hard to identify, understand, and agree upon, and it must be decided whether to include certain information or not. Such challenges have higher resemblance with the challenges found in product configurator projects [14,15] compared to, for example, PDM, PLM, and ERP system projects. However, as mentioned before, PIMS and product configurators are two different systems in regard to their purpose, architecture, and use, so their challenges also differ in other areas.

As possible explanations of the challenges identified, an analysis of the case data identified four main factors influencing the scoping phase, which are shown in Figure 7 and subsequently explained.

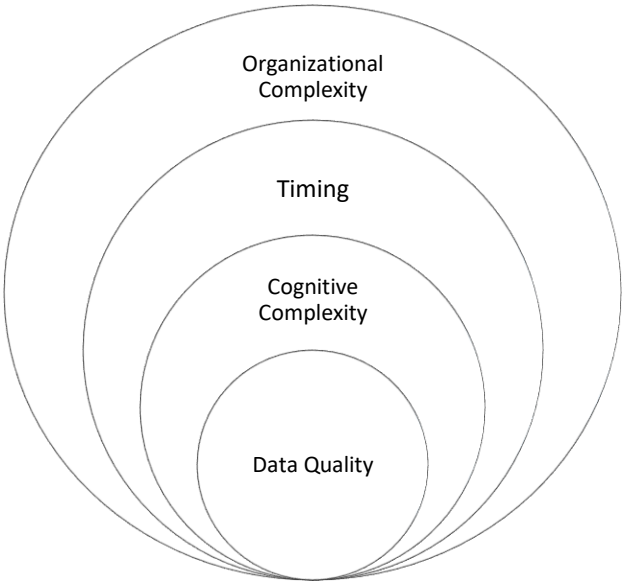

Figure 7. Factors influencing the scoping phase of a PIMS

First, the organizational complexity was reflected in the implementation process. The identified stakeholders were from different BUs characterized by distinct sizes, markets, portfolios, and countries. Consequently, during the scoping phase, we observed language issues in addition to conflicting needs between departments, local and global BUs, and markets. Through the implementation of a PIMS, the company wanted to achieve a shared way of managing product information. We observed that the current processes for managing information in the BUs were not clear or well documented. Therefore, it was difficult for the project team to define the information needed and to involve the stakeholders. Socio-cultural factors also affected the development of the implementation process.

Second, in regard to timing, the scoping phase is the initial step in the project implementation process, and usually a short amount of time is dedicated to it. Considering the goal of the project, size of the company, and unclear organizational processes and structure, we observed that three months was an overly ambitious timeframe. Additionally, the stakeholders involved in the project were doing their daily work and often did not have time to search for or share data, delaying the process.

Third, concerning cognitive complexity, it should be noted that PIMSs are a new category of applications focused on centrally managing product information. The implementation of this technology requires a large change in the management processes of an organization. Considering that information on PIMSs is still limited and that most stakeholders had not used

such a system before, providing the right information and requirements was very challenging for them.

Fourth, in relation to data quality, we observed that data governance, documentation, and structure were lacking. The product information process was based on manual ad-hoc processes or steps with multiple market localizations. Also, the data governance was not clear or documented, making the identification of the required data more challenging. During the development of the shared product model, several data quality issues were observed as a result of language issues, ambiguous data, and the lack of metadata and data structure. Also, the lack of data consistency and governance in the ERP system, the main source of information for PIMs, made the as-is analysis complex and time consuming. Therefore, we recommend implementing an MDM system before implementing a PIMS.

6. Concluding remarks

The number of companies implementing PIMSs to centrally manage their product information is continuously increasing [1,7]. However, the present literature review revealed that information on PIMS implementation is limited and sparse. Although PIMSs have some resemblance to other systems [1,6,10,13], they also have some special features [1,6,10,13] that produce unique challenges, including the need for a centralized generic product information model, which typically is not readily available in companies [1]. Thus, this paper provided a detailed illustration of the scoping phase of a PIMS through a longitudinal case study with the aim of contributing knowledge to this field on the challenges of the scoping phase and their causes. Such experiences are valuable since PIMS implementation processes are not reported in the literature.

In particular, eighteen challenges that PIMS projects may encounter during the scoping phase were identified, and a corresponding set of causes was identified for each challenge. These causes were reduced or clustered into four major factors influencing the PIMS project scoping phase: data quality, cognitive complexity, timing, and organizational complexity. Future research may use these findings as a point of departure for a more in-depth investigation of PIMS implementation or the development of PIMS implementation methods and guidelines. In this respect, the present study constitutes a first step in the development of guidelines to implement PIMSs, considering the development of implementation guidelines as a “research endeavour specifically designed to transfer accumulated [specific field] knowledge into practice” [34].

The study presents practitioners with an overview of possible challenges that may appear in the scoping phrase, or the first phase of PIMS implementation. These findings can be used to guide PIMS project scoping and to help practitioners prepare for any challenges in advance. Specifically, by having an overview of the main challenges and their causes, companies can know which pitfalls to avoid and which issues to be aware of during the scoping phase, which is especially important considering that most PIMS projects fail to start [1].

This research represents the first step in exploring PIMS implementation. Thus, to gain a deeper understanding, more cases need to be examined in order to compare the challenges facing different companies and the solutions adopted.

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6. THE CHALLENGES OF IMPLEMENTING PRODUCT INFORMATION MANAGEMENTS SYSTEMS: A CASE STUDY OF A CONSTRUCTION MATERIALS MANUFACTURER

This session presents Article 3:

Battistello, L., Haug, A., Hvam, L. (2020), 'Product information management system implementation: Identifying the challenges of the scoping phase', *Computers in Industry* (Under Review)

The presented research in Article 3 is targeted to build theory corresponding to the Sub-research Gap 2.2.

The Challenges of Implementing Product Information Managements Systems: A Case Study of a Construction Materials Manufacturer

Loris Battistello, Anders Haug and Lars Hvam

Abstract

Purpose: Companies offer an increasing number of products to their customers through online channels, which implies the need for various types of product description, including text, pictures and videos. To manage all the information in a single system, many companies have adopted product information management systems (PIMSs). However, while PIMSs are becoming increasingly common in companies, few studies have investigated the implementation of such systems. This paper addresses the research gap regarding PIMS implementation.

Design/methodology/approach: We conducted a longitudinal case study of a PIMS project at an international construction-materials manufacturer.

Findings: The case study provides three main contributions. First, the study reveals a number of issues related to the different phases of PIMS projects. Second, the study identifies certain special characteristics of PIMS projects, such as challenges regarding integration with other systems and the creation of the product information model. Finally, the paper defines a set of success factors for PIMS projects.

Originality: By identifying the challenges of and the success factors for PIMS projects, this paper fills a major research gap in PIMS literature. This research represents the first step in exploring PIMS implementation.

Practical implications: The study provides practitioners with an overview of the challenges that they may encounter during a PIMS project and identifies a set of factors for successful PIMS implementation. These findings can help practitioners in dealing with PIMS projects.

Keywords: Product information management system, Product information management, Product lifecycle management, Product data management, IS implementation.

1. Introduction

To tackle increasing global competition, companies offer an increasing number of products to their customers through physical and online channels, which implies the need for various types of product descriptions, including text, pictures and videos (Abraham, 2014). The many physical and online sales channels imply several challenges regarding information management (Abraham, 2014; Toews, 2012), especially when it comes to ensuring adequate information quality (Ventana Research, 2017; Hagberg *et al*., 2016). Often, companies use different information technology (IT) systems, managed by different departments, for handling the information related to the various sales channels. However, such diversity of systems and controllers greatly increases the risk of inconsistency across information systems (Abraham, 2014). In fact, studies show that organisations often do not trust their product information and face challenges related to data integration, data tools and data quality (Ventana Research, 2018).

To deal with the challenges of managing product information meant for a variety of sales channels, companies are increasingly turning to product information management systems (PIMSs). A PIMS is an IT system for the central management of product information across different departments, such as sales, marketing and product development – in short, customer-oriented product information (Abraham, 2014; Ventana Research, 2018; Dury *et al*., 2012). During the last decade, large international companies, such as Heineken, Pandora, Samsonite, Nikon Europe and Carrefour Market, started using PIMs more frequently (Abraham, 2014; Eppinger, 2017). However, more companies are following suit, and the PIMS market is expected to grow to USD 11.4 billion in 2024, with a 10.2% annual growth rate from 2019 to 2024 (PIMM, 2020). The software vendors offering PIMSs include IBM, Informatica, Oracle and SAP (Abraham, 2014; PIMM, 2020; Eppinger, 2017).

