FACULTY OF TECHNOLOGY

PRODUCT DATA MANAGEMENT PRACTICES IN A BANGLADESHI AGROCHEMICAL COMPANY

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ABSTRACT

Product Data Management Practices in a Bangladeshi Agrochemical Company.

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As businesses are relying more on information systems to carry out their processes, data is becoming an increasingly important factor for success. In particular, product data is necessary for tasks such as producing, selling, delivering, and invoicing a product within these systems. In the past, studies on product data and product data management management have primarily focused on product development and related activities, with little emphasis on PDM in other stages of a product's lifecycle.

The aim of this Master's thesis is to explain the contribution of PDM in enhancing a company's performance by improving its operational and business processes as well as the difficulties and requirements involved in implementing Product Data Management (PDM) practices in a Bangladeshi agrochemical company. The research encompasses overall comprehension of PDM as a company-wide initiative and suggests possible strategies for establishing company-wide PDM practices.

To improve their data management practices for handling a broad range of varying products, the case company was surveyed and analyzed in this study. The author utilized a case study approach and conducted interviews to gather data from practitioners with firsthand experience and perspectives. This empirical data has contributed to a better understanding of company-wide PDM.

The findings of this research suggest that standardized understanding of products throughout a company is necessary to facilitate effective management of product data. To establish effective PDM practices throughout a company, it is crucial to have a comprehensive understanding of the nature of product data, which encompasses both product master data and general product data from different stakeholder viewpoints. When dealing with a wide range of products that need to be effectively managed, higher-level product decisions have a considerable influence on product data management, and general guidelines may be vital for ease of management. The study emphasizes the significance of adopting a top-down approach for creating effective PDM practices, and the need for a generic product structure to facilitate consistent product management. The main contribution of this research is its guidance for managers in establishing true company-wide practices for managing product data.

Keywords: agrochemical, product data, product data management, product structure, PDM, PLM, PDM system, operational excellence, business performance

FOREWORD

The objective of this paper is to introduce the concept and improve the understanding of product data management in a Bangladeshi company. The unpaid thesis work started in January 2023 and the journey has been a roller coaster ride. It taught me how to deal with several simultaneous involvements like studies, work, job applications and thesis while managing strong feelings of frustration and uncertainty. I am thankful to Allah (God) for making all of this possible. Moreover, certain individuals have made the journey easier, and I owe them my sincere thanks.

First of all, I would like to express my gratitude to my supervisor, Dr Janne Härkönen, who supported and guided me throughout the Master's thesis. Thank you, Janne, for your constant encouragement. Your quick reviews and motivation have kept me on track to finish the work within a short time. It has been a pleasure to work with you.

Special thanks to my former colleagues, M. Shahrul Islam and Tashfin Hossain Rumman for making time for the case interviews and providing valuable insights. I hope this work adds value to your work and the company.

I am indescribably grateful to my family. My parents never stopped believing in me despite being thousands of miles away and always inspired me through words of wisdom. Abbu and ammu, thank you for being my light at the end of the tunnel. My wife, Sharmin, worked extra hours and took care of our home so I could focus fully on my thesis and other work. Beloved Sharmin, the first six months of 2023 have not been easy, but your down to earth perspectives and delicious meals enabled me to calm my storms of frustrations. I am grateful for your patience and support when I questioned my worth and competency at times. Thank you for being there. I also appreciate the encouragement from the rest of the family and friends during this project.

Oulu, Finland, June 2023 *Mohammed Towhidur Rahman*

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LIST OF ABBREVIATIONS

B2B	Business-to-Business
BOM	Bill of Material
CAD	Computer Aided Design
CRM	Customer Relationship Management
ERP	Enterprise Resource Planning
IT	Information Technology
PD	Product Data
PDM	Product Data Management
PLC	Product Life Cycle

1 INTRODUCTION

1.1 Background and Research Environment

Dependency on data and information has been escalating due to their significance in every business operation, from insights into customers to product development and management plans for the future (Laney & Jain, 2017). Modern technology enables storing more data than a company can handle, and various enterprise solutions usually result in confusion regarding data (Smith and McKeen, 2008). While erroneous and inconsistent data definitions, data formats, etc. lead to lost opportunities, invoicing issues, and inefficiencies, it is estimated that such circumstances in retail business costs $40 billion annually, and at the organizational level costs 10 percent of revenues approximately (Silvola et al., 2019; Hannila et al., 2019; Snow, 2008; Batini et al., 2009; Redman, 2001). According to Haug et al. (2009) and Dayton (2007), improved data leads to better business decisions. However, despite being a strategic asset for companies, data are not fully utilized (Weill and Woerner, 2018). While the amount of data have been skyrocketing (Li et al., 2015), the usage of it is a challenge owing to information reliability as it takes a longer time to find required accurate data (Aiken and Billings, 2013). Therefore, a PDM structure is needed. Furthermore, Porter & Heppelman (2014) have recommended the need for a new mind-set in terms of customer relationship involving intelligent and integrated products, which retrieve an extensive range of customer data from product usage for refined market segmentation alongside product and service customization and thereby for alternative pricing models.

In the era of highly competitive global market, companies are obligated to strive towards continuous innovation of products to improve, or simply maintain, their market position. In a work environment comprising multiple projects and culture across several sites, it is imperative for organizations to specifically ensure that accurate product data (PD) are flowing smoothly, ideally, automatically, between all stakeholders in the value chain (Gime´nez et al., 2008). For any given product, an ample amount of product data and

product-related business data are created throughout its entire lifecycle (Tao, Cheng, Qi, Zhang, Zhang, & Sui, 2018). Typically, such data involve various stages of a product like design, material procurement, manufacturing, distribution, sales, service, and termination. Each phase requires distinct data, which must be managed in a systematic manner to provide correct information at the appropriate time to several stakeholders (Yang et al., 2007; Rachuri et al., 2008). However, there are limited research articles related to systematic utilization of data – facts, figures, and quantitative approaches – for products to facilitate decision-making. Instead, companies rely on intuitions and emotional response (Maitlis & Ozcelik, 2004) adopting a "who shout the loudest" perspective often considering the opinion of the highest paid person (McAfee & Brynjolfsson, 2012). On top of that, since data are siloed, too much manual work is required to determine actual product costs (Jetson & Nelis 2008; Kumar Das & Mishra, 2011; Lans, 2012). Therefore, it is imperative to understand the significance and desirability of genuine fact-based analysis on company products in identifying which products are individually profitable, and which are eligible to keep as they generate profitable business (Lahtinen, Mustonen, Harkonen, 2021). Connecting data sets to company master data requires a magnified focus to provide an all-round view in determining new business opportunities (Walker & Moran, 2017), necessitating systematic data governance (Brous, Janssen, & Vilminko-Heikkinen, 2016; Fisher, 2009; Lans, 2012; Thusoo & Sharma, 2017; Waddington, 2008).

Existing business environments, especially involving manufacturing, are heavily dependent on data-systems because efficient data management practices have turned out to be vital for business performance. Companies collaborating with partners, suppliers, or subcontractors in relation to manufacturing are usually inclined towards data management practices. Challenges for manufacturing companies in recent times include shortening time-to-market, decreasing product lifecycles, increasing requirements for legal and environmental concerns alongside necessity for continuous cost reduction and operational excellence (Ameri & Dutta, 2005; Stark, 2005; Saaksvuori & Immonen, 2004; CIMdata, 2002).

To overcome these challenges, conventional solutions are not sufficient. Product Data Management (PDM) has turned out to be one of the most pivotal factors for companies, especially in manufacturing industries. The utilization and possibilities of visualization facilitated by PDM, as well as enhanced product data (PD) sharing come to considerable benefit to design and manufacturing processes (Chan & Yu, 2007). To gain competitive advantage, companies need a universal portrayal of PD that is electronically transferrable across business functions and organizations (Saaksvuori & Immonen 2004), however, the complete realization of this aspect is yet to be attained (Abramovici, 2007). The essential purpose of establishing PDM is to aid companies in streamlining their operations, increasing their effectiveness and efficiency. Usually, PDM systems manage all basic data involving design, maintain, and disposal of a product. Getting a product under control will become a major drawback, if a company is not able to control product related data (Stark, 2005). PDM facilitates in organizing and utilizing data, supporting the acceleration of time-to-market owing to reduced lead-times (Huang et al., 2004; Sulaiman, 2000; Philpotts, 1996). It has been put forward by numerous scholars that company level data management practices (Schaffer & Leyh, 2017; Silvola et al., 2019; Kropsu-Vehkapera & Haapasalo, 2011) is essential to make a company distinguished (Allen & Cervo, 2015) and survive with competitors (Terzi et al., 2010; Sriti et al., 2015). Figure 1 demonstrates how the existing business environment influences product data management in manufacturing companies (Modified from Kropsu-Vehkapera, 2012).

