FACULTY OF TECHNOLOGY

Integration of substance compliance and a product lifecycle management system in case organization

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ABSTRACT

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Substance compliance is the field of identifying applicable product material regulations and managing the product composition to match those regulations. As the various regulations expand and new standards are added, manufacturers must take increased precautions to ensure their products are in line with the latest regulations and standards for example by developing system integrations to ensure better management processes.

This thesis aims to study the development and implementation of an integration of a substance compliance management system with a product lifecycle management (PLM) system in a case organization. The perspective is on identifying how an integration of substance compliance and a PLM system can be conducted and what to take into consideration when introducing such an interface to current operations. The research methods used were two sets of semi-structured interviews and participatory observations.

The findings of this study indicate that substance compliance has connections to data quality. In the case organization in particular, in order to fully grasp the benefits of the integration, special care should be put into completing a three-step plan focused on improving data quality management, using change management to introduce the integration, and utilizing an early and proactive approach to substance compliance. The study largely focuses on giving actionable improvement recommendations, but it also contributes to the substance compliance literature by conducting a brief literature study on the topic and showing the connection of product data quality with the field of study.

Keywords: substance compliance, material compliance, product lifecycle management, PLM, change management

TIIVISTELMÄ

Aineiden vaatimustenmukaisuuden hallitsemisen ja tuotteen elinkaaren hallintajärjestelmän yhdistäminen kohdeyrityksessä

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Aineiden vaatimustenmukaisuuden hallitseminen on ala, jossa tunnistetaan tuotemateriaalien lainsäädännöllisiä vaatimuksia ja varmistetaan, että tuote ei sisällä vaatimustenvastaisia aineita. Tuotemateriaaleja koskevien säädösten määrän kasvaessa elektroniikkavalmistajien on huolehdittava entistä tarkemmin, että heidän tuotteensa noudattavat viimeisimpiä lainsäädäntöjä ja standardeja. Yksi tapa tehdä näin on esimerkiksi panostaa systeemien yhdistämiseen, joka takaa paremmat hallintaprosessit.

Tämän diplomityön tarkoitus on tutkia aineiden vaatimustenmukaisuuden ja tuotteen elinkaaren hallintajärjestelmän yhdistämistä kohdeyrityksessä. Pääpaino työssä on tunnistaa, miten kahden järjestelmän yhdistäminen voidaan toteuttaa, sekä mitä tulisi ottaa huomioon yhdistetyn järjestelmän käyttöönotossa. Diplomityössä käytettiin kahta eri puolistrukturoitua haastattelua sekä osallistuvia havainnointeja tutkimusmenetelminä.

Tutkimustulokset osoittavat, että aineiden vaatimustenmukaisuudella on yhteys tuotedatan laatuun. Jotta kohdeyrityksessä voitaisiin ottaa täysi hyöty yhdistetystä järjestelmästä, tulisi yrityksen toteuttaa kolmiaskeleinen parannussuunnitelma. Suunnitelman tavoite on parantaa tuotedatanlaadun hallintaa, hyödyntää muutosjohtamisen oppeja järjestelmän kehittämiseen ja käyttöönottoon, ja edesauttaa kohdeyritystä ennakoivaan aineiden vaatimustenmukaisuuteen. Työ keskittyy suurimmaksi osaksi kohdeyrityksen parannusehdotusten antamiseen, mutta se myös edistää aineiden vaatimustenmukaisuuteen kohdistuvaa kirjallisuutta pienellä kirjallisuuskatsauksella ja esittämällä linkin tuotedatan laadun kanssa.

Avainsanat: materiaalien vaatimustenmukaisuus, aineiden vaatimustenmukaisuus, tuotteen elinkaaren hallinta, PLM, muutosjohtaminen

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LIST OF ABBREVIATIONS

BOL	beginning-of-life
BOM	bill-of-materials
DQ	data quality
DQM	data quality management
EOL	end-of-life
E-PLC	engineering product life cycle
ERP	enterprise resource planning
MOL	middle-of-life
M-PLC	marketing product life cycle
MVP	minimum viable product
PDM	product data management
PLC	product life cycle
PLM	product lifecycle management
POP	persistent organic pollutants
REACH	registration, evaluation, authorization, and restriction of chemicals
RoHS	restriction of hazardous substances
SCM	supply chain management

1 INTRODUCTION

1.1 Study background

In last few decades, there has been a big push for organizations in different fields to join the "green" movement and operate in a more sustainable fashion (Duarte & Cruz-Machado, 2013). In the electronics industry this has directly resulted in the creation of various environmental regulations and standards such as the *restriction of hazardous substances* directive or the *registration, evaluation, authorization, and restriction of chemicals* regulation, which have the goal of eliminating harmful and hazardous substances and materials from products entering the markets (Scruggs et al., 2015).

Substance compliance – or material compliance as it has been coined in some literature – has risen as a field of study to aid organizations in complying with these regulations via various means (Buckreus et al., 2021). As new regulations and standards are being added each year, it has become increasingly important to conduct substance compliance thoroughly and efficiently. As such, more and more organizations have started utilizing external substance compliance solution providers or experimenting with various means of making the process of substance compliance management more efficient. One of these means is the introduction of integrating substance compliance management into another integral enterprise system such as an enterprise resource planning system, product data management system, or product lifecycle management system (Butler & McGovern, 2012). While the commercial development of these kinds of integrations and new solutions has been ongoing for a while, the academic literature concerning the topic has lagged behind and, as a result, research concerning integrating substance compliance management systems with other more widespread systems is extremely scarce. Furthermore, considering how increasingly important substance compliance is becoming for various organizations, the literature surrounding it is relatively limited.