As the discussion above indicates, using PIMSs offers many theoretical benefits, but implementing PIMSs in practice seems to be more difficult (Abraham, 2014). However, scholars have not investigated the causes of these difficulties. To address this research gap, we conducted a longitudinal exploratory study of a PIMS project at an international construction-materials manufacturer. The case study provides three main contributions. First, the study reveals a number of challenges associated with PIMS projects. Second, the study identifies certain special characteristics of PIMS projects. Third, the paper defines a set of success factors for PIMS projects.

The remainder of the paper is structured as follows: First, Section 2 discusses the relevant literature. Next, Section 3 describes the research method, and Section 4 presents the case study findings. In Section 5, we discuss the findings, providing the conclusion in Section 6.

2. Literature review

The literature review begins by surveying the PIMS literature in terms of definitions and implementation measures. Given the scarceness of the PIMS literature, we then focus on the general IT and Product Data Management (PDM)/Product Lifecycle management (PLM) systems literature.

2.1 PIMSs

Despite the many theoretical benefits of PIMSs and the rapidly increasing adoption of such systems by companies, the PIMS literature is extremely scarce and consists mainly of books and white papers while lacking academic studies. However, some scholars have discussed the need for systems whose focus corresponds to that of PIMSs. Specifically, Kärkkäinen *et al*. (2003) proposed an approach and a system for centralising product information, and Boyd (2006) identified the challenges of managing product information, pointing to the need for PIMS functionality. Similarly, Brunner *et al*. (2007) developed a semantic PIMS to improve the flexibility and scalability of existing systems, while Power (2010) described the benefits of creating a single product information hub across the enterprise. In spite of the literature described above, more extensive and detailed descriptions of PIMSs were not available until Abraham's (2014) book.

Table 1 shows the PIMS definitions that we identified in the existing literature.

Table 1. PIMS definitions

Definition	Reference
"A centralized software platform used to store, manage, and deliver product data such as descriptions, SKU numbers, pricing, images, and more to a variety of different channels."	Plytix, 2020, p. 4
"A business application that centralizes the management of product data and digital assets and streamlines collaborative data enrichment."	Informatica, 2019, p. 5
"A category of dedicated applications that support product processes as well as the departments that contribute to and use product information for their business needs."	Ventana Research, 2018, p. 3

"Software that enables organizations to manage product information efficiently in a unified way, supporting business processes and the interconnected customer-to-supply-chain network."	Ventana Research, 2018, p. 2
"A set of business practices and a category of business applications focused on managing product information for use across an organization from the supply chain to commerce to customers."	Grizaut, 2018, p. 4
"An enterprise application enabling an organization to identify or derive trusted product data across heterogeneous data environments, enabling transactional, bidirectional synchronization across upstream production sources, downstream analytical target systems, and external trading communities and data sync networks."	Sheldon and Goetz, 2014, p. 5
"Processes and technologies focused on centrally managing information about products, with a focus on the data required to market and sell the products through one or more distribution channels."	Abraham, 2014, p. 3

As indicated by the definitions in Table 1, PIMSs are IT systems that manage customer-oriented product information by centralising and synchronising previously disparate sets of product information (Abraham, 2014; Boyd, 2006; Informatica, 2019). Using PIMS, product information can be distributed to other systems, thus removing the need to re-enter product information in different systems. Research has identified such centralisation of information with a range of benefits, including extended product assortment, reduced time to market, more uniform information for customers across sales channels, improved complexity management, better content distribution control, reduced cost, faster information retrieval, improved data quality, fewer logistical errors, fewer returns and fewer information enquiries (Abraham, 2014; Ventana Research, 2017; Informatica, 2019).

With regard to PIMS implementation, Abraham (2014) described it as involving the four phases shown in Figure 1.

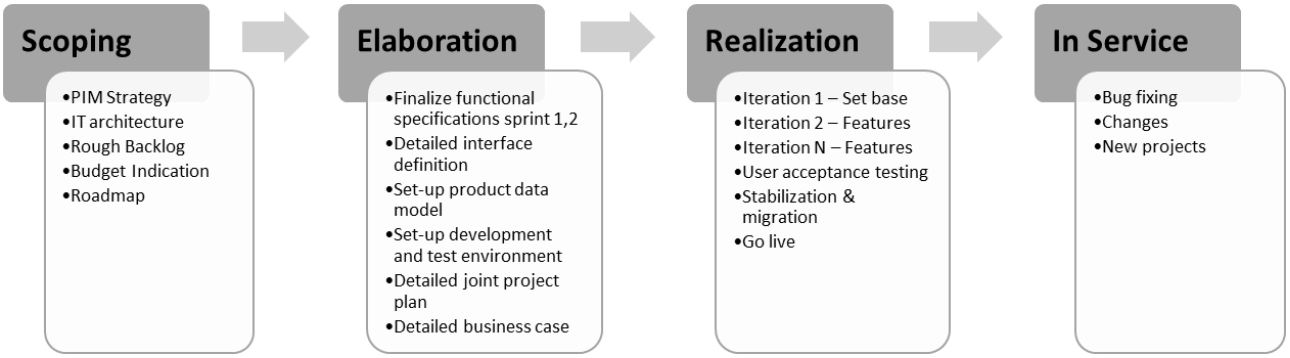

Figure 1. PIMS implementation (source: Abraham, 2014).

Abraham's (2014) analysis of PIMS projects showed that the most common challenge in PIMS implementation involved the shared product information model. Specifically, in several cases, companies underestimated the complexity of constructing the product information model as well as the time needed to develop it. Other challenges included underestimating the extent of product information, developing interfaces to the enterprise resource planning (ERP) system, underestimating storage space and lack of confidence in the new PIMS solution.

2.2 IT literature

Given the limited number of studies on PIMS implementation, we now focus on other parts of the IT literature to establish a foundation for understanding the challenges associated with PIMS implementation.

First, there is "project failure," which is typically defined in relation to one or more of the following three elements (Whitney and Daniels, 2013): (1) failing to meet time plans, (2) failing to meet cost objectives and (3) failing to provide the elements included in the system scope. Such failures can occur for a number of reasons, and Lyytien and Hirchheim (1987) provide a more extensive categorisation of IT project failures: (1) not meeting design objectives or systems specifications (correspondence failure); (2) not developing a system within the budget or time schedule (process failure); (3) failing to achieve adequate user satisfaction and use frequency (interaction failure); and (4) failing to meet stakeholder expectations or requirements (expectation failure).

To understand the causes of such types of failure, we will now focus on PDM systems (Do, 2018) and PLM systems (David and Rowe, 2016), which are similar to PIMSs. A major difference is that PIMSs mainly focus on sales and marketing, whereas PDM/PLM systems focus on the data related to product development and manufacturing (Abraham, 2014; Dury *et al*., 2012). Therefore, the sales and marketing information included in PIMSs is not included in PDM/PLM systems (Dury *et al*., 2012; Hakkarainen, 2016). Nevertheless, PIMSs share many characteristics with PDM/PLM systems, meaning that some overlap between the two types of system can be expected. The literature review by Singh *et al*. (2020) has identified the following 17 PLM implementation success factors organised according to three themes, as shown in Table 2.

Table 2. Success factors in PLM implementation

Business processes and practices	S1 Business-process re-engineering S2 Information sharing or communication S3 Risk management S4 Clear business goals and objectives S5 PLM system evaluation and selection S6 Selection of PLM systems solution provider S7 Implementation budget S8 Implementation methodology S9 PLM project monitoring
People	S10 Leadership and commitment S11 Training and education S12 Knowledge sharing from previous experiences S13 Organisational culture
Technology	S14 Project team spirit and commitment S15 IT infrastructure S16 Interoperability among all systems S17 Data security and user authentication

3. Research method

As the literature review has shown, information on PIMS implementation is limited. Therefore, we chose to employ an exploratory approach (Eisenhardt and Graebner, 2007; Yin, 2009) in the form of a longitudinal case study. This type of study allows the researcher to obtain deep insights into the phenomena studied and to understand the causal links between events and constructs (Åhlström and Karlsson, 2009). Specifically, we studied our case for a period of 32 months.