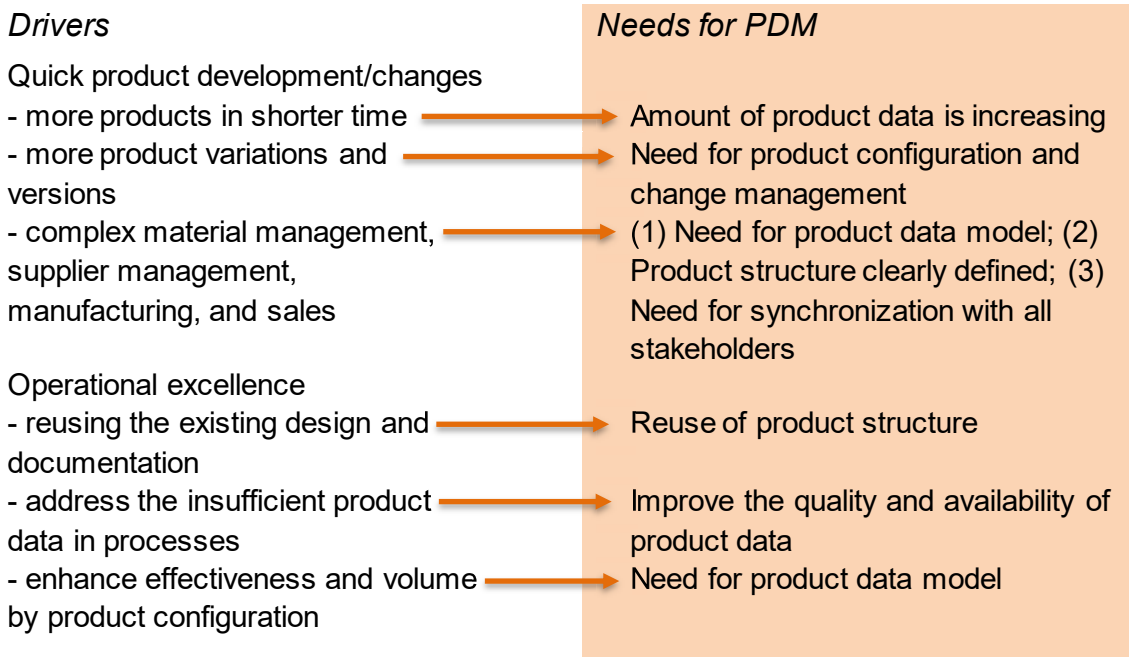

Figure 1. Current business environment increasing the significance of product data management in manufacturing companies.

1.2 Objectives and scope

The purpose of this thesis is to evaluate the existing product data management practices in a Bangladeshi agro-chemical manufacturing company and provide recommendations in this respect to enhance company performance in an increasingly competitive market.

The case company, established more than 50 years ago, reserves an immense silo of data. Recently, it has adopted an Enterprise Resource Planning (ERP) system to streamline the flow of transactional data across business functions but much work is yet to be done to ensure operational and business excellence. It must be mentioned, by virtue of company's age as well as a flourishing agrochemical industry in Bangladesh, the case company appears to be running smoothly, however, owing to the entrance of global competitors into the market, the company must emphasize business and operational excellence to stay in business; for instance, define and standardize product data management practices.

Therefore, to tackle one aspect, the master's thesis focuses on "Product Data Management" addressing the following research questions:

1) How can PDM practices improve company performance via business / operational enhancement?
2) What PDM practices are utilized, and what are the prime PDM related challenges in the case company?
3) Where to start the improvement scheme, and what should be the improvement actions?

1.3 Research Process

The purpose of this thesis is to enhance understanding of product data management and its significance in company performance by utilizing existing literature as key source. The empirical study consists of industrial interviews, based on which, improvement recommendations have been proposed. Since prior comprehension is limited, the research is qualitative in nature (Eisenhardt, 1989). The research process is portrayed in Figure 2.

The study involves reviewing present literature and analyzing product data management related practices in one agrochemical manufacturing company in Bangladesh. The company was selected based on possibility to gain access, interest in product management and the fact that the author is a former employee. The company represents business-to-business, and its products are physical in nature.

Empirical data have been obtained via semi-structured interviews (Bell et al., 2018). The interviewees were asked about the company's products, amounts of products and variants/versions, their understanding of product data and product data management alongside related challenges, the enterprise applications in use, and their consistency between different products.

Two interviewees have been chosen based on the best possible knowledge on the interview topics and their long tenure at the company of more than a decade. The interviewee titles include Manager, Supply Chain, and Assistant Manager, Administration. Both interviewees have played multi-faceted roles, hence they possess the insights of the entire company and its data management practices. The interviews were recorded when allowed and notes were taken.

The analysis was followed by inductive reasoning where the overall focus is pragmatic to certain degree. Analytic generalization has been attempted. Conclusions are drawn based on analyses, and implications are distilled.

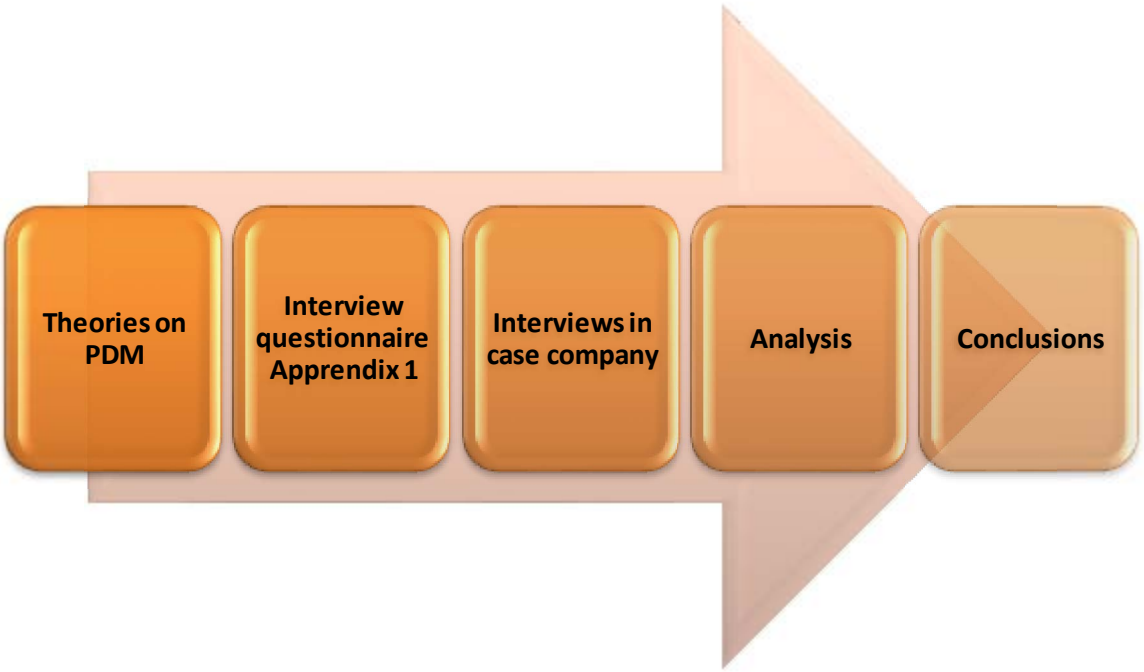

Figure 2. The research process.

2 LITERATURE REVIEW

2.1 Product

A product is the appropriate amalgamation of tangible and intangible constituents resulting in an offering to be sold to customers to satisfy their needs. It can be offered in the form of a service, physical object, software, or a combination of these (Karl & Steven, 2015). In the case of intangible products, customers' needs are fulfilled without transfer of ownership of a tangible asset - for instance, a software comprising data analysis tools, computer programs, and associated documentation (Harkonen et al., 2017). Furthermore, the process of deciphering, combining, and developing a suitable mixture of physical and non-physical elements into a product is referred to as productization (Harkonen, Haapasalo & Hänninen, 2015).

2.1.1 Product Variant and Revision

A product can be offered to the customer in the form of several variants or configurations and delivered as per demand (Peltonen, 2000). Products can be interpreted with various distinct terms like product version, product variant, product revision and product configuration Kropsu-Vehkapera (2012).

The reason behind upgradation of products can range from quality or performance enhancement to cost-reduction, usually resulting in product versions (Kropsu-Vehkapera et al., 2011b), which can be further segregated into revisions (new version of a product replacing the older one) and variants (Westfechtel, Munch, & Conradi, 2001). The quantity of sellable products is not increased by new revisions (Kropsu-Vehkapera, 2012). In fact, the new product variants are introduced to address additional customer requirements (McKay, Erens, & Bloor, 1996), which slightly vary from the original product variant (ElMaraghy et al., 2013), leading to an increase in the number of product variants (Kropsu- Vehkapera et al., 2011b). Peltonen (2000) put forward some examples of product variants like color change or electrical appliances with different voltage rating.

A variant is important to keep separated from option, which can be either included or left out (Kropsu-Vehkapera et al., 2011b).

It is tricky to consider if the new product version is a new variant or a revision. Typically, new product revision is introduced if the fit, form and function remain the same, otherwise, if either of these are altered, a new product variant is created (Peltonen, 2000). Product configurations can be formed on the basis of a set of predefined components (ElMaraghy et al., 2013; Kropsu-Vehkapera et al., 2011b) for effective and precise fulfillment of customer requirements (Kropsu-Vehkapera et al., 2012; Zhu, Wang, Yang, Mo, & Zhao, 2008).

2.2 Product Data in Organizations

An extensive amount of product data is created, altered, transferred, stored and converted during the product lifecycle while being used in daily operations (Lee & Suh 2009). The definitions of a product data do not explain enough to describe the actual content of product data (Sudarsan et al. 2005).

As per Saaksvuori & Immonen (2004), product data can be explained by dividing the concept into three groups:

- Definition data: Referring to fit, form and function of a product, this determines the physical or functional properties of a product from the perspective of a particular party (e.g., customer or manufacturer) and links the information to the understanding of the party in consideration. In addition to specific technical data alongside abstract information, this group also includes conceptual visualizations that characterize a product, portraying a complete product definition (Kropsu-Vehkapera & Haapasalo, 2011).
- The life cycle data: This involves connecting the product with its phase in the order-delivery process. Relevant information in this group comprises research,

design and development, production ramp-up, maintenance, recycling, disposal of the product and so on (Yang et al., 2007; Rachuri et al., 2008).

- Meta data: This group of information describes the product data – for instance – the type of information, its location, who has recorded it and when or how it can be accessed (Schrader, 2013).

Since product data is not a standardized concept spread out throughout an organization and created and utilized in various business functions, it is difficult to define the its contents (White 2007, Sudarsan et al. 2005). As one of the few scholars, Vroom (1996) has proposed different attributes of product data:

- Product identification code and product name
- List of parts, materials, drawings, testing manual, technical design data
- Parts of product prototype
- Conception of production process design, tooling, inspection guidelines
- Logistics data, such as the number of products per box, transportation package, description of packing materials, packaging instructions
- Product target price.