This thesis aims to shed light on the field of substance compliance and to further study the topic of integrating substance compliance management into a product lifecycle management (PLM) system both in theory as well as through a case study conducted with a European electronics manufacturer case organization.

1.2 Research problem and questions

The aim of the thesis is to study the topics of PLM systems and substance compliance systems in the electronics industry, how these two topics relate to each other, and how an integration between the two could be handled successfully. The scientific interest in the topic of the research could be deemed relatively high, as while the topics of product lifecycle management and change management are widely studied on their own (Saaksvuori & Immonen, 2008; By, 2005), there is a scientific gap of knowledge when it comes to general frameworks for substance compliance management, the systems that are used in such operations, and their integration with other organizational information systems (Buckreus, 2021). In order to study the phenomenon, the following four research questions have been set:

RQ1: What connections does substance compliance have with product lifecycle management?
RQ2: How can a PLM integration project be implemented, and the changes sustained?
RQ3: What is the current state of PLM, substance compliance, and the system integration in the case organization?
RQ4: How can the case organization ensure successful use of a PLM-integrated substance compliance system?

The first two research questions have the intention of guiding the construction of the theoretical framework through the literature review. The first question focuses on substance compliance and product lifecycle management, especially in the electronics industry. It also has the goal of drawing connections between the two topics, as innately the integration of substance compliance management and a PLM system interweaves them together. In a way, the research question shows how the two systems are fundamentally connected and provides a theoretical view on which elements could be combined or enhanced through a system integration.

The second research question focuses on incorporating a change management aspect to the literature review, as a technical- or process view on PLM and substance compliance alone is not enough to analyze the implementation and deployment of the integrated interface. By providing a theoretical foundation on how PLM integration projects can be implemented, and the benefits sustained, the reader as well as the writer of this thesis are

better armed to analyze the real-life integration happening in the case organization. Like the first research question, the second one is answered in the literature review synthesis.

In contrast to the first two research questions, the third and fourth focus specifically on the case organization's circumstances rather than having a general viewpoint. The third question aims to guide the current state analysis in the case organization, where the topics at scope are the current practices and processes for both PLM and substance compliance, but also the current state of the integration project. The answer to the third research question is then presented in the synthesis of the current state analysis findings chapter.

The fourth research question aims to wrap all the parts from the previous research questions together. The answer to it is formed by mirroring the findings from the current state analysis with the theoretical framework built in the literature review and thus uncovering topics and concepts to consider when trying to ensure successful use of the PLM-integrated substance compliance management system in the case organization both in the short- and long-term. The research question is first implicitly answered in the fifth chapter, and then explicitly in the conclusion.

The justification for having four separate research questions comes from the nature of the integration project. As the ultimate goal of the master's thesis is to conduct a current-state-analysis on product lifecycle management and substance compliance at the case organization, while also analyzing how the integration project is conducted with the aim of giving actionable recommendations on how to deploy the integration and sustain the benefits it provides, the scope of the thesis is both multidisciplinary and particularly vast. As such, the literature review cannot focus on just one specific focus area as is traditional in master's theses but must take into account three large concepts of product lifecycle management, substance compliance, and change management. The four research questions mirror this multidisciplinary and vast scope.

1.3 The structure of the thesis

The structure of the thesis is divided into six distinct parts. Firstly, the study background, research problem and questions, the structure of the entire thesis, and the scientific impact of the thesis are introduced in the introduction. Then, the second chapter – the literature review – focuses on building a theoretical framework on the three topics of product

lifecycle management, substance compliance, and change management. This theoretical framework not only prepares the reader, but also the writer of the thesis to have the adequate understanding of the three topics to be able to analyze the current state of the case organization. Furthermore, the two first research questions are explicitly answered in the synthesis of the literature review. The third chapter of research methods and process describes the research process in detail, while also explaining the case context and case organization. In the fourth chapter, the research findings from the current state analysis are introduced and an understanding on the current processes of PLM, substance compliance and the state of the integration project based on observations, interviews, and technical analysis is presented. Likewise, the third research question is answered in the synthesis of current state analysis findings. The fifth chapter of ensuring successful use of the integrated system works as the discussion of the thesis, by mirroring the theoretical framework built in the literature review to the findings from the current state analysis in order to present ideas and concepts to take into consideration in the ongoing development, implementation and introduction of the PLM-integrated substance compliance management interface in the case organization. And then, in the sixth and final chapter – conclusion – the key results of the thesis are presented, in addition to giving condensed explicit answers to each of the four research questions. Additionally, the study limitations and potential future studies are covered and explained in the last chapter.