Our case was a mineral-wool production company, a market leader with more than 20 global production facilities and over 10,000 employees. The company has 18 individual business units (BUs) that operate in different markets, each of which is responsible for managing its own assortment. At the start of our study, the company had yet to begin the scoping phase and had only performed a preliminary analysis to determine whether to engage in a PIMS project. Our choice of case company was based on the possibility of studying a PIMS project from start to operation while having a high level of access to the case (Sanday, 1979). The PIMS implementation was still ongoing by the time our research was finished, which is why this article covers only the first three BUs.

For data collection, we mainly relied on participant observation and interviews (Åhlström and Karlsson, 2009; Sanday, 1979). Specifically, one of the researchers participated in project meetings and documented the relevant events by taking notes. We complimented participant

observation with formal and informal interviews and document studies. The purpose of the interviews was to clarify the observed phenomena and parts of the collected documents. Such documents included meeting protocols, business cases and official reports. The participant observation process involved 76 project meetings, seven stakeholder workshops, 53 weekly project-team meetings, five steering-group and steering-committee meetings and 31 individual stakeholder meetings.

The formal interviews followed the PRISM model by Pan *et al*. (2007). Specifically, the interviewers asked the interviewees to comment on: (1) the formation of the project team, (2) software selection, (3) the choice of the project manager, (4) the choice of implementation contractors (consultants), (5) system integration problems, (6) the change of the existing business process, (7) the consultants' role, (8) end-user involvement, (9) data conversion and (10) contract disputes. Additionally, we asked about the challenges in PIMS implementation, the differences in implementing a PIMS compared to other information systems and the main challenges encountered. Table 3 provides an overview of the formal interviews.

Table 3. Overview of the formal interviews

	Role	***No. of interviews***	***Total interview time (hr)***
1.	Enterprise product manager	2	3.0
2.	3rd project manager	2	2.5
3.	Nord Europe BU product manager	1	1.5
4.	Business analyst	1	1.5
5.	Master data governance specialist	2	2.0
6.	South Europe product manager	1	1.0
7.	1st project owner	2	3.0
8.	2nd project owner	1	1.5
9.	PIMS specialist	2	3.0

The observation notes and interview transcripts were analysed in three stages: (1) data reduction, (2) incident identification and (3) incident coding (Åhlström and Karlsson, 2009). Two researchers were involved in these steps to enhance the validity of the study (Eisenhardt, 1989).

4. Case study description

At the beginning of 2017, the company decided to launch a product digitalisation initiative to increase its presence across digital channels (e-commerce, mobile apps, retailer websites, etc.). First, the company chose to implement an e-commerce platform. To do so, the company needed to create a centralised product information hub and decided to implement a PIMS as a supporting tool for gathering, managing and delivering product information. PIMS implementation started in October 2017 with the scoping phase, which was followed by a vendor-selection phase and concluded with the technical implementation of the system. By the time our study ended in November 2020, the PIMS had been implemented in three BUs.

The difficulties and the complexity encountered during the implementation process lead to delays, at least doubling the amount of time that was proposed in the original business plan. The company adopted an agile implementation methodology, starting with two BUs as a pilot test and adding a third BU right after. Several issues arose during the implementation process, including two changes of project managers (PMs), two changes of project owners (PO), dismissed employees and dissatisfaction among the stakeholders.

Figure 2 shows the PIMS implementation process and the main organisational changes.

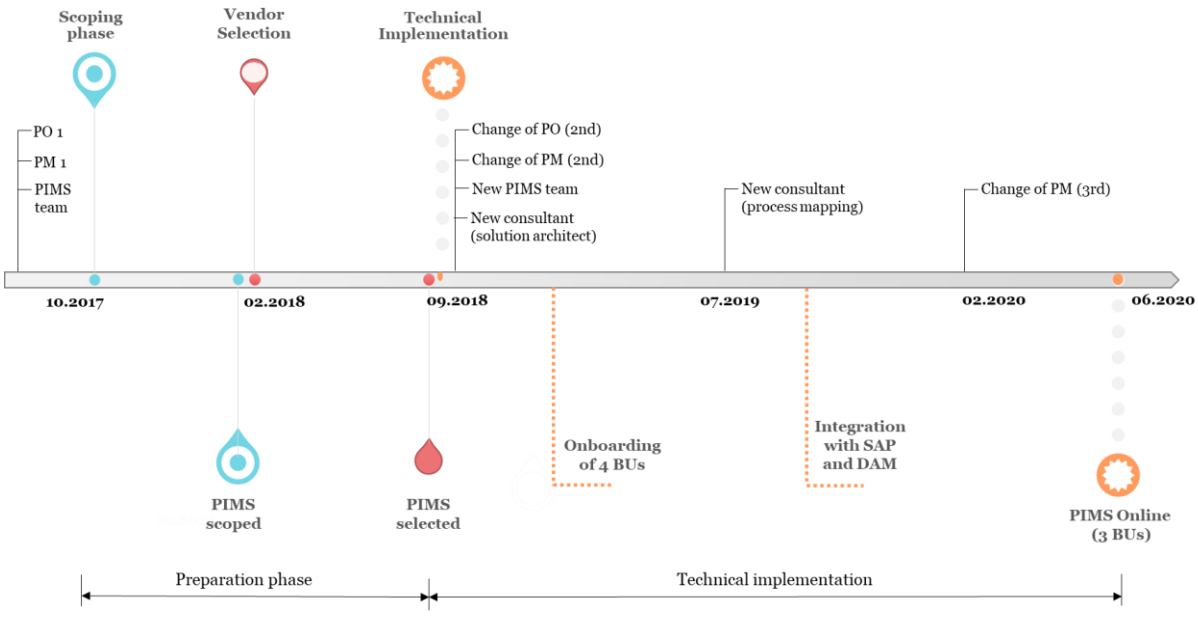

Figure 2. Roadmap with the main organisational changes.

To establish a frame for analysing the project, we divided the project into four overall phases and split the implementation tasks into main tasks and a general continuous task that lasted

throughout the project. Each task resulted in its own unique challenges. The main tasks are also shown in Table 4. Below, we discuss the tasks and the associated challenges.

Table 4. Project phases and tasks

Phase	Main tasks	Continuous task
1. Preparation	1A: Formation of the project team	5. Project management
	1B: PIMS selection	
2. Technical implementation	2A: Technical-implementation team	
	2B: Systems integration	
	2C: Development of the product information model	
3. Organisational implementation	3A: Organisational implementation team	
	3B: Business-process change	
	3C: End-user involvement	
4. Operation	4A: Allocation of operational costs	
	4B: Maintenance and further development	

Task 1A: Formation of the project team

In October 2017, when the PIMS implementation started with the scoping phase, the PIMS project team was composed of the project manager (PM1) from the IT department, the PIMS specialist and the project owner (PO1) from the marketing department. PM1 had solid project management skills, while PO1 had no experience with PIMS but possessed solid knowledge of the business due to having worked at the company for a long time. After the selection of the PIMS, the management decided to overhaul the project team. From January 2019, the second setup of the project team involved a new project manager (PM2) from the IT department and a newly hired project owner (PO2) from marketing with experience in PIMS but new to the company. For the role of the PIMS specialist, a new external consultant was hired. Two more positions were allocated to the project at this time: a product manager and a Master Data Management (MDM) expert. Within the first two settings, the ownership of the project belonged to the IT department. In September 2019, a new external consultant joined the project group with the goal of mapping the current product information processes. The complete overhaul of the personnel in the project team had a big impact on the implementation process. Specifically, there was no communication between PO1 and PO2, which resulted in loss of knowledge and contacts during the transition. A PIMS specialist stated the following:

> *Since the new resources joined the group in spring 2019, the implementation quality started to fall apart. This happened because the project team wasn't mature for this*

implementation project and because of the big cut-off between the first and second project team.