In a manufacturing firm, information about a product is a foundation of the integration of business functions and processes as the internal and external parties utilize and produce data in their day-to-day activities. For instance, internal functions are involved with product data comprising design, planning, and engineering connected with procurement, manufacturing, and customer service whereas external functions are concerned with collaborative stakeholders such as suppliers, maintenance services, etc. The control and distribution of product data is emphasized by companies operating in a networked environment, specifically, for business functions closely related to product process throughout its lifecycle – e.g., design, production, after-sales service, etc. (Yang et al., 2007; Rachuri et al., 2008; Saaksvuori & Immonen, 2004)

2.3 Product Structure

A product structure describes a particular product component, product element, or subsystem where the relation between various objects can be mutually hierarchical in different levels (Saaksvuori & Immonen, 2004). In connection with the concept of productization, product structure is a sequential representation of what the customer purchases and a breakdown of its technical configuration in the form of two segments: commercial and technical (Lahtinen, Mustonen, Harkonen, 2021). The commercial portion is usually seen, chosen and bought by customers whereas the technical section comprises unseen components contributing to the creation of those commercial offerings.

To explain further, product families, configurations and sales items form the commercial structure while version items, components, sub-components, etc. build the technical structure (Harkonen, Tolonen & Haapasalo, 2017). Following the establishment of a product structure, relevant stakeholders in an organization gain a clear view of the product. For example – as further elaborated by Harkonen, Tolonen & Haapasalo (2017) and Lahtinen, Mustonen, Harkonen (2021); sales and marketing department is concerned with commercial side, and departments like manufacturing, supply chain, product development, etc. are involved with technical aspects. In addition, by segregating hardware, software, and service as separate sales items, they can be individually addressed by respective technical departments. For instance, production personnel only deal with physical sales items along with their technical structure. At the same time, if service is a sales item (for a product delivery service provider), access to it will only be provided to logistics providers. Therefore, the product structure facilitates the distribution of specific product data to relevant stakeholders and avoids distracting employees with unnecessary information (Harkonen et al., 2019). Figure 3 illustrates the potential view derived from product structure. Item category views, and examples of stakeholder specific views have been represented as per proposals by Kropsu-Vehkapera &

Haapasalo, (2012); Jansen et al. (2005); Svensson & Malmqvist (2002); Andreasen et al. (1996).

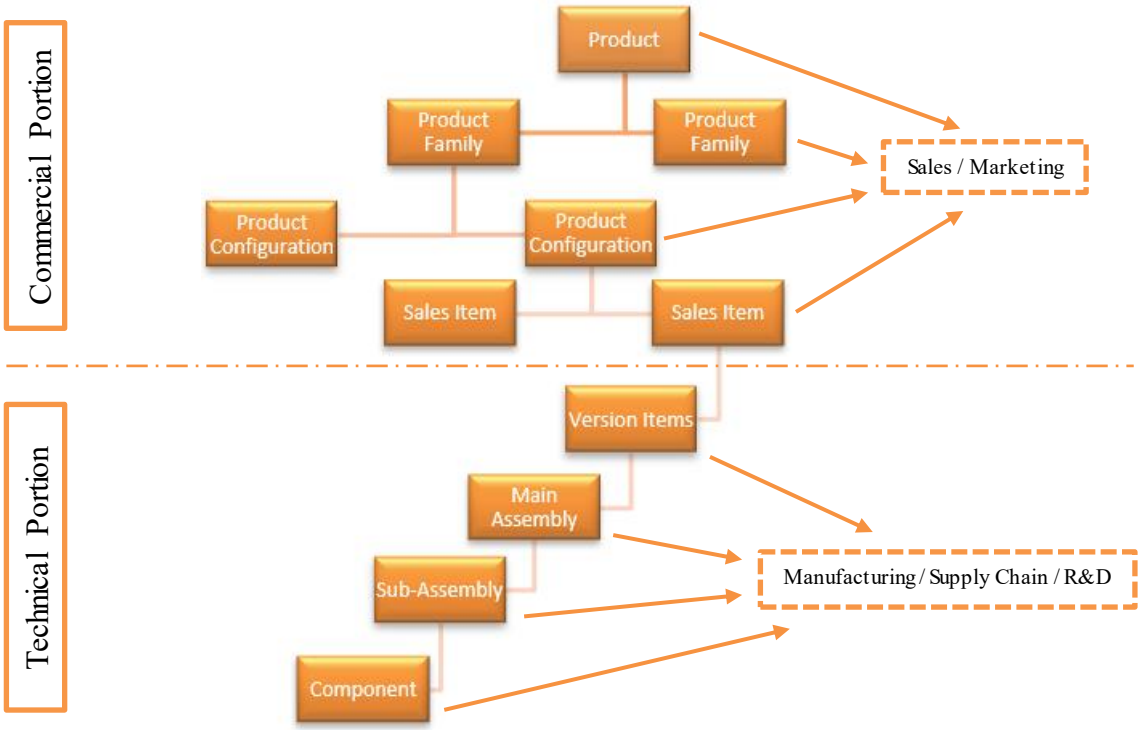

Figure 3. Idea of product structure.

2.4 Company Data

Back in the 1990s, data infrastructures were built in accordance with transaction data created by business applications like ERP and CRM, which were considered as the majority of data in companies. Since the entrance of the internet, an increasing quantity of global data have been generated via interaction between people, machines, social media, and in various structural formats (Thusoo & Sarma, 2017). Hannila et al. (2019) stated that data assets of an organization can be divided into three types: 1) **Structured data**, which is stored and processed with respect to a data model and can usually be managed or utilized with the help of Structured Query Language (SQL) (Vasarhelyi et al., 2015; Beal W. Webopedia, 2022). It is simple to enter, store and analyze this type of

data. As explained by Roger Wolter, Microsoft Inc (2006), structured data consists of the following data types; *Metadata* is data about data stored in the form of report definitions, XML documents in a log file within a data warehouse (Sadiq et al., 2017); *Hierarchical data* is involved with storing relationships between other data, usually as separate descriptions of real information, such as, product lines (Buneman et al., 2004); *Transactional data* refers to data generated by business processes and business applications. For example, orders, invoices, payments, etc.; *Master data* comprises vital business information related to customer, vendor and product integrated across the company (kumar Das et al., 2011) and ideally, remains mostly unaltered (Silvola et al. 2011). 2) **Semi-structured data** is structured data that does not have a strict data-structure. 3) **Unstructured data** is the most common data category consisting of up to 90 % of the enterprise data. This includes data that does not abide by a particular arrangement such as row-column tables – for instance, multimedia content, magazine articles, etc. (Laney, 2017). Collection and maintenance of these data with reliability and accuracy are a necessity for all business functions within a company. Therefore, all functions within an organization must be capable of creating and maintaining data with efficiency (Fisher T., 2009).

In this paper, emphasis is put on the role of master data and transactional data in product data management.

2.4.1 Master Data and Transactional Data

Master data explains the properties of data objects under the light of businesses as they are used in different applications across a company in association with their definitions, roles, connections, metadata, and taxonomies (Loshin, 2009; Dayton, 2007). Berson and Dubov (2007) describe master data as data utilized across several business processes after they are cleaned, verified, and integrated into an enterprise-wide system. Primary entities include groups (e.g., organization, customer, employees, suppliers, etc.), positions (e.g., locations, facilities, etc.) and facets (e.g., products or services, assets, accounts, policies, etc.) (White et al., 2006; Moss, 2007). All the company data are not classified as master

data but only the key business elements that have the biggest impact consisting of subset of elements required for data sharing and standardization (Loshin, 2009; White et al., 2006). The scope of master data is wide and may consist of product data, customer data, supplier data, etc. Although, many master data related activities prioritize on product or customer data, any business data can be master data (Berson & Dubov, 2007). Usually referred to as "the single version of truth", Berson & Dubov (2007) mentions that master data is an imperative aspect to facilitate an organization to transform from account centric business to agile customer centric business.

On the other hand, transactional data includes the relevant events generated by all business processes in a company such as orders, invoices, payments, deliveries, etc. (Haug et al., 2013). Since transactions usually utilize master data related to products, customers, or suppliers in association with business applications like Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM), they are heavily reliant on the high quality and consistency of master data throughout the product lifecycle (Haug et al., 2013; Thusoo & Sarma, 2017; Silvola et al. 2011).

2.4.2 Data Governance

Growing data volumes stored using modern technology and convulated business environment are going beyond a company's capability to handle (Smith and McKeen, 2008), raising the necessity for properly integrated processes, controlled data architecture as well as consistent data and information management, for a company to survive (Chaki, 2015). Therefore nowadays, the task of data management has altered and entirely novel technologies and processes are needed to govern data and guarantee data quality (Chaki, 2015). The burning requirement for data management is the consequence of data explosion (Brous et al., 2016).

Data governance is the process of standardizing business data and related measures throughout an organization, involving data definition, distribution, ownership and quality (Waddington, 2008; Fisher, 2009). It guarantees high quality, consistent, and appropriate

data throughout the company (Bonnet, 2010). As per Brous et al. (2016), data governence is unique for a particular company depending on its specific data. The foundation of data governance includes availability, consistency, usability, data security and data integrity (Korhonen et al., 2013). One primary function of data governance is assigning data owners to every data element in the organization, which specifies who possesses the authority to gather and manage certain types of data to ensure data quality and availability (Silvola, 2018; Waddington, 2008; Fisher, 2009; talend, 2022). As put forward by Silvola (2018), data governance includes defining, organising and implementing guidelines for data management, and product data management functions based on the set guidelines, which develops the foundation for data management.