1.4 Scientific impact

The scientific impact of the master's thesis could be seen as one of the first steps in invigorating studies focused on PLM-integrated substance compliance systems, where a more diverse and interdisciplinary view on substance compliance can be reached. The master's thesis also additionally offers a new perspective on the use of the PLM system, as the substance compliance integration is the first of its kind in the specific PLM system and therefore can be seen as a unique addition. The topic of PLM-integrated substance compliance systems or interfaces is also rather new, and as such only few commercial examples exist, and the literature concerning such integrated systems is near nonexistent. It could be a fair assumption, that after the integration project and the publishing of this master's thesis, the use of integrated substance compliance becomes more widespread across companies already utilizing PLM software, similarly as how the use of supplier relationship management has become more widespread in many PLMs after the introduction of supplier relationship management system integration.

2 LITERATURE REVIEW

The literature review has the aim of providing a concrete foundation for the study as well as give the reader the readiness to understand the interplay of the integration's topics. As the implementation project of integrating a substance compliance management system with a product lifecycle management system can be seen as a multi-disciplinary endeavor, the readiness to analyze it must be equally multi-disciplinary. As such, the literature review aims to shed light on three separate topics of product lifecycle management, substance compliance, and change management, that are ultimately linked in the integration project.

Firstly, the theories of product lifecycle management are presented. In order to better understand the concept, the preliminary topics of product structure, life cycle and product data are explained. Then, the focus is shifted into the technical implementation of product lifecycle management systems, where the underlying theorems of data quality, data governance, and system connectivity are addressed.

Secondly, the literature on product substance compliance is approached – similarly as with PLM – from the viewpoint of technical implementation. The basics of material compliance and substance compliance management are presented in addition to the most prominent compliance standards and -requirements in the electronics industry. The different ways of implementing substance compliance management – with some added focus on substance compliance systems – in electronic manufacturer organizations are also examined.

Thirdly, after the building the big picture, as well as the technical view for the theoretical framework, the more humane side is explored through change management. The inclusion of the topic is well justified, as being able to analyze the timeline of a change project – which a system integration project undoubtedly is – and acting accordingly can be beneficial and prevent issues down the timeline. The focus is majorly on the change management process and more specifically on how to implement change and how to sustain the change efforts.

Then finally, the first two research questions which had the aim of guiding the literature review are explicitly answered in the literature synthesis. Some connections between the

topics are drawn to better highlight how they are connected in the light of this study. A complete visualization of the topics introduced in the literature review is presented in figure 1.

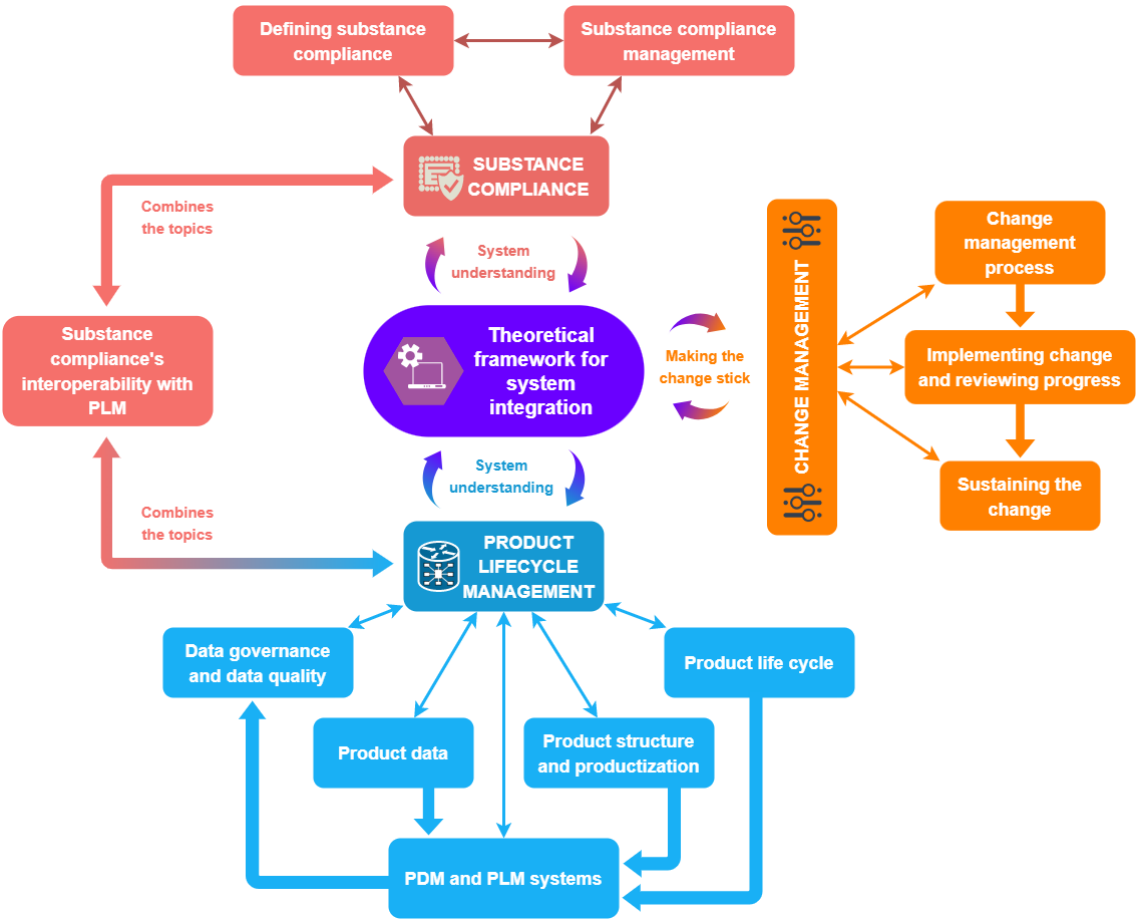

Figure 1: Visualization of the structure of the theoretical framework.