In February 2020, the ownership of the project moved from the IT department to the marketing department with the introduction of a new PM (PM3) from the marketing department. The management thought that the old setup was incorrect because too technical. Table 5 describes the issues encountered in relation to the formation of the project team.

Table 5. Formation of the project team

	Issue description
1	The project team was set up as an IT project, with many IT resources but without proper business representation.
2	The roles and responsibilities were very unclear.
3	There ratio between business and IT resources was not adequate.
4	The collaboration between IT and business personnel was poor.
5	Inadequate resources were allocated to the project, with the PIM team having too much work.
6	The organisational change capabilities of the team members were insufficient for the project.
7	It was difficult to find available and skilled personnel on the market for PIMS.
8	The project team lacked experience with taxonomies.
9	It was difficult to find a passionate candidate for the project manager role in the PIMS team.

Task 1B: PIMS selection

Vendor selection started at the beginning of 2018 and ended in September 2018. A long discussion between the marketing and the IT departments took place, with mutual agreement being difficult to establish. The marketing department clearly favoured user friendliness and user experience over the advanced IT features, whereas the IT department preferred more advanced technical solutions to the detriment of user friendliness. The company had three shortlisted system providers: Riversand, inRiver and Informatica. The vendor selection was based on finding the most user-friendly and service-oriented PIMS – that is, the system that best met the marketing department's requirements. One of the business analysts explained the situation as follows:

The marketing department decided to go for an IT solution that was not supported by the internal IT department. But that's very common around here. Where the team failed was not bridging that gap between the two departments.

Table 6 describes the issues encountered during the PIMS selection.

Table 6. PIMS selection

	Issue description
1	During the vendor selection, the project team did not ask the right questions.
2	The platform promised more than it could actually deliver.
3	The company did not have MDM in place when the PIMS project was initiated.
4	The limitations of the PIMS were not detected during the vendor selection.
5	The selection was based on the needs described by a very narrow group.
6	Technical employees thought that the selected system was not right because it required much customisation.
7	The scope did not seem to match the selection of the system.
8	The marketing department decided on an IT solution that was not supported by the IT department.
9	The IT department wanted a process-heavy (and not user-friendly) solution similar to the ERP system.
10	The company was sourcing something that they did not know much about (a new type of software).
11	It was difficult to scope the system due to a lack of knowledge about the system type.

Task 2A: Technical implementation team

The company did not have experience in PIMS implementation and decided to engage an external consultant to assist in the implementation. After detailed market research, the company chose an implementation partner that seemed to be the best in terms of knowledge and quality for the selected PIMS. The implementation-partner team was composed of three coding specialists working four days a week and one PM working two days a week.

Table 7 describes the issues encountered in relation to the choice of the technical implementation team.

Table 7. Technical-implementation team

	Issue description
1	The implementation partner was doing the technical but not the advisory part and hesitated to voice their opinions.
2	The implementation partner did not provide any kind of consultancy, doing only what they were asked to, while the company did not know what to ask for.
3	The project's scope changed, and the way that the group worked with the implementation partner should have changed accordingly
4	It was difficult to find the right personnel on the market to assist in the implementation.

Task 2B: Systems integration

The project made slower progress than expected due to outbound integration problems. Specifically, the company's overall IT strategy was to acquire the best systems available in relation to the particular application, regardless of whether the different IT systems were from different suppliers. While this approach enabled acquiring the best systems available, it also posed challenges for systems integrations. Specifically, the PIMS was importing data from an old and highly customised ERP system as well as the DAM (digital asset management) systems while exporting data to the e-commerce systems and a web content management system. From a technical perspective, the upstream integration with the ERP and the DAM systems implied various challenges as the PIMS came from a different vendor. However, the major problem concerned the quality of the data imported from these two systems. For example, a major issue was that the data in the DAM system, rather than being standardised across the company, was stored differently by different BUs. The data in the ERP system, SAP, was also inconsistent – that is, common structures and definitions were missing. The MDM specialist commented as follows:

> *It was anticipated that we could get structure, information and everything from SAP, which would make it much easier for PIMS to start with. And then you discover that SAP was inconsistent and did not fit commercial profiles.*

The integration of the PIMS and the downstream systems required intense development efforts from the implementation partner. For example, the implementation partner had to create a cloud data hub in order to transfer the data from the PIMS to the web content management system. These issues delayed the implementation process and led to dissatisfaction among the stakeholders. Some BUs, after enriching PIMS with all the data, could not use the system for several months due to the lack of integration with outbound channels. A BU representative expressed their disappointment in the following comment:

> *Right now, the PIMS is just another database because it is not fully integrated. So, every time we are making a change in an SKU, we need to update the data in around 12 systems, with the PIMS being one of them.*

Table 8 describes the issues encountered in relation to systems integration.

Table 8. Systems integration

	Issue description
1	Many integration issues between the ERP system and the PIMS were related to the lack of data definitions.

2	Technical challenges occurred due to multiple interfaces with the old ERP system and a missing MDM policy.
3	The ERP system was old and structured in a decentralised manner, meaning that every time the PIMS needed to be introduced in a new BU, the implementation partner had to carry out customisations.
4	Without integration, the PIMS was just another system that BUs had to maintain manually.
5	The PIMS needed to be integrated with a high number of systems, which was difficult and time consuming.
6	A PIMS is a hub for storing, integrating and editing data; however, it was treated as a stand-alone system project.

Task 2C: Development of the product information model

The data-conversion process was challenging in several respects. First, it was hard to acquire information of adequate quality – sometimes, the information was not available, and other times, the information was of poor quality. Also, organising information using a common information model to enable sharing across IT systems from different BUs was extremely complicated. This was partly because the BUs were managing and storing the data in the ERP and the DAM systems in different ways, without uniform rules and definitions. One of the project managers described the situation as follows:

> *When you are trying to implement a very centralised system in a very decentralised company, you are going to have a very hard time.*

Table 9 describes the issues encountered in relation to the development of the PIMS's product information model.

Table 9. Development of the product information model

	Issue description
1	The company did not have an overall data-management strategy.
2	Data quality and uniformity between the two main sources (ERP and DAM) was poor.
3	The project team found it difficult to locate the relevant information.
4	The project team found it difficult to create useful product models based on the retrieved information.
5	The project team struggled to involve the domain experts in the information-modelling process.
6	The project team found it difficult to model within the constraints imposed by the PIMS design.
7	The team tried to align everything globally, but it was hard to fit different kinds of data using a single standard.
8	The team found it hard to develop a (generic) information model that could support all the BUs' particular requirements at the same time.

Task 3A: Organisational implementation team

During the PIMS implementation, the company hired two consultants. The first was a PIMS specialist with solid knowledge of PIMS implementation, and the second consultant was hired to map the company's existing information-management processes, joining the team almost one year after the start of technical implementation. Process mapping was an activity that had been planned before the start of implementation but which had not been carried out. After this eventually got done, the company became concerned with losing a significant amount of knowledge with the departure of the consultants.

Table 10 describes the issues encountered in relation to the organisational implementation team.

Table 10. Organisational implementation team

	Issue description
1	The consultants' departure would result in loss of relevant project knowledge.
2	While the consultants had the necessary capabilities, they were not experienced as consultants and often did not know how to act during the project.

3B: Business-process change

Change management, both at the corporate and BU levels, was not initiated before starting the technical implementation of PIMS. Normally, change management is part of the pre-analysis before system implementation, but it was not so in this case. Rather, the implementation appeared to be a trial-and-error process, with the corporate level convincing the BUs to change their processes after they got the PIMS.

Table 11 describes the issues encountered in relation to the phase of business-process change.

Table 11. Business-process change

	Issue description
1	A change-management process that would happen in parallel with the PIMS implementation was missing.
2	There was a lack of clarity on who was making decisions – that is, the BUs or the corporate management.
3	It was not clearly defined how the business processes were going to change as a consequence of the PIMS implementation.
4	One of the purposes of PIMS was to simplify the existing processes; however, this simplification was not possible before full implementation.
5	The PIMS was less user friendly than expected and thus more difficult for users to like.
6	Some users did not want to change existing job routines.