2.5 Product Master Data

Product master data is one form of master data integrating critical business information (Kumar Das & Mishra, 2011) with respect to attributes of products distinguished by item codes, classification, product structure, phase of life-cycle, supplier, intended cost/price, etc. generally stored in a PDM/PLM system or ERP system (Snow, 2008). In practice, product master data is created once during the new product development (NPD) stage before it is circulated across the company for use in other business functions and processes (Ameri & Dutta, 2005; Hannila et al. 2019).

As explained by Silvola et al. (2019) and Wu et al., 2014: product master data is inspected and authenticated in several development phases through departmental and cross-functional collaboration to ensure that the resultant data content abides by the requirements for usability in the business processes. Therefore, a set of base data is identified and integrated within an enterprise system to enable smooth and accurate data flow by connecting company business process, master data, product data and enterprise applications. As a result, correct information about a product can be quickly accessed, which facilitates making the right decisions in the context of a product's lifecycle stage or change requirements.

2.6 Business Processes

The principle behind business processes is to create value, both in primary and supplementary aspects (Margherita, 2013; Neubauer, 2009). Primary value is produced through product development, manufacturing, marketings and distribution as well as services (Corallo et al. 2010; Gunasekaran & Sandhu, 2010; Margherita, 2013). The structure of business processes can vary (Lin, Yang, & Pai, 2002), as company operations are linked to customers' requirements (Kock, 2005; Lee & Dale, 1998), to fulfill customer requirements over organizational, cross-functional drawbacks (DeToro & McCabe, 1997). Since business results are ensured by cross-functional processes and individuals in a company (Rummler & Brache, 1990; Womack & Jones, 1996), it is vital to implement strong business process management, alignment with company strategy, competent workforce and technology (Jeston & Nelis, 2008).

Company business processes are related to productization, product structure and enterprise applications, describing how products are developed, manufactured, maintained, marketed, ordered, sold, supplied, delivered, invoiced, etc. (Tolonen et al., 2014; Tolonen, Harkonen, et al., 2015; Hannila, Tolonen, et al., 2019; Harkonen et al., 2017; Kuula et al., 2018). Based on explanations put forward by Lin et al. (2002), Jeston & Nelis (2008) and Tolonen et al. (2015a), the idea of business processes within a company has been developed (Figure 4).

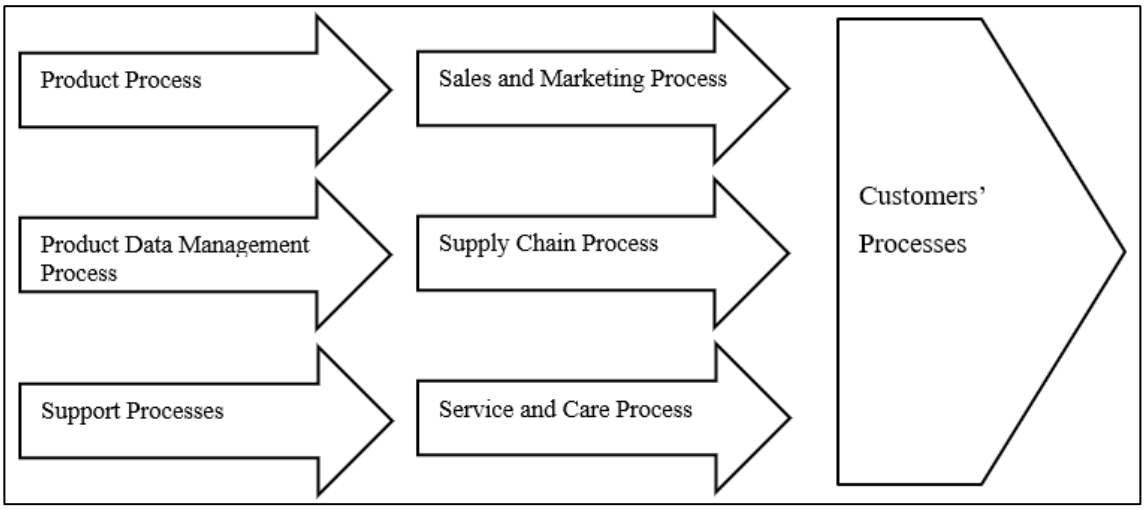

Figure 4. Business Processes.

2.7 Enterprise Applications

CIMdata (2001) states that in an ideal business scenario, Product Data Management / Product Lifecycle Management (PDM/PLM) system is an enterprise application utilized to manage the product structure. The essential data comprising design, maintenance and disposal of a product, without which, product management by companies would become a challenge, are incorporated into PDM systems (Stark, 2005). The enterprise application facilitates in organizing and utilizing data to enable a product to reach the market faster (Huang et al., 2004; Sulaiman, 2000). PDM systems, as explained by Hannila et al. (2019), Silvola et al, (2019), Stark (2005) and Svensson (2002), are IT systems fulfilling the purpose of a central database for history and process of products in a company while expediting integration via smooth sharing of information across relevant business functions / processes like sales, manufacturer, product manager, etc., involved with the product. The product master data (created once during new product development phase), is usually reserved in PDM/PLM systems before being distributed for utilization in other business functions/processes (CIMdata, 2002; Stark, 2005; Hannila, Tolonen, Harkonen, & Haapasalo, 2019; Svensson & Malmqvist, 2002; Silvola et al., 2019).

PDM system links product data in relation to product and process management, incorporating an infrastructure for sharing and managing data for stakeholders alongside a related user interface (Rueckel et al., 2005; Stark, 2005). PDM systems consist of at least the following fundamental modules (Kumar and Midha, 2006; Stark, 2005):

- Information warehouse or data vault
- Information warehouse management: tracing any data related actions
- Document management
- Configuration management (CM)
- Product structure management
- Product and workflow structure: definition modules
- Workflow and process management
- System administration management.

With reference to above list, an essential element of PDM systems is compatibility with other IT systems (Wei et al., 2009; Maletz et al., 2007). Design and model data created by Computer Aided Design (CAD) software along with engineering data and supplementary documents are stored and managed in PDM/PLM system, and other enterprise applications retrieve relevant information from them. For example: in case of purchasing, manufacturing or assembly of a product, Enterprise Resource Planning (ERP) system obtains data related to manufacturing instructions, Bill-of-Material (BOM), supplier information, etc. from PDM/PLM system. In addition, the Customer Relationship Management (CRM) system collects data in relation to product family, configuration, sales items, customer data, etc. from PDM/PLM system to support the work of marketing and sales departments. As an overview, the vital contribution of a PDM/PLM system is its integration with all business processes to share accurate and live information to the right place throughout the organization Harkonen et al. (2019) and Stark (2005).

2.8 Integration of Product Data Management into Business Processes

2.8.1 Product Data Management

The product structure plays a pivotal role in product data management (Boton et al., 2016). The structure also contributes to the management of bills of materials as well as numerous product configurations, offering functionalities for version items and linked parts (Eynard et al., 2004).

Product data, product structure and enterprise applications can also be managed by adopting standards such as STEP (Standard for the Exchange of Product Data Model) (Pratt, 2001). Different functions, such as design, production, procurement, order management, maintenance, etc. usually work in different systems because of their changing needs for the breakdown of product structure and functionality of enterprise applications (Svensson & Malmqvist, 2002). With respect to technical composition in manufacturing related activities, bill-of-material (BOM) is the most common product structure (Wu et al., 2010) usually stored in PDM/PLM system, or in ERP system and is freely transferred to other enterprise applications (Hannila et al., 2019; Svensson & Malmqvist, 2002).

On the other hand, Tolonen et al. (2014) explained that even though commercial aspects are linked with customer, sales, marketing, and product management, it is usually not connected to enterprise applications in companies. Hence, the commercial structure can include entities like product families, product configuration and sales items (Harkonen et al., 2017, 2018; Tolonen et al. 2014, 2018) formed between different companies to cooperate commercially (Mustonen et al., 2019). Ideally, relevant data is stored in and retrieved from a Customer Relationship Management (CRM) system as it assists sales and marketing in their work (Harkonen et al., 2019). To clarify further, establishment of product structure facilitates relevant stakeholders to gain a clear perspective of the product. For instance, sales and marketing departments only deal with commercial side, while product development and manufacturing departments are concerned with technical

aspects. In addition, by differentiating hardware, software and service as individual sales items, they can be distinctively addressed by respective technical departments (Harkonen et al., 2017; Lahtinen et al., 2021).

The idea of product structure and related master data is aimed towards data consistency to allow fact-based analysis (Hannila et al., 2020). For instance, real-time evaluation of product profitability by comparing revenue and cost information can be performed with the help of data, enterprise applications and product structure (Hannila et al., 2019), necessitating the use of both commercial and technical structures (Harkonen et al., 2019). The technical product structure is not rigid and requires updates in enterprise applications with respect to data and product structure (CIM Data, 1998; Hannila, Tolonen, et al., 2019; Pinquié et al., 2015). According to Svensson & Malmqvist (2002) changes in technical product structure can take place due to engineering change management throughout a product's lifecycle as well as activities related to cost reduction or quality improvement.

2.8.2 Integration with Business Processes

To manage product master data within large volumes of company data, companies implement specific applications (Silvola, Jaaskelainen, Kropsu-Vehkapera, & Haapasalo 2011), utilized over the life-cycle of the product (Stark, 2011; Silvola, Tolonen, Harkonen, Haapasalo, & Männistö, 2019; Hannila, Tolonen, et al., 2019). Das and Mishra (2011) highlighted how master data links business processes and enterprise applications, while Silvola et al. (2011) have connected the data, process and IT applications and portrayed the significance of master data quality by comparing it with human DNA. Figure 5 illustrates the combination of business processes and product data management by utilizing business IT tools.