2.1 Product lifecycle management

As according to the prevalent literature, product data management – shortly put PDM – is the slightly smaller field of study found within the predominant field of PLM (Sudarsan et al., 2005). While PLM focuses on managing the product throughout its entire life cycle via processes, systems, guidelines, and other methods, PDM has the singular focus of aiding product development through the management of data (Philpotts, 1996). A prerequisite to understanding PDM – and by extension, PLM – is to understand the life cycle, data, and structure of a product.

2.1.1 Product data

Creating, manufacturing, marketing, and selling products creates a huge amount of various data and knowledge (Patil et al., 2005). As such, it is imperative to be knowledgeable on what exactly is product data and how it can be classified. As explained by Silvola (2018) "product data broadly covers all the data related to a product". This means that each piece of data that is connected to a product in any stage of the product's life cycle can be classified as product data. The data can be in physical or – much more commonly – digital format, and can be for example specifications, test reports, purchase orders, or CAD drawings (Stark, 2005).

Product data and its use can be understood through diverse types of views depending on the perspective. One way is to look at all the operations of different departments and divisions of an organization and see how they create and utilize product data. Product development for example is often the essential division that creates new product data, marketing division uses product data to visualize the appeal and cost of a product, and manufacturing utilizes product data to manufacture products while also potentially adding new product data, for example, through manufacturer test data (Peltonen, 2000). Another viewpoint is to categorize product data. Saaksvuori and Immonen (2008) divide product data into three categories: data that defines the product, life cycle data of the product, and data about other data i.e., *meta data*. The definitive data completely describes the product as well as it is functional and/or physical attributes. The product's life cycle data consists of product data that is functionally attached to a certain stage the life cycle or supply chain, for example recycling or maintenance data at the end-of-life of the product. Meta data is the descriptive data about other data, such as the date, time, and author of test reports (Saaksvuori & Immonen, 2008).

Another important aspect of product data in relation to product data management is the prevalence of *product master data*. According to several studies (Kropsu-Vehkapera, 2012; Kropsu-Vehkapera & Haapasalo, 2011; Silvola, 2018) product development practitioners perceive product data as a combination of product master data and other generic product data with a more functional role. Product master data is understood as the data that is born in the product development phase, for example the definitive data of a product, along with the products name and stock-keeping-unit. Additionally, Otto, Hüner and Österle (2009) describe that product master data differs from other data in four distinct means:

- Unlike transaction data (e.g., invoices, orders, or delivery notes) and inventory data (e.g., stock on hand, account data), master data describe always basic characteristics (e.g., the age, height, or weight) of objects from the real world.
- Pieces of master data usually remain largely unaltered. For example, as the characteristic features of a certain material are always the same, there is no need to change the respective master data. And while during the lifecycle of a product various attribute values are added over time (dimensions and weight, replenishment times etc.), the basic data remain unaffected.
- Instances of master data classes (data on a certain customer, for example) are quite constant with regard to volume, at least when compared to transaction data (e.g., invoices or purchase orders).
- Master data constitute a reference for transaction data. While a purchase order always involves the respective material and supplier master data, the latter do not need any transaction data in order to exist.

2.1.2 Product life cycle

An important factor in determining the right product development strategies and gaining competitive advantage is the clear understanding of *product life cycle* (PLC). The term was first introduced by Theodore Levitt in his publication "*Exploit the product life cycle"* (1965), where he went on to describe how the life cycle of a new product can be split into four distinct stages. These four stages – market development, market growth, market maturity, and market decline – are often visualized in the context of sales volume likewise on figure 2. In the market development stage, a brand-new product is introduced to the market with low – but rising – demand (Levitt, 1965). In the second stage – market growth – the product starts to take off economically and users start adopting the products in a widespread manner. Usually this is the de-facto situation where new users get introduced to new products, and where the probability of a new customer entering the product ecosystem is the highest. The third stage – market maturity – marks the start of an end to the life cycle of a product, as the market demand starts to decrease, and the competition gets fierce, as potentially better, and cheaper products start entering the market. Usually in this stage the product still has some minor growth in terms of sales, but it is nowhere as explosive as in the stage of market growth. And finally in the market decline stage the demand for the product gets incrementally lower each day, and eventually the product reaches the state of obsolescence, where competing products have passed the product

either via superior styling changes or via quality improvements and thus have made the original product inferior to the point where new customers have no reason to even think about purchasing it (Levintha & Purohit, 1989).