Task 3C: End-user involvement

Problems began to emerge after the project team was overhauled and PM2 started to lead the project. As mentioned earlier, the result of the overhaul was a loss of technical and user knowledge. Furthermore, another problem was the inability to manage the end users, in the sense that during the technical implementation, communication with the stakeholders was almost non-existent. Therefore, the project failed to address user requirements and to understand the way that the users worked. A PIMS specialist commented as follows:

> Because the PIM project has been running without progress for so long, it is almost impossible to have users' involvement.

Table 12 describes the issues encountered in relation to end-user involvement.

Table 12. End-user involvement

	Issue description
1	Project communication and general communication with the management was missing.
2	BUs needed to feel involved in the project and in the bigger decisions, which did not happen.
3	Stakeholders did not know what was happening during implementation.
4	PO1 maintained contact with the stakeholders, but there was no formal user involvement.
5	PO2 had access to PO1's contacts but used the user community only for one-way communication instead of engaging the users and receiving feedback.
6	The company was pushing behavioural changes without involving the end users.
7	The project team was not listening to the needs of the BUs.
8	The project team failed to communicate adequately regarding the PIMS while waiting for the system to go live.

Task 4A: Allocation of operational costs

The corporate IT department's allocation of the IS costs consisted of charging the BUs a fixed annual fee for the solutions implemented. The BUs were charged the same cost independently of their revenue size. The main contract disputes were between the corporate group and the BUs because the BUs did not want to pay the full amount of the first fee, seeing that the system was not working.

Table 13 describes the issues encountered in relation to the allocation of operational costs.

Table 13. Allocation of operation costs

	Issue description
1	BUs were at odds with the corporate level, and when they were asked to pay the first fee, the BUs did not want to pay the full amount because they had not yet received any value from the system.
2	Agreements on how the system should be financed were not fully clarified before implementation.

Task 4B: Maintenance and further development

Finally, as the PIMS was rolled out in the first three BUs, users began to report problems and request changes. However, the company had yet to set up a well-functioning organisation for the maintenance and further development of the PIMS.

Table 14 describes the issues encountered in relation to maintenance and further development.

Table 14. Maintenance and further development

	Issue description
1	A functioning organisation for the maintenance and further development of the PIMS had not been created, meaning that users received poor service.
2	Funds were not allocated for error fixing and further development.

Task 5: Project management

Over the course of our study, the role of project manager was handled by three different persons. PM1 was into hardcore project management. He did not have much knowledge of PIMSs, but he had experience with several ERP implementation projects. The management stated that he did not fit with the company's culture because of his "strong personality" and asked him to leave. At the beginning of January 2019, PM2 joined the project group and took over. PM2, who had a very strong digital-architecture profile, lacked the experience for leading such a large-scale implementation project and thus ended up facing several coordination issues. The change of project manager contributed to several implementation problems due to different working styles and several coordination issues. Moreover, no proper handover was made during this change of project leadership. At the same time, a new product information manager joined the company and took over the role of the project owner (PO2) as the previous PO had resigned from his job. Again, no proper handover was made during the change, resulting in a total break with the job previously done. One of the BU managers described this step as follows:

After that day [from PM1 to PM2 and from PO1 to PO2], all the information meetings to keep us updated disappeared. After that, we have been in the dark. I don't know what they are working on right now. I have to ask them to get any information.

To deal with the project management challenges, PM3 took over in February 2020. This person came from the marketing department and had to bring clarity to the project in terms of the roles and responsibilities and had to impose more discipline to get things done. He believed that the complexity and lack of responsibility resulted in underachievement.

Table 15 describes the issues encountered in relation to project management.

Table 15. Project management

	Issue description
1	Many employed believed that PM2 did not know how to handle project management.
2	The project team perceived PM2 as a solution architect and not a project manager.
3	BUs perceived PM2 more as an IT person than a project manager.
4	PIM is also about managing culture differences within a company. Marketing employees do not work in a data-structured way, meaning that an IT-oriented project manager was not the best solution.
5	It was not clear how much of the project PM2 was managing because, from his perspective, he was a technical project manager.
6	When the scope changed, the entire plan should have been re-evaluated, which did not happen.
7	PM2 and PM3 were going too much into technical details and not enough into the business part.
8	Some employees stated that they were really surprised by PM1's removal because he was doing a really good job.
9	PM2 worked on at least five other internal projects, and his attention was spread too thinly.
10	With PM2, the project group did not have deadlines anymore, and all the planning and coordination fell apart.
11	Risk management was completely missing, leading to poor decision-making and problem-handling.

To summarise, we identified various issues that the case company encountered during the different phases of the PIMS project. We also showed how the decisions made in one phase affect not just the next but all subsequent phases. As illustrated by the case company, some bad decisions were made in the "preparation" phase, resulting in the project team being reorganised several times during the project because it did not have the right technical, business or management expertise. This caused problems for technical implementation, which, in turn, made organisational implementation more difficult. In the end, the PIMS project failed in terms of the time frame, cost objectives, and systems elements included in the system scope (Whitney and Daniels, 2013). Figure 3 illustrates the relationships between the implementation phases.

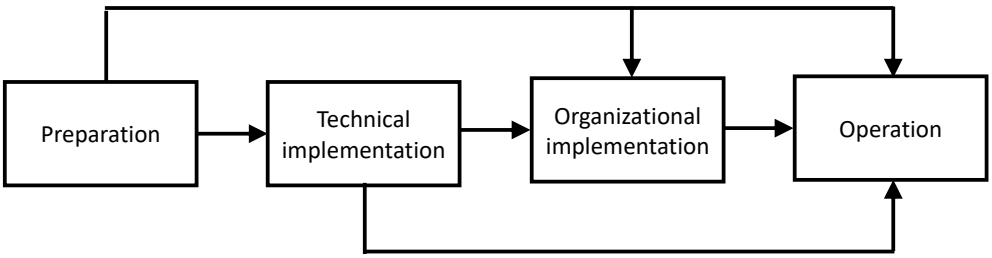

Figure 3. Relationships between implementation phases

5. Discussion

The studied PIMS project supported Abraham's (2014) analysis, which showed that the shared product information model was a major challenge in PIMS implementation. More specifically, some information cannot be readily implemented in PIMSs, without requiring extensive modelling (Boyd, 2006). This is because PIMSs include generic product information models, which, prior to the project, are usually not readily available in companies (Abraham, 2014). Therefore, PIMSs involve some particular challenges regarding the development of the system's product information model in relation to scoping and other implementation phases. It should be noted that such challenges when developing generic product information models are known in product configurator projects (Haug, 2010; Haug *et al*., 2019). However, in other respects, product configurators are much different. Specifically, the aim of a PIMS is to document and share product information, while a product configurator is an expert system that can automatically generate product specifications based on user requirement inputs (Haug *et al*., 2019; Forza and Salvador, 2002).

The creation of generic product information models is illustrated in Figure 3, which compares a typical IT project with a PIMS project.

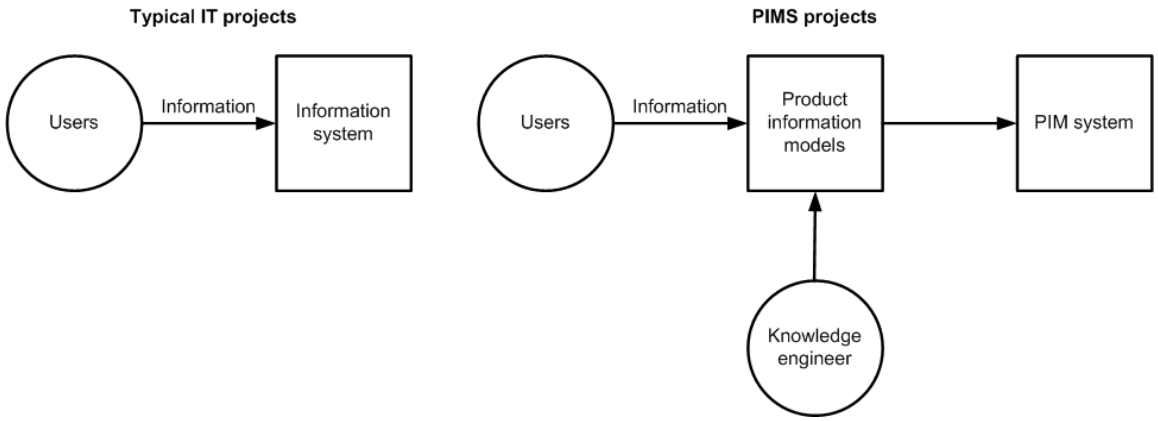

Figure 3. Information-system implementation.