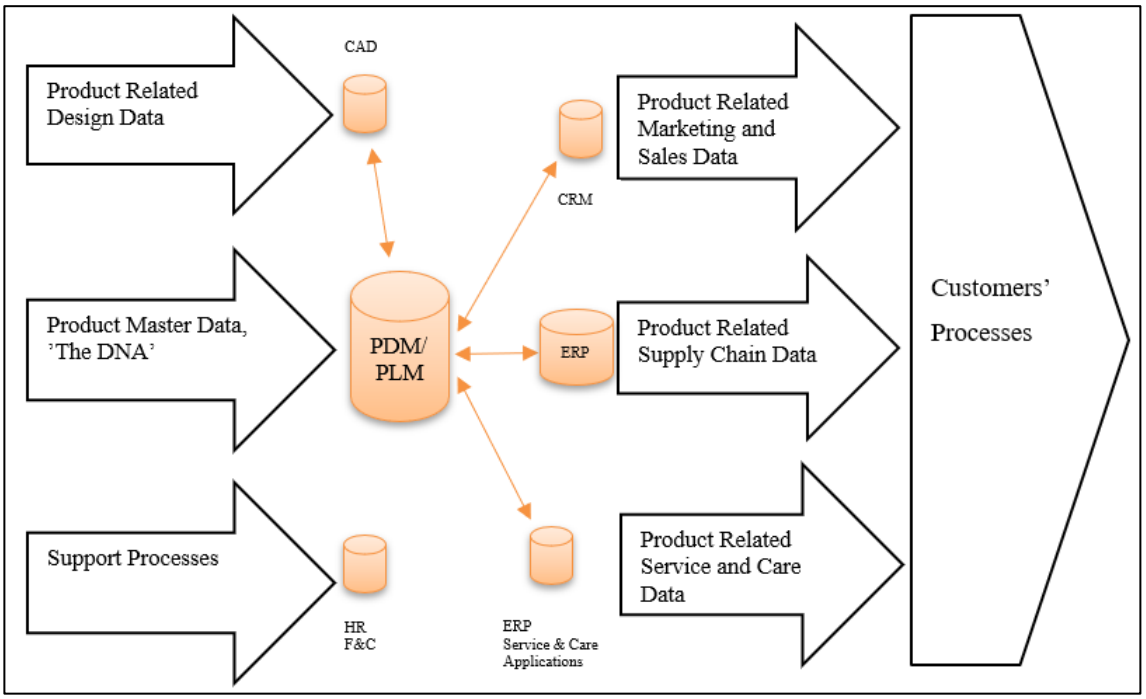

Figure 5. Incorporating Product Data Management into Business Processes by utilizing business IT tools.

In an ideal situation, product data would flow smoothly through the primary enterprise applications and essential business processes (Silvola et al., 2019). Integration of business process and functions of a company are affiliated with information about the product, while the factors of creation, management and distribution of data connect the expertise of the organization (Sääksvuori & Immonen, 2008). The purpose of master data is to integrate the business processes and the information system tools, hence highlighting the necessity of considering data as a strategic asset (Aiken & Billings, 2013), including product master data throughout the entire product lifecycle (Silvola et al., 2019). Product master data is created during the new product development phase before being distributed to other business functions and processes, further enriching, and supplementing it with other product-related business data based on changing functional needs. However, the missing link is the mutual agreement on who owns and manages the data within organizations (Aiken & Billings, 2013). To prevent data quality issues, data flow across

the business process and business IT systems must be systematically governed in relation to corporate strategy (Gao et al., 2010; Haider, 2015; Otto et al., 2007; Schaffer & Leyh, 2017; Silvola et al., 2019). A standard master data architecture facilitates the utilization of data to aid in decision-making within business process interfaces (Baghi, Schlosser, Ebner, Otto, & Oesterle, 2014). In complicated business scenarios, real-time information is required, and can be the only entity to bring competitive advantage, which highlights the significance of product data management in the management of a company (Chaki, 2015).

2.8.3 Challenge in integrating PDM into Business Processes

It is not possible to attain accurate product data management without first comprehending the product and relevant data from a business perspective. The understanding of product data is a challenge due to the complex arrangement of various stakeholders. Scattered throughout the organization and managed individually, product data are complicated and have varying meanings (Snow 2008, Saaksvuori & Immonen 2008, Boyd 2006, Sudarsan et al. 2005). Furthermore, product data exists in various forms in different applications (Feng et al. 2009; Liu & Xu 2001), usually in inconsistent formats due to little or no standardization (Baïna et al. 2009, Lee et al. 2006), resulting in discrepancy in business concepts and object definitions (Moss 2007). Therefore, integration of applications, data and process throughout companies is challenging to implement (e.g. Qu & Wang 2011, Silcher et al. 2010, Shu & Wang 2005).

2.9 PDM and Company Performance

Today's business environment, with its fierce global competition, raises the necessity for companies to continuously find innovative methods of reducing cost and enhancing operational efficiency to ensure a sustainable business. In our current business scenario, competitive advantage is typically dependent on data-systems, especially in manufacturing companies where efficient data management practices have become pivotal for business efficiency. Some of the challenges influencing change in processes

and the steep increase in the amount of product data (Li et al., 2015) include growing competition and tighter budgets, internationalization of business, shortening delivery times, common industry standards, increase in legal and environmental requirements, etc. alongside demand for cost reduction and higher productivity. This complex business environment has made it more difficult to find and maintain the right product-related information, leading to sluggish retrieval of data because the information is scattered across different systems. As a result, stakeholders cannot trust the product data in the company information system, which makes them establish their own documentation methods. This brings a huge drawback in the work of other stakeholders, who need the information, leading to a vicious cycle of product management. To break this vicious cycle causing hindrance in all operations and overall business performance, the implementation of PDM practices and a PDM/PLM system is imminent. (Saaksvuori & Immonen, 2008; Ameri & Dutta, 2005; Stark, 2005; Saaksvuori & Immonen, 2004; CIMdata, 2002). PDM/PLM has a pivotal role to enterprise sustainability. The revolutionary steps in relation to PDM/PLM implementations are to eradicate fragmented, convoluted, and opaque company activities, such as design (e.g., mechanical, electrical and software development), production, supply chain management, logistics, and services. (CIMData, 2015).

2.9.1 Operational Performance

Nowadays, although many manufacturing companies are internally networked with CAD systems, ERP systems, sales systems, etc., their heterogeneous nature demands integration for smooth information transfer. PDM/PLM systems can be utilized to improve direct communication, transfer of files and conversions between different file formats (Saaksvuori & Immonen, 2008). Design and manufacturing processes are highly benefited by sharing of product data as well as usage and visualization functionalities offered by PDM (Chan and Yu, 2007). The main purpose of introducing PDM is to facilitate electronic transfer of product data across organizations to manage their operations electronically, making it more efficient and effective (Saaksvuori and Immonen, 2004; Stark, 2005).

For instance, to aid in collaborative engineering and management of product development projects, product structures, documents and quality, enhanced solutions for managing product data are required (Yang et al., 2007; Rouibah and Ould-Ali, 2007). At the same time, supply chain performance is heavily reliant on product related data handling, as adopting appropriate PDM practices can help: 1) *Reduce inventory tied capital*: better management of component information and suppliers reduces component stock by expanding the convertibility of components; 2) *Improve employees' productivity*: individual knowledge is converted into intellectual capital available to the whole organization, hence reducing the resources used to retrieve and manage product related data; 3) *Improve quality and reduce cost of re-work*: fast, efficient and traceable change management due to streamlined product processes. (Saaksvuori & Immonen, 2008; (Huang et al., 2003, 2005; Johansson & Medbo, 2004).

2.9.2 Business Performance

At present, companies are obligated to prioritize information about markets and competitors alongside internal data on products and processes to improve, or simply maintain, their position in the market. The importance of product data has grown due to complexity in products and demand for product variations while companies face challenges related to product data because the required information is scattered and is usually located in different parts of the organization and in multiple data bases with varying file formats (Gime´nez et al., 2008; Kropsu-Vehkapera, 2012).

PDM enables quicker time-to-market due to reduced lead-time by helping to organize and utilize data (Huang et al., 2004; Sulaiman, 2000; Philpotts, 1996). In recent times, to enhance business performance, companies are seeking company-wide solutions through better product data management (CIMdata 2002). The existing approach in discussion about PDM comprise the entire product lifecycle in data management stressing more on integrated lifecycle management (e.g., Giménez et al. 2008, Sudarsan et al. 2005). Consequently, product lifecycle management has become a predominant concept now and also covers PDM activities. (Stark, 2005, Sudarsan et al. 2005, CIMdata 2002).

2.10 Synthesis of literature review

Based on the literature review, the sequence of relationship between three factors has been explained in Figure 6 as answer to the first research question; 1) product data, necessitating, 2) product data management, to, 3) enhance company performance. These factors comprise several concepts connecting the entire idea of product data management and how it improves performance of a company. The interlinked concepts include e.g., product structure, product master data, data governance and enterprise applications. After developing the product structure, company has a clear idea of product in accordance with relevant stakeholders in commercial and technical aspects, which is then incorporated into product master data while all related data are stored and transferred using enterprise systems. At the same time, a holistic data governance idea has been put forward to combine the concepts together by enabling the regulation of high-quality product-related business data. All these concepts must be managed systematically and synchronized with each other to derive the best results from product data management practices.