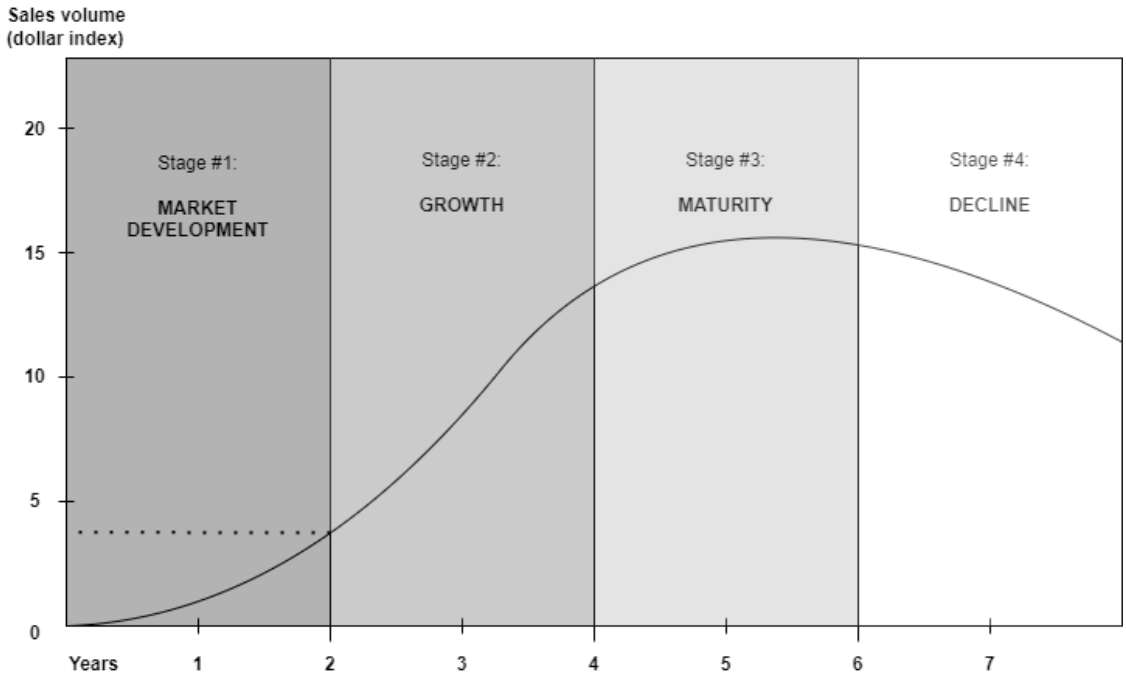

Figure 2: The product life cycle (modified from Levitt, 1965)

After the introduction of the original product life cycle model presented by Levitt (1965), different variations of it also started to come to light. One of these variations is to divide the products life cycle into three main phases: beginning of life (BOL), middle of life (MOL), and end of life (EOL) (Kiritsis et al., 2003). In comparison to Levitt's model, the beginning-, middle-, and end of life model takes a more product development focused perspective to the products life cycle. Planning, design, and production take place in the BOL, distribution, service, and maintenance in the MOL, and recycling, refurbishing, and retiring the product in the EOL. As is apparent, some PLC models focus more heavily to the profitability and market aspect of products, while others lean more heavily into the development and engineering side of product life cycle. As such, Cao and Folan (2012) divide product life cycle models into two categories: the more traditional models that are marketing focused (*marketing product life cycle model* or *M-PLC*) and the more engineering and product development focused models (*engineering product life cycle model* or *E-PLC*). Levitt's original four-staged PLC model is an excellent example of a M-PLC. Some other M-PLC models tacked on a fifth stage such as pioneering or saturation, but usually they all have the visualized bell-curve and high relation to the sales volumes. For E-PLC's, a good example is the model by Kiritsis et al. (2003), where the

product's life cycle was divided into BOL, MOL, and EOL. Basically, taking the original PLC's stages and repurposing them for a broader view outside of just marketing. Other E-PLCs follow the same formula of identifying the products life cycle in the context of their own – such as engineering, manufacturing, or logistics – rather through marketing. While Cao and Folan (2012) divided the two types of PLC models into M-PLC and E-PLC, the use is not widespread in literature and as such the terminology is often used interchangeably as the product life cycle. Going forward in the literature review, the perspective of engineering product life cycle model is taken if not specifically mentioned otherwise.

A very important factor aiding product development is the field of product lifecycle management, or PLM for short. As defined by Stark (2005) "PLM is the business activity of managing, in the most effective way, a company's products all the way across their life cycles; from the very first idea for a product all the way through until it is retired and disposed of". PLM is very closely tied to the engineering life cycle of a product (E-PLC) and incorporates many different software tools, databases, and management techniques within itself. At the core of PLM is the management of product related information, which is often the backbone of product related decisions and processes. Still, categorizing PLM as *just* the management of product related information seems dismissive, as it – depending on which definition is used – engulfs the whole of the product development process in addition to portfolio management, supply, and EOL management among many others (Ming, 2005). It is also important to differentiate the business strategy of PLM – which is the management of products through their life cycle – from the systems that are used to implement PLM. The distinction is important, as in literature both the business strategy and the systems use the same PLM abbreviation (Saaksvuori & Immonen 2008).