A further complicating factor was that the PIMS needed to include information that had not been stored centrally before, such as “product description,” “sales arguments,” “performance information,” “CE certificate number” and so on. Such information was published using both digital channels and printed catalogues while being managed in local systems and in local languages across BUs. In other words, the PIMS product information model had to support different information needs in different languages.

Another major challenge encountered in the studied project, which may be special for PIMSs, had to do with systems integrations. Specifically, for a PIMS to manage the product data used by a range of other IT systems pointing towards customers, the systems integration has to be of particularly high quality. As the case study showed, achieving high-quality integration was particularly challenging, and without downstream integration, the PIMS becomes just another database, with companies having to spend resources and time maintaining information that is already stored in other systems. In short, PIMS ends up doing the opposite of what it is supposed to do.

Figure 4 illustrates the challenges of creating a suitable product information model and managing interfaces with other systems. As can be seen, the idea is that the PIMS should be a central point for managing customer-oriented product information, which would then be distributed to other systems across BUs. As each BU has its own data requirements and provides different information through its interfaces, the PIMS’s information model (or dataset) needs to provide all the unique representations of its data subsets.

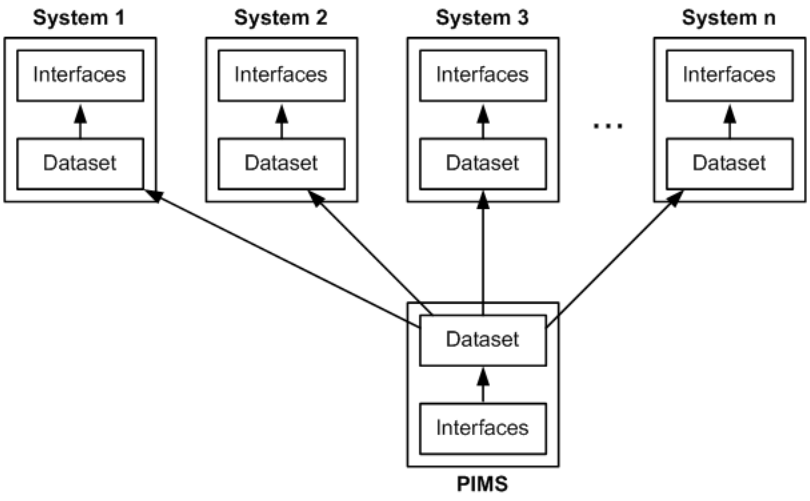

Figure 4. PIMS interfaces.

To build a PIMS's product information model, one must collect the data and specifications from all the individual systems across the BUs. For those in charge of the project, particularly for the project manager, this means understanding the data requirements of all the systems holding product information at the various BUs in order to meet their needs. Thus, as our case showed, technical understanding of PIMSs is far from enough as one has to understand the BU processes as well.

Another observed challenge for PIMS project management was the significance of change management. End users were an active part of the implementation process because they had to create the product model, enrich it with the information, establish the relevant attributes to store, make the decision on the structure/taxonomies in the system and decide on the nature of certain data (string, integer, etc.). Therefore, project managers needed to navigate between the business requirements and the IT solutions.

The type of stakeholders involved also seemed to affect project management – for example, marketers have to start working not only cross-functionally but also cross-market, which involves issues related to languages and socio-cultural aspects. Furthermore, marketing employees usually do not work in a data-structured manner, meaning that they need to get outside their comfort zone while working on a PIMS. In PIMS implementation, marketers face many activities related to structures, such as the product model, the system structure and the like, and to the IT specialists, who work in a completely different way. Thus, PIMS projects also require significant skill at handling different types of users.

Based on the analysis of the case study, we identified a set of success factors for PIMS projects, as described in Table 16. As the table shows, these factors overlap significantly with the 17 success factors for PLM implementation identified by Singh *et al*. (2020) (as shown in Table 2). However, the factors identified in our study place a greater emphasis on balancing business and technical expertise as well as on the development of the PIMS information model. This is not surprising, considering that PLM systems have more of an internal information sharing focus, while PIMSs handle data that reach different consumer groups through a variety of channels.

Table 16. Success factors for PIMS project

Phase	Main tasks	Success factors
1. Preparation	1A Formation of the project team	Adequate balance between technical and organisational implementation expertise
	1B PIM selection	Match between PIMS and organisational needs
		Ensuring that the system can be easily and quickly integrated with outbound channels
2. Technical implementation	2A Technical implementation team	Adequate balance between technical and business expertise
		Ensuring that the team has people skills to bridge different user requirements
	2B Systems integration	Carefully planning systems integrations in advance to utilise synergies
	2C Development of the product information model	Ensuring information quality before importing data
		Ensuring that product information modelling expertise is available
3. Organisational implementation	3A Organisational implementation team	Ensuring the balance between technical and business expertise
		Ensuring that the team has people skills to bridge different user requirements
	3B Business-process change	Ensuring that the system fits business processes
	3C End-user involvement	Involving the stakeholders from the start of the project
		Preparing and harmonising the local stakeholders even before the implementation
4. Operation	4A Allocation of operation costs	Making agreements early on in the project
	4B Maintenance and further development	Ensuring functional organisation for maintenance and further development
5. Project management		Ensuring competent and consistent project management throughout the project
		Ensuring that project manager has the right balance of business and IT knowledge or creating a project-management team that does.

6. Conclusions

An increasing number of companies are implementing PIMSs to centrally manage their product information (Abraham, 2014; PIMM, 2020). Nonetheless, as our literature review revealed, the scholarship on PIMS implementation is limited. To address this research gap in the PIMS implementation literature, we conducted a longitudinal case study and spent three years observing a PIMS implementation project at an international construction-materials manufacturer. Our investigation has resulted in three main contributions. First, we identified a number of issues related to the different phases of PIMS projects. Second, we identified some

of the special characteristics of PIMS implementation projects, which specifically concern integrating PIMS with other systems and the population of the system with information, particularly challenging tasks for PIMS projects. Third, based on the findings above, we defined a set of success factors for PIMS projects.

For practitioners, this study provides an overview of the challenges that they may encounter during a PIMS project. Furthermore, the paper details a set of success factors that may help to ensure the success of PIMS projects. Practitioners can use our findings to navigate PIMS projects. Specifically, having an overview of the main challenges and their causes as well as a set of success factors enables companies to know which pitfalls to avoid and which issues to be aware of.

The three main contributions of our study address a gap in the literature, thus providing a foundation for future research on PIMS projects. Future studies should investigate additional PIMS projects to improve the understanding of the types of challenges that such projects face. Future research may also focus on the development of methods and techniques for supporting PIMS implementation. By identifying the challenges and characteristics of PIMS projects, we have provided a foundation for such work.

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7. DISCUSSION

This chapter opens with a discussion of the individual contributions of the three articles. It then interprets them within the broader digitalisation context and synthesises the overarching contribution of the present thesis to existing theory. Table 6 summarises the gaps in the literature and the corresponding contributions of each article.

Table 6: Summary of the research

Gap in literature		Research question	Individual contribution
Gap 1: Lack of identification of relevant challenges to product variety reduction strategies		**RQ1**: What barriers do companies encounter during product variety reduction projects?	- identifies 32 barriers to the implementation of PVR strategies described in the scholarly literature - provides a classification system for these barriers - identifies an additional category of barriers
Gap 2: Lack of management practices for implementing product information management systems (PIMS)	**Gap 2.1**: Lack of understanding of the challenges affecting the scoping of a PIMS	**RQ2**: What challenges do companies encounter in PIMS implementation regarding the scoping phase?	- identifies 18 challenges to the scoping phase of a PIMS and their causes - provides four major factors influencing the PIMS project scoping phase
	Gap 2.2: Lack of understanding of the factors influencing the implementation of a PIMS	**RQ3**: What challenges do companies encounter in the PIMS implementation phase?	- identifies several issues related to the different phases of PIMS projects - identifies some of the special characteristics of PIMS implementation projects - defines a set of success factors for PIMS projects

7.1 Barriers to product variety reduction strategies

Gap 1 constitutes the foundation for understanding the challenges to the implementation of PVR strategies in organisations. Article 1 addresses this gap by analysing and classifying the barriers found in the literature and then exploring these through a case study. This contributes to the PVM literature in three ways. First, it identifies 32 barriers to the implementation of PVR strategies described in the scholarly literature. Second, it provides a more complete classification of these barriers, dividing them into nine categories: 1) cross-functional integration; 2) strategy and organisational alignment; 3) executive sponsorship; 4) fears and negative beliefs; 5) data/information quality; 6) implementation framework; 7) product architecture; 8) customer/supplier collaboration; and 9) manufacturing process. Third, through a case study, it identifies an additional category of barriers, namely 10) socio-cultural factors.