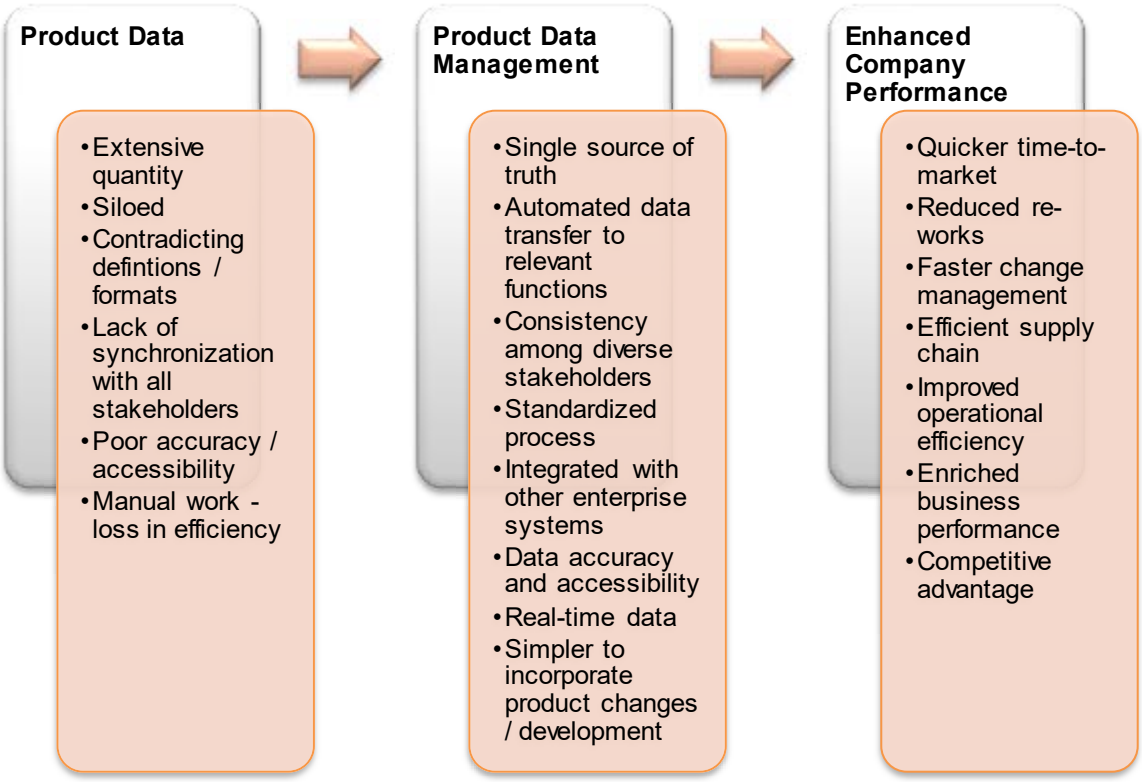

Figure 6. Product Data Management leading towards enhanced company performance.

To summarize: with the help of PDM, it is possible to undertake product development or incorporate product changes smoothly to introduce the offerings to the market at a quicker pace than competitors. Furthermore, owing to faster accessibility of real-time PD, change or improvement schemes can be performed with minimum attempts, as re-works would be reduced. This will also bring down supply chain-related costs as well as enhance the productivity of employees because of the elimination of manual work. The overall circumstance will not only improve operational performance but will also have positive impact on business performance of a company.

3 CURRENT STATE ANALYSIS

3.1 Case Company

The case company has been established and operational for over five decades and reserves an immense silo of data. The company is characterized as Business-to-Business (B2B) representing mature operations with a long business history and an annual turnover of around 52 million euros. With respect to literature review, case interviews and understanding of author, the offerings of the company are crop protection chemicals comprising several pack-sizes (or variants) usually having long lifecycles, and training for usage of these chemicals. In this circumstance, the sales items are various agrochemicals in specific sizes of bottles or packets available in cartons whereas the technical components include chemicals as well as packing materials such as high-density polyethylene (for bottle caps), low density polyethylene (for bottles), labels, glues, seals, etc. The other sales item is service to train farmers to use these chemicals. However, the product structure is not defined as such, as explained in the following section.

The finished products are transferred to distributors or resellers (customers) spread out in several locations across the country who would then sell to farmers (end-users). In the business process, marketing and sales promote the products in relevant regions while they determine the demand and sell the products to distributors; and supply chain is involved with importing the agro-chemicals in bulk quantity followed by re-packaging in the manufacturing unit based on required pack-sizes, before distributing the finished products to various branches across the country. At the same time, services in the form of training and development are offered by marketing teams to farmers to teach them about the usage of chemicals. Notably, the offered pack-sizes, chemicals and outlook designs of many products must be altered from time to time because of changing nature of demand, effective/appropriate chemical formulas and growing competition leading to requirement for cost optimization, reformulation of chemicals, and new promotional activities, respectively. In particular, a common phenomenon is, if an agro-chemical product is

found to be too harmful for the environment or less effective, it is brought back from market, reformulated with other chemicals before re-dispatching to customers, hence resulting in several changes.

Recently, the company has adopted a new Enterprise Resource Planning (ERP) system to streamline the flow of transactional data across business functions alongside a strong dependency on Microsoft Word and Excel as well as the previous ERP system, but much work is yet to be accomplished to facilitate product data management.

3.2 Current PDM practices and prime challenges

3.2.1 Current PDM practices

During the interview sessions, PD have been defined by the interviewees to involve all the data in relation to a product. It can be the technical formulation, quality / safety related PD, production, supplier, or sales.

PDM was viewed as organizing all the product related data, with particular emphasis on ensuring that all data were shared and available at the right time for stakeholders who needed the information. A major part of PDM, as understood by interviewees, was the efficient and effective utilization of controlled data. Furthermore, PDM comprised systematization of processes with regard to data management and product changes maintaining a record, which enable standardized methods of working, facilitated by enterprise applications.

On the other hand, based on the responses from interviewees, it was not possible to conclude on a common definition for PLM. Typically, the understanding of PLM was narrowed down as the length of time from introduction of a product till its removal, but the activities dedicated towards every phase of PLC were not specifically considered. Moreover, there was little or no knowledge about PDM/PLM systems.

3.2.2 Challenges in PDM practices

The interviewees were asked about the challenges they experienced in the existing PDM practices within the company and their responses have been explained below:

Lack of mutual understanding of the company's products. The interviewees' interpretation of company's products had been queried from different angles to determine the consistency of their understanding. As per the responses, it was clear that in addition to absence of a common viewpoint of products, there was also a deficiency in clarity as to who the customer was – distributor or end-user. While BOM was organized and managed by supply chain department, a deficit in uniformity between products or other departments was observed. For instance, both interviewees had opposing views of service being a sales item. It was obvious that different business functions perceived the products differently; e.g. view on products possessed by sales functions varied from that of finance, production or inventory, leading to fragmentation of product-related information. Some of the product related data were based on customer information or individual preference (usually influenced by top-management), which was the reason behind inconsistent data format. Case-by-case configuration of products (varying pack-sizes) without a strategy was a key contributor in the mix-up as product level analysis was not performed due to scattered and confusing data as well as an ineffective sales structure. On top of that, sales item level analysis required arduous manual work. Overall, this scenario was a major obstacle in developing a product master data and product data model, which further jeopardized communication and data quality.

Product Structure. It was observed that the case company did not have a defined product structure, but reporting methods using business IT systems were derived from a half-formed commercial and technical product structure. Concepts of product configuration and sales item were partially understood as outlook of products in the market while sales items were perceived as the commercial product structure. Moreover, only physical products were considered sales items, not services. Although sales figures were monitored on a daily or scheduled basis, it was not possible to track cost of goods sold

without unnecessary manual effort. Consequently, technical product structure was viewed as BOM only. Despite the presence of BOM, it was unclear as to which components should be considered as part of the product due to inconsistency in logic between products or business functions.

On the other hand, the company considered commercial and technical portions of product structure as isolated entities. The aspect of version items as portrayal of product versions was somewhat clear, but more than one simultaneous version items hampered the entire reformulation process due to inefficient management in changeovers. At the same time, renewal or removal of old products was viewed as a huge burden due to non-uniformity in technical structure of old products, resulting in stockpile of materials and data related to discontinued products from several years ago. It is imperative to have a vivid and mutual understanding of products to create a product master data, calculate total product cost and efficiently incorporate changes in configurations, while both commercial and technical product structures must be aligned.

Product data management process. This section emphasizes a fundamental factor of PDM; data governance, which includes data ownership, data maintenance and availability. Despite some comprehension of data ownership within the case company, it was observed that data were siloed, and data ownership was not specified, which led to waste of resources, lack of clarity in managing data and determining which data must be synchronized between IT systems. Furthermore, a defined data strategy and structured corporate-level data model were non-existent as data ownership was found to form naturally based on seniority level or responsibilities – the person who created a data became the inevitable owner of it. Additionally, every department manages their data in their own preferred way. In a particular circumstance, one batch of products was repeatedly failing and was returned from the market, but it was a challenge to identify the specific lot of imported chemicals that was defected, hence it required six months to resolve the issue and send the products back to market. In another example, procurement manager was responsible for PD related to material requirement planning (MRP) –

however, owing to lack of defined data ownership, the MRP data were sometimes sought by other departments from distribution or warehouse personnel who subsequently had to turn to procurement manager for the data, unnecessarily delaying the overall process. Moreover, PD for sales analysis and forecasts were separately maintained by supply chain and sales departments and periodically distributed to top-management, which engaged an additional employee and also compromised data quality. On top of that, while some data such as "material safety data sheet" were restricted within product development and quality control teams, flow of data was also hindered due to employees' tendency to keep their respective data to themselves to prove their individual significance within the company.

Due to deficiency in accountability, data generated were sometimes erroneous, which hampered the work of the stakeholder who utilized that incorrect data. This not only led to extra work and cost but also resulted in loss of trust from top management, who later decided to cross-check the data almost every time before approval, in spite of verification from respective department head. Recently, because of mismatch in communication with supplier in terms of technical specification, a machine was returned after it arrived in the factory. On top of that, owing to a lack of uniform product structure, data maintenance was difficult and time consuming because of huge amount of PD and manual work. In case of changes in configuration of products over their lifecycle, change data were incorporated based on ambiguous rules. As a result, extra effort was directed towards continuous monitoring and verification of data quality. In addition, PD were available on both, new ERP and old ERP, and searching and managing the relatively unorganized data was time consuming.