2.1.3 Product structure and productization

While very basic structures of products – such as that of a chocolate ice-cream with whipped cream in an ice-cream store – are easy to visualize and model, more complex ones – such as the manufacturing of a brand-new car – are not. To help with this end comes the concept of a product structure which has the aim of modeling manufactured products through representing the product, information linked to it, and the relation between different components within the product (Saaksvuori & Immonen, 2008). Each family, offering, assembly, sub-assembly, and component of a product can be modeled through the product structure, so in other words the *configuration* of a product should be

clearly visible. The modeling of generic product structures is standardized by the International Organization for Standardization as the STEP – *Standard for the Exchange of Product model data* – standard ISO 10303 (Pratt, 2001). Furthermore, Tolonen (2016) divides the concept of the product structure into two; firstly, there is the commercial product structure, which consists of the product solution, product family, different product configurations, and sales items. The commercial product structure can be conceived as the part that is "visible" to the customer. Then there is the technical product structure – which is also commonly referred to as the bill-of-materials (BOM) – which consists of all the things that are *under-the-hood* of the product offering i.e., not visible to the customer. These contain the components, sub-assemblies, main assemblies, and version items among other things. A visualization of a generic product structure can be seen in figure 3. The product structure – and especially the technical product structure or BOM – forms the backbone of both PLM and PDM as many of the functions of these systems are built upon the product structure and it's connected items (Hannila, 2019; Saaksvuori & Immonen, 2008).

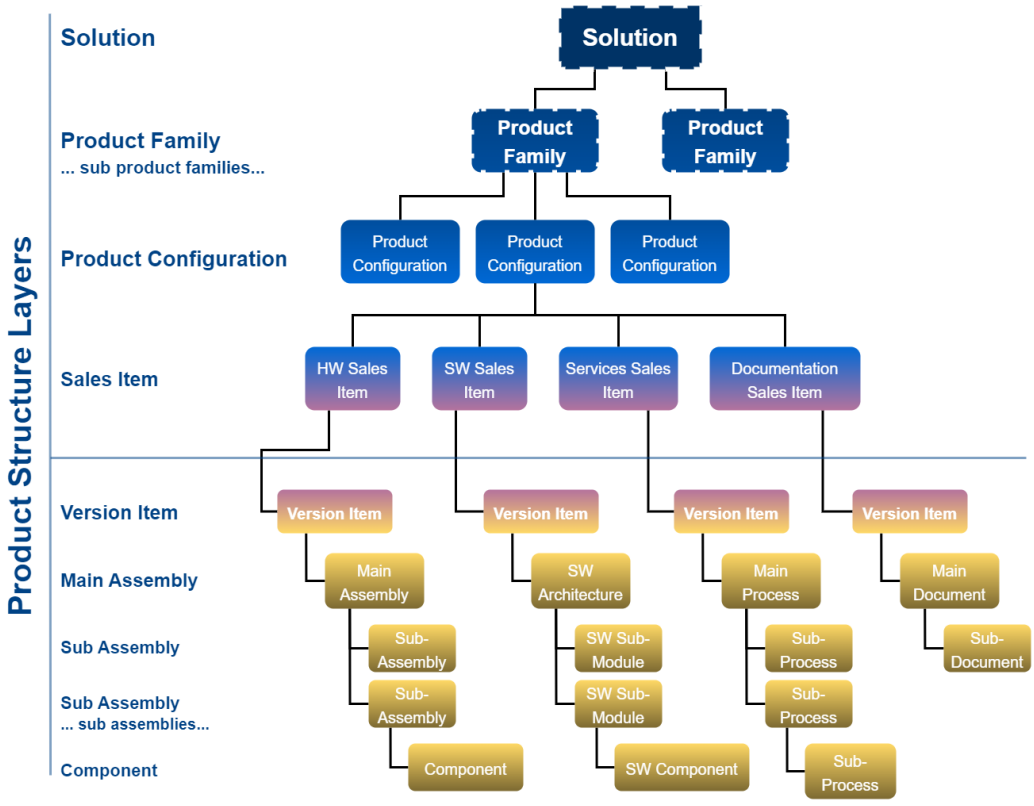

Figure 3: A generic product structure (modified from Mustonen et al., 2019)

A continuum from the topic of modeling the product structure is productization (or productisation). While Simula et al. (2008) argue that the literature has not yet come to

an understanding on what exactly is the specific definition of the term, Harkonen et al. (2015) define productization as "the process of analyzing a need, defining and combining suitable elements, tangible and/or intangible, into a product-like defined set of deliverables that is standardized, repeatable and comprehendible". While the term originated from the needs of intangible products, i.e., services, it has also become widespread in manufacturing industries, where a more technical and product centric viewpoint is taken. At the heart of productization is the use of *modular product components* which are product components that can be used interchangeably from one product to another (Rajahonka, 2013). Through productization, modular product structures also allow for configurability and customizable products, where customers can choose the right product configuration depending on their wants and needs. An example of this could be a customer choosing a smartphone with a certain color and extra in-built memory. As with the product structure that can be divided into the technical and commercial, so too can the concept of productization be divided into the commercial and technical. On one hand, productization supports new product development via systematically enabling efficiency, scalability, and understanding the voice of the customer, but on the other it also goes beyond engineering aspects by connecting other activities – for example marketing – that make the product easier to understand, tangible, and more valuable to the customer (Harkonen et al., 2015).