The literature regarding the approaches to and challenges of PVR is sparse and fails to analyse the issues that companies encounter when engaging in PVR programmes. Article 1 contributes to the PVR literature (Alfaro & Corbett, 2003; Berman, 2011; Byrne, 2007; Enz et al., 2019; Sloot et al., 2006) by providing an organised overview of the barriers, which may help researchers to further develop guidelines for implementing PVR strategies and help companies to avoid those barriers through pro-active effort. Table 7 presents the categorisation of the barriers to PVR strategies.

Table 7: Categories of barriers to PVR strategies

Category of barrier	Description
Cross-functional integration	PVM strategies must have cross-functional involvement so that functional biases are understood and addressed. Ease of interaction across functions enhances a firm's ability to quickly introduce new products.
Strategy and organisational alignment	The way in which the objectives for the PVM project are aligned with corporate goals and strategies should be clearly communicated throughout the organisation.
Executive sponsorship	A PVM strategy requires executive sponsorship in order to overcome strongly competing functional priorities. The initial phase of the project involves the creation of an awareness that SKU proliferation is a priority problem.
Fears and negative beliefs	A PVM strategy can scare both management and staff inside an organisation. Before the implementation, companies tend to be concerned about losing customers and revenue. During the implementation, the staff may be scared about the changes required by the initiative.

Data/information quality	PVM strategy decisions require data, revenue and cost information to be available that managers from different functions understand and can trust. This information must be disseminated throughout the organisation to build support for the project as well as an understanding of its benefits.
Implementation framework	A PVM strategy requires a formal implementation framework, and it helps to implement that strategy in a structured manner (resolve conflicts, achieve consensus within the team, analyse the existing portfolio, create new SKU methodology etc.).
Product architecture	Architecture is a mayor determinant of how a firm can differentiate and variegate its products. The product architecture can influence the selection of a PVM strategy and its implementation.
Customer/supplier collaboration	The benefits of a PVM strategy are greater with key customer/supplier collaboration.
Manufacturing process	Manufacturing process flexibility is a key capability for managing the implementation of a variety strategy. Flexible technologies, point of variegation (decoupling point), logistics and supply chain elements can influence the application of a PVM strategy.
Socio-cultural factors	Society and culture have an impact on every aspect of the overseas business of multinational companies. Although they are not directly included in business operations, they indirectly appear as key elements in shaping how the business is managed. The key socio-cultural factors that have a major impact on the operation of the multinational companies are culture, language, religion, level of education, customer preferences and the attitude of the society towards foreign goods and services.

7.2 Challenges and success factors to the implementation of product information management systems (PIMS)

Gap 2 concerns the lack of understanding of suitable management practices for implementing PIMSs. Article 2 addresses this gap by providing a detailed illustration of the scoping phase of a PIMS through a longitudinal case study. This contributes to the product information management (PIM) literature in two ways: first, by identifying eighteen challenges that PIMS projects may encounter during the scoping phase and a set of causes corresponding to each, and second, by clustering these challenges into four major factors that influence the PIMS project scoping phase—organisational complexity, cognitive complexity, data quality and timing.

Article 2 contributes to the PIMS literature (Abraham, 2014; Boyd, 2006; Brunner et al., 2007; Kärkkäinen et al., 2003) and scoping IS literature (Shafiee et al., 2018; Shafiee et al., 2014;

Sulgrove, 1996) by providing a detailed illustration of the scoping phase of a PIMS and identifying its challenges and the respective causes. The study is valuable because PIMS implementation processes have not been reported in the literature, and it constitutes a first step in the development of guidelines for implementing PIMSs.

Article 3 adds to the limited insights on PIMS implementation in the literature (Gap 2) by investigating not only the scoping phase, but also the technical implementation of a PIMS. This contributes to the PIM literature in three ways. First, it identifies 59 issues related to eleven main tasks of PIMS projects: formation of the project team; PIMS package selection; the technical implementation team; system integration; development of the product information model; the organisational implementation team; business-process change; end-user involvement; allocation of operation costs; maintenance and further development; and project management. Second, it identifies some of the special characteristics of PIMS implementation projects, and the issues related to such characteristics are connected with the integration of PIMS with outbound channels, the creation of a central product model across the organisation and the balance of business and technical knowledge during the overall implementation process. Third, based on these findings, the study defines a set of success factors in PIMS projects related to the five phases of implementation: preparation, technical implementation, organisational implementation, operation and project management.

Article 3 contributes to the PIMS literature (Abraham, 2014; Boyd, 2006; Brunner et al., 2007; Kärkkäinen et al., 2003) and IS failure literature (Lyytinen & Hirschheim, 1987; Pan et al., 2008; Whitney & Daniels, 2013) by providing an overview of the challenges to PIMS implementation projects and detailing a set of factors that may help to ensure their success, which are presented in Table 8.

Table 8: Success factors for PIMS projects

Phase	Main tasks	Success factors
1. Preparation	1A: Formation of the project team	An adequate balance between technical and organisational implementation expertise
	1B: PIM selection	A match between the PIMS and organisational needs
		Ensuring that the system can be easily and quickly integrated with outbound channels

2. Technical implementation	2A: Technical implementation team	An adequate balance between technical and business expertise
		Ensuring that the team has the people skills to bridge different user requirements
	2B: Systems integration	Carefully planning the systems integrations in advance to utilise synergies
	2C: Development of the product information model	Ensuring information quality before importing data
		Ensuring that product information modelling expertise is available
3. Organisational implementation	3A: Organisational implementation team	Ensuring the balance between technical and business expertise
		Ensuring that the team has the people skills to bridge different user requirements
	3B: Business-process change	Ensuring that the system fits the business processes
	3C: End-user involvement	Involving the stakeholders from the start of the project
		Preparing and harmonising the local stakeholders even before the implementation
4. Operation	4A: Allocation of operation costs	Reaching agreements early in the project
	4B: Maintenance and further development	Ensuring a functional organisation for maintenance and further development
5. Project management		Ensuring competent and consistent project management throughout the project
		Either ensuring that the project manager has the right balance of business and IT knowledge or creating a project management team that does

7.3 Managing the digitalization of product information

As a whole, this thesis contributes to the PIM literature and the DT literature by providing an in-depth theoretical and practical understanding of how manufacturers can overcome the challenges they face during the digitalisation of product information (Brunner et al., 2007; Forza & Salvador, 2007; Kärkkäinen et al., 2003; Power, 2010). It does so by introducing a proposal framework for digitalising product information (Figure 10).