Information systems. The interviewees responded that the case company did not utilize a separate PDM/PLM system. The primary information systems in use were a recently implemented ERP software as well as the old ERP alongside Microsoft Word and Excel. A CAD application was used as an isolated system for product design or changes, and related files were manually transferred from one department to another while ERP was

used to store the files. A manufacturing module, incorporating the BOM, built in with the ERP system was used for production execution as well as to generate and circulate production reports from factory. Furthermore, the ERP system also consisted of a CRM module, which facilitated activities related to sales items, which was viewed as commercial structure by the company. Although CRM would generate customer-related data and sales figures, additional excel files were maintained by assigned personnel. However, the interviewees commented: *"Same data entry work is done multiple times, in Excel as well as ERP", "Data sources are both ERP systems, old and new".*

Cost calculation and data analysis were performed manually on Excel by downloading the data from ERP, but the absence of an appropriate commercial structure made it difficult to compare costs of individual sales items when numerous ones were added. On the other hand, information sharing with customers were undertaken via email or phone calls because neither distributors nor farmers were accustomed to any information system, which is why Excel files were manually maintained before updating the data in ERP. The unfavorable circumstances linked with customers' capability did not allow enhancement of the communication process in this regard. At the same time, the company did not openly share PD with suppliers and all relevant correspondence were manually performed via email based on documents and data obtained from ERP. Therefore, design files, specifications, purchase orders, etc. were created in ERP and sent to suppliers via email, while data were stored in company's database for indefinite duration of time. On top of that, for example, data for suppliers specified to what products they offered were not smoothly available at the click of a button and manual work were required. This process was perceived as: *"new ERP system is not user-friendly as data is not always available and integration is still ongoing".* It must be pointed out; despite all drawbacks, the integration between the ERP modules; procurement, CRM, manufacturing, human resource, etc., could be slightly more efficient if additional obstacles would not be raised due to lack of mutual understanding of products as well as an absence in defined product structure and data governance.

3.3 Synthesis of current state analysis

With respect to the factors explained in previous chapter, the current state of the company has been analyzed to derive a synthesis summarized in Table 1.

Table 1. Synthesis of current state analysis.

	Challenge
Mutual understanding of products	Lack of common perception. Fragmented product information. Inconsistent data format. No product master data / data model. Case by case configuration instead of configuration strategy.
Product Structure	No defined product structure. Difficulty in defining products. Arduous work in tracking cost of goods sold. Poor clarity of relevant components. Managing product changes. Commercial and technical structures are isolated. Stockpile of discontinued products' data.
Product Data Management Process	Data ownership not defined. No data strategy / model. Ownership forms naturally based on responsibilities or seniority. Little accountability leading to inferior quality data. Searching and managing data from multiple platforms - manual and time consuming. Continuous validation of data quality.
Information Systems	No dedicated PDM/PLM system. One fundamental system, ERP. CAD is separate software. Manual PD analysis and cost calculation using Excel. Extra work – using both old and new ERP systems, converting to Excel format and uploading into ERP. Information exchange with customers and suppliers is not streamlined, occurs over phone calls or email.

To summarize: it has been observed that the lack of common understanding of products is the biggest challenge leading to fragmented product information and inconsistent data formats. Furthermore, the absence of a defined product structure and data strategy has made it even more difficult to perform day-to-day operations because of manual repeated work and little or no accountability resulting in poor quality PD. On top of that, only one enterprise system is in use, which does not facilitate quick simple accessibility of data and cost calculation. Overall, the current practices and challenges of the company and the connection with inadequate PDM practices are clear and has been addressed in the following section.

4 RECOMMENDATIONS

From the literature review and empirical study highlighting the current business environment and imbalanced business processes of case company, it is clear that there is a need for development of PDM practices or implementation of a PDM system to facilitate integration with existing CAD and ERP systems. However, it must be understood that only introducing a PDM system will not solve everything, and a several other factors must be taken care of simultaneously.

4.1 Development proposals

Based on the analysis of existing challenges and consideration of literature review, it was possible to propose some improvement schemes to the case company and explain where to start and what should be the actions to enhance their practices related to product data management. The research indicates that the case company must *first* abide by a *top-down approach* to enhance their product data management practices.

Top-down approach. To initiate the improvement scheme, the top-management must start by considering product data management with strategy rather than focusing on micro-level aspects. For instance, when dealing with numerous products comprising many configurations, common understanding of products should begin from product design phase. Therefore, a *product strategy* must be developed, which specifies the mechanisms and rules for handling and defining products. This will ensure that every product is maintained by the same logic and guarantee harmony across the company. Furthermore, it is imperative to grasp the high-level idea about how changes in configuration affect operational processes and how a particular mechanism for managing and defining products impacts information systems. At the same time, a *PDM culture* must be embraced in connection with company's mission or goal to spark the people's interest and facilitate the adaption of this approach, which is new to the majority of employees. The concept of PDM and how it makes everyone's lives easier must be clearly explained

to all employees to positively influence their view and attitudes towards utilization. In particular, people must comprehend how entering accurate data in a standard format can avoid unnecessary challenges in change management and day-to-day operations. On top of that, maintaining product data in relation of its lifecycle and relevant responsibilities of the personnel must be clarified.

As the subsequent step in the improvement scheme, the results highlight that the company needs a *defined generic product structure* to facilitate product data management. In addition to supporting the standardization of products and how they are viewed across the company, this will aid in cost calculation of individual products and help characterize all product variants to smoothen the incorporation of configuration changes. Since the company is already partially familiar with the concept of product structure, their perception must be reformed by combining the commercial and technical product structure. As a result, *distinct views of separate stakeholder groups* can be created, which will develop a mutual understanding of the company's products and relevant data. In particular, sales and marketing will only be involved with descriptions of saleable entities, both physical and training services, while procurement, supply chain, production and inventory will cover technical product aspects such as BOM, raw material, production process, workers, etc. *Outlining stakeholder-specific views* on related PD has a huge impact on enhancing product handling and product data management practices. Consequently, an approach towards *developing a product master data* can be considered by determining the fixed basic PD of each product.

Finally, to make effective progress towards appropriate PDM practices, relevant information systems, specifically, a *PDM system*, is required to enable integration of CAD and ERP. PDM systems can guarantee an organized way to manage PD, including relevant processes, standard operating procedures and applications. The interviewees agree that smooth availability of high-quality up-to-date data is a necessity to ensure operational excellence, optimized decision-making, cost calculation as well as quick resolution of issues related to product quality, market complexities, supplier

collaboration, etc. In this respect, all PD must be gathered in a single platform to build a single source of truth. At the same time, compatibility of different applications for uninterrupted data transfer must be ensured. PDM systems are capable to flexibly respond to changes in business practices.

5 DISCUSSION

This study is related to the field of product data management contributing to the research stream involving management of product data throughout a product's lifecycle. Extensive research has not been conducted concerning product data management in general. Furthermore, no reliable publications have been found on PDM concerning agro-chemical industries. Notably, PDM is still an alien concept in Bangladeshi industries.

5.1 Key Results

The research paper has identified the significance of PDM in the performance of a company. From empirical study, it is clear that the case company, despite holding a long-term business record, is at a rudimentary level in terms of PDM practices. However, the interviewees have a level of perception regarding the concepts and benefits of appropriate PDM in the company and are positive about the contribution it can bring, if implemented. Therefore, the key results have been summarized as follows:

- Effective PDM is vital in enhancing operational excellence and business processes of companies, especially manufacturing types.
- Huge change is needed in people's, especially top-management's behavior towards utilization of PDM practices to spark their interest and understanding of the topic. Hence, "PDM culture" must be adopted in company's strategy.
- Initiating PDM practices by utilizing a top-down approach is needed in case company.
- Defining a consistent standardized idea of product data throughout the company by product structure modelling is a necessity.
- Identifying key stakeholders and their specified needs for data facilitates data flow.
- A PDM system is required to integrate other enterprise applications.

5.2 Scientific Implications

The results include different descriptions and models deriving the significance of PDM in improvement of operational and business process of a company. This study's main contribution is to provide a broader view of product data management in the context of the agro-chemical industry. This includes theories on product data, product structure, data governance, master data, enterprise applications, etc. Empirical evidence on existing PDM related challenges is exploited to further clarify the need for a strategy and data ownership, harmonized product data representation and stakeholder-specific views based on defined product structure.

The paper complements previous PDM literature (e.g. Harkonen et al., 2019; Hannu Hannila et al., 2019; Kropsu-Vehkapera, 2012; Kropsu-Vehkapera et al., 2009; Saaksvuori & Immonen, 2008; Stark, 2005; Sudarsan et al., 2005) by describing generically, the product structure, PD handling, data ownership and modelling, and linking these to operational excellence as well as business processes.

This paper highlights the significance of top-down approach from a higher level and stakeholder-specific views to ensure harmonized PDM practices throughout a company. In addition, the importance of product structure and data-driven decision making has been put forward. Therefore, the findings of this research clarify and contribute to previous studies (e.g. Harkonen et al., 2019; Hannu Hannila et al., 2019; Kropsu-Vehkopera, 2012).

This research creates new theoretical knowledge by describing the implementation of PDM practices in agro-chemical industry where frequent version changes are undertaken due to changes in chemical formulation or promotional reasons. Furthermore, a proposal has been put forward to adopt a “PDM culture” and utilizing product structure model to specify stakeholders’ views on product data, hence combining with previous literature (e.g. Harkonen et al., 2019; Kropsu-Vehkopera, 2012; Saaksvuori & Immonen, 2008;

Svensson & Malmqvist, 2002) to provide a more evident example of how these concepts can be realized.

Overall, the Master's thesis provides a clear definition of product data and suggests a suitable model for enhancing the management of product data across the organization. By doing so, it contributes to the unification of a disjointed domain of product data. Furthermore, the research demonstrates that companies will be benefited from adopting a more business-oriented perspective when analyzing and handling product data.