2.1.4 PDM and PLM systems

PDM systems – or shortly PDM as referred to as in literature – emerged in the 1980s as the de facto product data management tool when the design data amounts used in CAD (Computer Aided Design) systems started to grow into unmanageable portions (Lee & Chen, 1996). Back then the primary aim of PDM was to conveniently store and share CAD design data, which while not untrue in today's PDMs, is a far cry from all the different applications of modern day PDMs. While the literature has varying views on what exactly the basic functionalities of PDMs are, the following functionalities are typically found in every PDM (Liu & Xu, 2001; Stark, 2005; Philpotts, 1996):

- Data vault/information warehouse and document management
- Workflow and process management
- Product structure and configuration management
- Parts management
- Program management

As is apparent from these five qualities, a high connectivity and compatibility with other IT systems is a must for any PDM, as without it the information flow is impeded and the natural aim of PDMs – i.e., "ensuring that the right information is available to the right person at the right time and in the right form" (Liu & Xu, 2001) – cannot be reached (Wei et al., 2009).

The first important functionality of any PDM is secure storage of documents and other files, i.e., *the data vault*. Through the data vault users can retrieve, store, and reference via metadata any product data safely and be sure that the data can easily be found, even though the exact path to it may not be known (Peltonen, 2000). Importantly, the access rights also come into play with the data vault, as not all users should have the same rights to modify, delete, or cross-reference all data.

Continuing from access right, the *workflow and process management* is also an important aspect of PDMs. As changes to product data can have multiple effects on other data/systems, the changes should always be approved before submitting. Workflow and process management ensure that each change is authorized – sometimes through multi-step approval process – or unauthorized. Additionally, each change is saved as a previous iteration or level so that the entire change history can be seen at all times and – if necessary – the data can be rolled back to an earlier version (Philpotts, 1996).

Product structure and configuration management functionality forms the technical structure of the product by handling BOMs, product configurations, and design versions as well as linked variations (Liu & Xu, 2001). Handling the product structures includes creating and maintaining attribute, instance, and location information in addition to the traditional BOM data. Linking or associating test reports and other types of data to the product structure should be possible as well (Philpotts, 1996). Additionally, the product structure and configuration management functionality allow the automatic generation of generic BOMs from the product structure, which can be used for a multitude of tasks such as prototyping, design, testing.

Parts management in PDMs reference the ability to group and find specific parts according to entered specifications. For example, if a mechanical engineer is searching for a specific type of a gear to use in the next prototype, the parts management functionality would let the engineer easily find gears suited to that purpose. The searching criteria can also be the manufacturer of the component, its latest data modifier, or weight

for example (Peltonen, 2000). Having a component library where different kinds of parts can be found facilitates the re-use and standardization of product components and decreases the time needed for product design (Philpotts, 1996).

Program management – or project management in some literature as described by Philpotts (1996) – in PDMs aims to facilitate coordination between different processes, resource scheduling and project tracking, in addition to providing work breakdown structures (Liu & Xu, 2001). Combining resources with managed data creates a functional network to observe the completion of different tasks in the product development process, which – with the addition of an approval system – provide an added level of planning and tracking (Philpotts, 1996). Program management also gives individual users a good grasp of who is responsible of which task, as tasks and approvals can be assigned to specific users.

In modern PDM literature, the topic of PLM systems often comes up. While hugely similar – to the point where in some literature the terms are used interchangeably – the two types of systems are not identical and should not be mixed up, as while all PLM systems can be used for the same purposes as PDMs, PDMs potentially cannot perform all the necessary tasks required from PLMs. This is because PDMs are engineering focused information systems that manage and store product data and facilitate different processes through the use of product data in the new product development process, while PLMs on the other hand aim to track and manage the product data along the entire product life cycle and enhance it via offering "a set of tools and technologies that provide a shared platform for collaboration among product stakeholders" (Ameri & Dutta, 2005). In other words, the functionalities of PDMs should be always included in PLMs, as product data management is but one of the functionalities that full-blown modern PLMs offer. This is also apparent when the typical features of PLMs are discussed; often the same five functionalities – albeit with different terms or categorizing – that were crucial for PDMs are listed à la Saaksvuori and Immonen (2008).

The similarities and connections of PLMs and PDMs to other information systems is also highly discussed, as the first evolutions of proper PLMs came out nearly concurrently to the first batch of enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM) systems (Ameri & Dutta, 2005). From those three, the ERP system is historically seen as the most similar to PLMs/PDMs as it

too has the objective of managing all data enterprise-wide, but with the small difference of having the major focus be on manufacturing rather than on the product itself (Peltonen, 2000). Still, as the systems are similar in a lot of ways, they do of course have some overlapping features and functionalities, and as such some organizations might ponder about implementing PLM functionalities in an ERP or vice versa. Historically though, this is seen as a bad move, as both systems serve different purposes and thus cannot be used as a replacement for on another. Saaksvuori and Immonen (2008) worded the difference of ERPs and PLMs the best: "*PLM is the system for product data producers; ERP in turn is a system for product data consumers*". PLMs/PDMs relationship in regard to CRMs and SCMs is quite straightforward. CRM and SCM focus on improving the business practices of an organization either through the customer via CRM (e.g., customer analysis, relationship management, marketing) or through the supply chain via SCM (e.g., logistics oversight, inventory management, total pipeline coordination) (Chalmeta, 2006; Misra et al., 2010). Incidentally, as both systems rely heavily on product data, they should be well integrated – or at least communicate in some manner – with PDMs/PLMs.