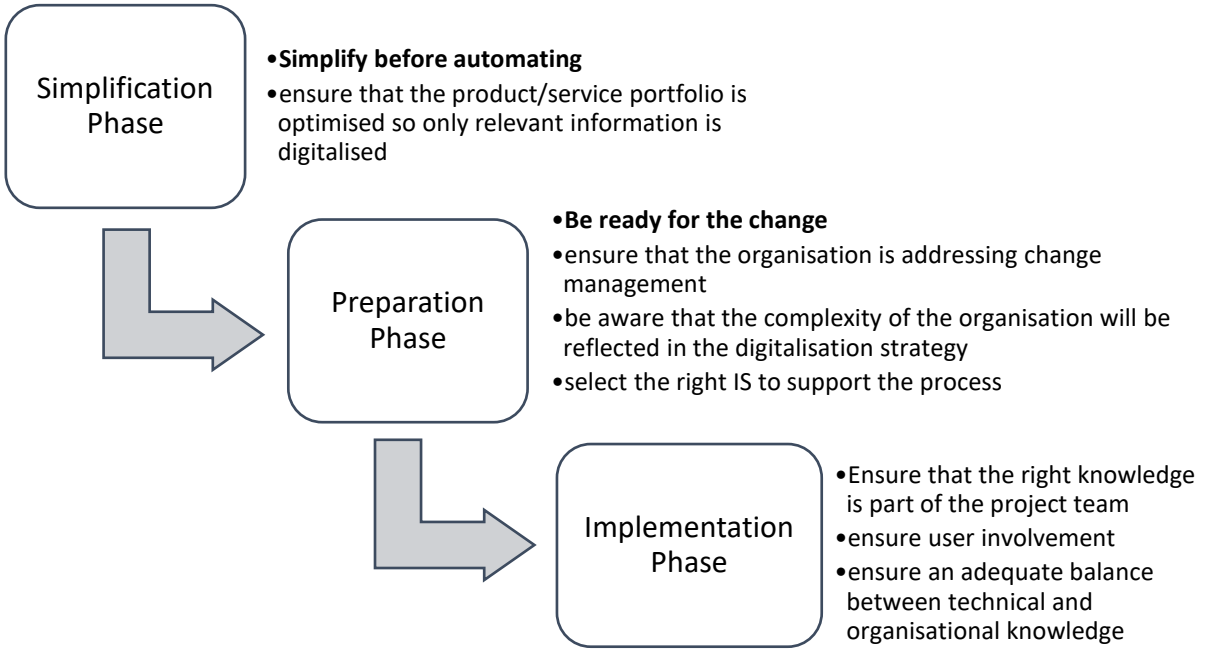

Figure 10. A framework for the digitalization of product information

Companies can manage the digitalisation of product information in three sequential steps. First—and following the logic of "simplify before automating"—companies need to optimise their product variety in order to store, manage and maintain only relevant product information. Here, they need to pay close attention to the barriers (see Table 7).

Second, companies need to prepare the organisation for the transformation process by establishing a common understanding of the benefits of the DT, building a knowledgeable project team, selecting the right IS to support the process and addressing change management. Here, companies need to pay close attention to four major factors influencing the process: organisational complexity, cognitive complexity, data quality and timing.

The third phase relates to the "physical" digitalisation of the product information with the implementation of a supporting IS, i.e., a PIMS. Here, companies need to pay close attention to ensuring competent and consistent project management throughout the project, an adequate balance between technical and business knowledge in the project team and end-user involvement. The present thesis also contributes to the literature by providing an in-depth case study of the digitalisation of product information in a multinational company, offering insight into and observations of the challenges and success factors of a real DT process.

8. CONCLUSION and FURTHER RESEARCH

Customers nowadays gather information about products online, regardless of whether they will ultimately shop online or in-store. Customers expect to find rich, clear and precise information during their research that helps them to select the products that match their requirements. Following this trend, companies are digitalising how they do marketing and seeking to provide consistent and accurate product information across their digital channels. However, collecting, managing and distributing such information across multiple channels can be a very complex process, making a digitalisation strategy harder than might have been expected. The digitalisation of product information and its management have also yet to be studied, leaving important gaps in the literature and a critical lack of answers to practitioners' questions. To address these gaps, this thesis investigated the following research question:

How can companies manage the digitalisation of product information?

The articles presented in this thesis enable a significant answer to this question by providing a proposal framework for the digitalisation of product information and analysing the DT process of a multinational company.

Companies can manage the digitalisation of product information in three sequential phases: simplification, preparation and implementation. First, and following the logic of "simplify before automating", companies need to optimise their product variety; second, they need to prepare the organisation for the transformation process by establishing a common understanding of the benefits of the DT, building a knowledgeable project team, selecting the right IS to support the process and addressing change management; and third, the digitalisation of the product information should be accomplished with the implementation of a supporting IS.

8.1 Implications for practice

Managers can better understand and manage the digitalisation of product information during DT strategies in several respects. First, practitioners can utilise the PVR barrier classifications as part of the preparation phase for digitalisation to help anticipate the barriers they will meet while pursuing a PVR programme. Such an overview would reveal where management should focus attention and resources in order to overcome scepticism and even resistance in the implementation of the strategy. In other words, an overview of possible barriers may help companies to avoid those barriers through pro-active effort.

Second, the thesis presents an overview of possible challenges that may appear in the scoping phase. These findings can be used to guide PIMS project scoping and help practitioners to prepare for any challenges in advance. Specifically, by having an overview of the main challenges and their causes, companies can determine the pitfalls to avoid and issues to be aware of during the scoping phase, which is especially important given that many IS projects fail to even start.

Third, the study in the current thesis offers insights into how PIMS implementations can go wrong, thus providing an overview of the challenges that may be encountered during the implementation phase, and provides a set of factors that may help ensure PIMS project success, which can be used to guide practitioners through such projects. The experience related in the study is valuable as very few PIMS implementation processes have been reported in the IS literature, and managers would benefit from learning from the mistakes of others (Lyytinen & Robey, 1999).

8.2 Limitations

The contribution of the present thesis must be understood in the context of the inevitable limitations. The first limitation relates to the methodology selected for the study. One of the main challenges of qualitative case studies is the ability to generalise the results (Flyvbjerg, 2006; Yin, 2009), particularly for single case studies, such as the one in this thesis. (Yin, 2009). Qualitative research—particularly single case studies resulting from longitudinal field work—cannot be generalised in the statistical sense, but statistically generalisable results are not the purpose of this approach (Åhlström & Karlsson, 2009), and the focus should be on analytical generalisation (Yin, 2009). The ability to generalise in qualitative studies relies on structural corroboration—the structure of the evidence (Spencer & Dale, 1979)—and a comparison with existing theory allows generalisation from a longitudinal field study using structural corroboration (Berg, 1981). The challenges and success factors identified in this thesis were thus compared with the existing theory from similar ISs, particularly PLMs and configurators, and the results can consequently be analytically generalised (Yin, 2009) to other DT contexts in large manufacturers.

Multiple case study approaches are preferred over single case study approaches for obtaining a more complete and robust dataset (Herriott & Firestone, 1983), but time constraints influenced the development of the study in this regard. Using participant observation as the main method for collecting data required the researcher to be in close contact with the studied

event for the entire duration of the process (Åhlström & Karlsson, 2009), and the digitalisation of the product information in the analysed company is an ongoing process that, in order to study the complete implementation for three BUs, the researcher spent three years observing. It might therefore be difficult to find the opportunity for a multiple case study design.

Another limitation of longitudinal field study is related to emotional difficulties that might affect the researcher during participant observation (Barley, 1990). The researcher may be influenced by the emotional life of the observed phenomena (Schwartz & Schwartz, 1955) and by relationships with people in the organisation, thus affecting the collection of data (Scott, 1965). To limit this risk, the researcher alternated between the research field (the case company) and the academic environment, increasing the level of abstraction of the observations (Åhlström & Karlsson, 2009).

8.3 Future research

The present thesis developed existing theory by identifying and presenting both the central concepts in the management of product information for digitalisation strategies and their relationships. The research studied the digitalisation of product information in a multinational company, and future research could investigate, through an exploratory study, whether the identified concepts and their relationships are also relevant to small and medium-sized enterprises (SME). Moreover, although the study was conducted from the enterprise perspective, the analysed organisation consists of eighteen individual BUs operating in different markets, with each BU managing its own assortment. Additional research could study the effects and challenges of the digitalisation of product information at the BU level; it might be interesting to see the difference between the challenges and enablers within the same company at the aggregated and those at the disaggregated level. Additional research should also confirm and develop the categorisation of the barriers to PVM strategies presented in this thesis, and case studies of companies that want to apply—or have applied—a PVR strategy could enrich the list of barriers with some real-world examples.

This thesis represents the first step in exploring PIMS implementation. Further studies of PIMS projects are needed to improve the understanding of the types of challenges such projects face, and more longitudinal field studies are needed to gain a deeper understanding of the dynamics of PIMS implementation in various contexts. Future research may also focus on the development of methods and techniques to support PIMS implementation. By identifying the challenges and characteristics of PIMS projects, this study provides a foundation for such work.

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