5.3 Managerial Implications

The purpose of this Master's thesis is to describe the impact of PDM in a company's performance and evaluate the current state of the agro-chemical case company to identify challenges followed by proposing solutions and a way forward. Agro-chemical products must be reformulated from time to time to make them more effective and environmental friendly; moreover, new promotional activities are adopted requiring different packaging materials - both circumstances result in several product variants. On top of that, little idea on PDM at a company-level as well as undeveloped PDM practices have led to lack of mutual understanding of products, absence of master data and a silo of data individually managed by stakeholders in their own way, further complicating the adaptation of PDM.

The practical implications of this paper include providing older agro-chemical companies in Bangladesh that are still adopting outdated processes with an overall perspective of PDM-related challenges and potential solutions, as well as pointing out where to initiate the whole implementation process. In addition, other industries in Bangladesh can benefit from the results, especially when harmonizing their products, developing product structure and utilizing a PDM system.

This research presents novel insights for Bangladeshi managers who seek new perspectives on PDM, as relying solely on technical product data is inadequate to

establish PDM across the entire organization. The study suggests that PDM managers must broaden their purview to encompass the complete product lifecycle, rather than solely focusing on product development and manufacturing. While it may not be feasible to provide customized guidelines for other companies because of lack of empirical data, a general set of challenges and possible solutions can be identified that enhances product data quality and accessibility throughout a product's lifecycle. Therefore, this paper offers useful recommendations to managers seeking to implement comprehensive PDM practices across the entire company.

Additionally, this thesis emphasizes that PDM entails the amalgamation of product management, data management, and organizational functions responsible for product information. As a result, developing effective solutions for PDM cannot be accomplished by individual organizational units in isolation; instead, it necessitates cooperation across the entire company. Senior managers responsible for decision-making must recognize the significance of such collaboration.

There are a variety of challenges associated with PDM, and many of them cannot be addressed solely by implementing a PDM / PLM application. Consequently, company managers need to abandon their conventional perception of PDM as merely an IT problem. One effective approach to initiate IT projects is for the company to establish a common and comprehensive understanding of its products, which can serve as a requirement list for IT solutions.

There are numerous internal stakeholders in companies, all of whom require access to product data, albeit from different perspectives. Companies aim to establish a shared understanding of their products and the associated data across the entire organization. This research recommends using product structure as a foundation for this harmonization effort. By leveraging a general product structure, organizations can ensure that products and their attributes are comprehended consistently throughout the company. Furthermore, a general product structure reduces the number of new products and related data, and also aids in defining product variations, which clarifies the final offering. However, managers

should be aware that the requirements for product structure are highly specific to each company. The research demonstrates that product structure is a suitable framework for describing all product types, as well as any possible combinations thereof. In order to manage products systematically in data systems, product structure should encompass all diverse product types. Moreover, the study reveals that a well-designed product structure not only enhances the efficiency of product data management, but also facilitates the integration of different data systems. Managers can leverage a general product structure to enable multiple perspectives on product data among various stakeholders.

It is important for managers to understand that any development process takes time, and it would be unwise to endanger current business relationships, functioning operations, or existing product portfolios. This also applies to improving product data management practices.

5.4 Assessment of Results

The objective of this research is to explore the management of product data across the entire company, and to achieve a deeper understanding of this phenomenon. The insights and perspectives of practitioners from a practical perspective have contributed to the knowledge in this area. Hence, the use of qualitative research methods is deemed appropriate for this study. The case study method was selected because it has the potential to offer a comprehensive perspective on the subject matter. According to Bryman & Bell (2003), the reliability and validity of qualitative research can be evaluated by addressing the following questions:

1. *How trustworthy are the results?*

   The degree to which research findings correspond with the actual world can be considered as the trustworthiness of the results. Although two personnel from different business functions have been interviewed, it must be noted that both have been working there for a long time and have been assigned with multi-faceted

roles, which provided them with insights of almost all aspects within the company. During the interviews, a semi-structured approach was used to allow for a flexible and interactive discussion between the researcher and the interviewees, giving the interviewees the opportunity to elaborate on the issues in the way they deemed best. Although the interviewers did not attempt to influence the responses of the interviewees, it is still worth considering their impact on the interview, as the topics discussed were somewhat ambiguous and required further clarification in some questions. Moreover, since once researcher has undertaken the interviews, there may have been a degree of researcher bias. However, it is worth noting that the researcher was a former employee of the company and already possessed significant insights, which increases the reliability of results.

2. *Are the results valid in another environment?*

   The studied case represent only one Bangladeshi agro-chemical company, which cannot be a portrayal of the entire agro-chemical industry. The selection was based on the fact that the author was a former employee and had easier access and better understanding if company's information. Furthermore, the case company has implemented an ERP software, which is a decent yet unintended progress towards PDM. Therefore, the author planned to show a way forward in terms of PDM.

3. *Are he findings likely to occur at other times?*

   The research setting is unique and it is unlikely that another researcher would be able to replicate it exactly. The findings are based on the conditions that existed at the time of data collection, which implies that the replication of the research is limited. It is believed that companies will continue to evolve their practices, making it impossible to replicate the research. Furthermore, each interview was unique, so even if the same questions were asked, full replication would not be feasible.

4. *To what extent have the researcher's own values influenced the results?*

   The researcher's prior experience working in the case company has shaped his perspective on the topic under investigation to some extent, but the presumptions and value judgments are primarily based on the literature review and the

experience gained during the preparation of the research project. However, since there was a single researcher involved, some bias may have occurred, even though he tried to remain neutral.

5.5 Limitations and Future Research

This Master's thesis aims to improve the perception of company-wide product data management as a method of improving PDM practices in one agro-chemical company. Generally speaking, there have been limited research to fully comprehend product data across an entire company. This qualitative study aims to explain this research area and offer a solution for organizing product data to support company-wide PDM. The study identifies the prerequisites for PDM at the company level and provides practical descriptions and models for achieving consistency in PD representation throughout the organization. The findings are preliminary and highlight the factors that should be considered to take a holistic approach to managing product data. Further research is recommended to confirm and expand upon these findings.

The study suggests a top-down approach to initiating implementation of PDM alongside adopting a product structure that incorporates the perspectives of relevant stakeholders to achieve a standardized product concept across a company. Moreover, it recommends the utilization of a PDM application. However, since these solutions have not yet been tested extensively in the case company as well as among different audiences and industries in Bangladesh, further research is necessary to evaluate its effectiveness. Additionally, the general product structure model requires validation in various scenarios and more precise explanation to facilitate easier application for companies. Furthermore, potential future research could explore incorporating external stakeholders in the stakeholder analyses.

Companies usually search for established methods that can expedite the implementation of new initiatives. Therefore, it would be beneficial to perform a longitudinal study to monitor companies that have already employed the top-down, product structure and

stakeholder-specific views approaches over an longer period of time. Hence, further research could involve descriptive case studies that examine the process of establishing a PD strategy / model as well as identifying stakeholders and their viewpoints.

The study has been conducted on one medium-sized agro-chemical company, which indicates that the applicability in small companies or other companies in the agro-chemical industry is unclear. Nonetheless, accurately defining products and their associated data is a significant concern for all companies. To avoid challenges with product data management, greater understanding is required regarding when it is crucial for a company to adopt a more organized approach to managing product data.

To describe some inevitable situations leading to an adaptive approach: it must also be understood that ERP integration in the case company is a work-in-progress and any company struggles with its day-to-day operations during these phases, let alone, PDM practices. Furthermore, it is not possible to develop the supplier and customer communication systems for the case company because of lack of capability in both external stakeholders. At the same time, in some circumstances of new agro-chemical products, there is no previous data related to its compatibility with the soil composition of local regions or with existing packaging materials, which necessitates iterative experimentation to find the appropriate chemical formulation or packing material respectively.

This section proposes numerous promising areas for future research to advance product data management practices. Although the study was performed in the agro-chemical sector, the recommended research directions are not industry-specific and can be applied in other sectors where better product data is critical for ensuring and enhancing operational and business efficiency.

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Appendix 1: Interview Questionnaire

Part A. Company information

1) Name of Company.
2) Primary products; main customers.
3) Year of establishment, number of employees and annual turnover.
4) Names of interviewees; job titles; years of experience in industry and tenure at the company.

Part B. General questions on Product Data Management (PDM)

1) Please describe your perspective on product data.
2) What is PDM? What is a PDM system?
3) What are the major challenges in the area of PDM in your company? Product structure and/or data related limitations, process related problems and/or information system weaknesses.
4) What are the benefits of a PDM system?
5) What would be a genuine contribution of PDM to make a big impact on your company's success?

Part C. Product structure and Product Lifecycle Management (PLM)

1) What is PLM?
2) How do you define a product structure?
3) What are the reasons for changes in product structure throughout a product's lifecycle?
4) Do you offer different product variants/versions to your customers? If yes, how do you utilize product variants? Is the number of product variants limited or uncountable?
5) What does product traceability mean to your company?

Part D. PDM processes and data ownership

1) Is it difficult to manage and maintain product data (PD)?
2) How are the PD maintained within the organization in practical level? (Description of the operational model of the data maintenance).
3) How is the ownership of data defined in different business functions / departments throughout the company (for example, in product development, procurement, manufacturing and sales operations)?
   - Who/which department owns the PD that you (your department) utilize? (Who is the responsible personnel to sustain the data)?

- Can you identify, who is delivering/creating the PD that you use?
- How do you use PD and/or product structure (in which operations/tasks)?
- From your operation point of view, what kind of changes have an impact on the PD?

Part E. Information systems

1) Which tools do you have for PDM and/or PLM activities? Can you describe the solution/application/system you have? Is the system customized for your needs or are you using a standard version? Do you have some other administrative tools in use for that purpose like MS excel, etc.?
2) What is the level of integration between PDM and/or PLM system (if any) and systems like computer aided design (CAD), manufacturing resource planning /enterprise resource planning (ERP), etc.?
3) Do you have separate systems to share/transfer PD information with suppliers and/or customers?
4) Any additional comments/suggestions related to the topic?