The literature on how to implement a new PLM – or PDM – system seems plentiful (e.g., Batenburg et al., 2006; Schuh et al., 2008), but unfortunately the aspects of how to implement an integration to an already ready and utilized system are usually not considered in this type of literature. Still, some important points can be drawn from the literature, such as the notion of PLM *maturity* as defined by Nolan (1979). While the term was firstly used in the context of IT-adoption, it suits the implementation of PLMs as well due to general view on the topic. In broad strokes, PLM maturity describes how far an organization is in its PLM implementation in contrast to full PLM implementation (Kärkkäinen & Silventoinen, 2015). PLM maturity also considers the goals that need to be reached for perfect implementation. The technical steps on what to improve of course vary greatly depending on the organization, it's processes and PLM maturity, but a general framework defining and improving PLM maturity can be identified. Batenburg et al. (2006) define such a general framework as the PLM roadmap process, where the organization's PLM maturity is analyzed in five steps. (1.) Analyze the current PLM maturity and alignment, (2.) benchmark maturity, (3.) identify the desired PLM maturity and alignment, (4.) identify items to be improved, and (5.) define the PLM roadmap. The PLM maturity analysis similarly has five categories on which the state of the PLM is measured, which are information technology (IT), organization and processes (OP), management and control (MC), people and culture (PC), and strategy and policy (SP). A

full visualization of this can be seen in figure 4. The roadmap defined in the fifth step can be seen as an actionable plan to improve the PLM with a schedule. The process is also described as an iterative one, so the people in charge of the PLM integration should come back to the PLM roadmap process time and time again in order to optimize the process.

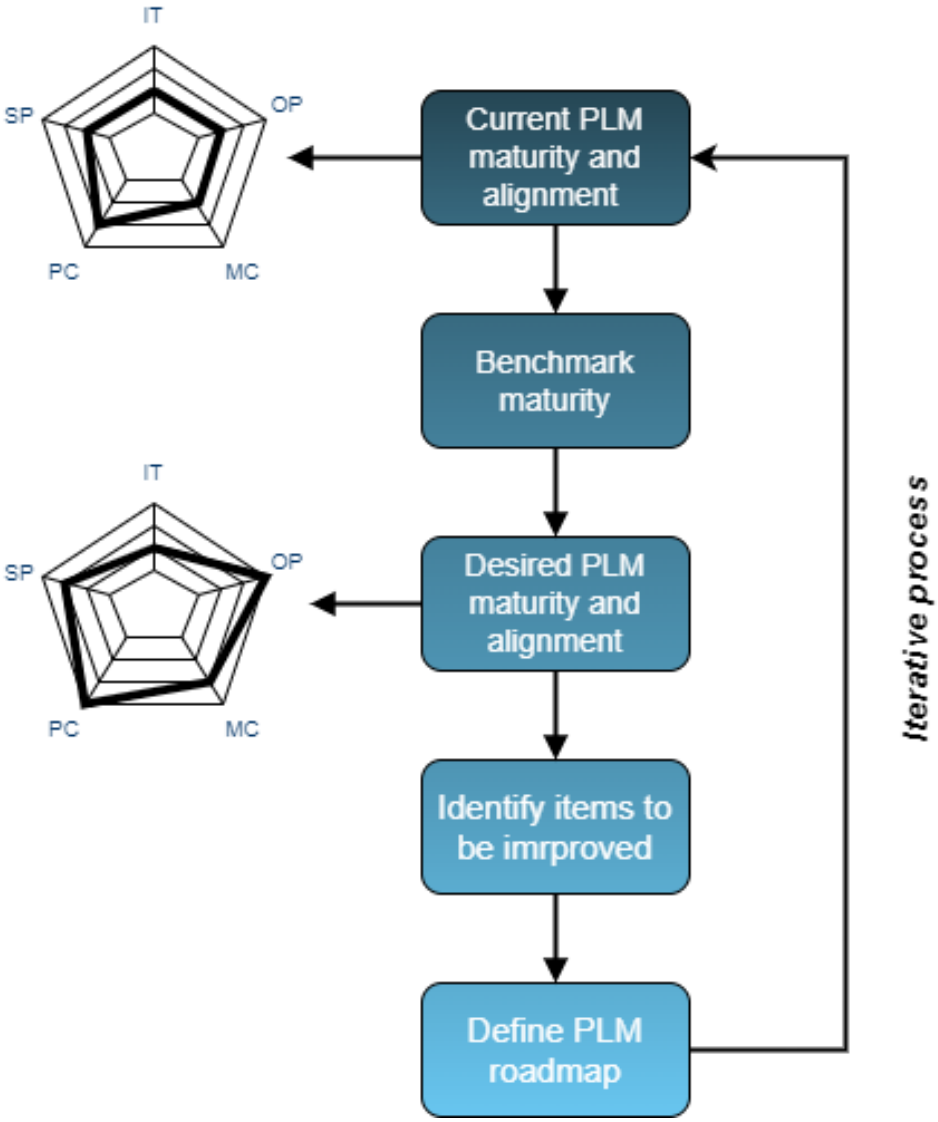

Figure 4: PLM roadmap process to improve PLM maturity (modified from Batenburg et al., 2006)

The benefits to utilizing PLMs are numerous, but also vary in nature depending on the organization and the way the system is used. It should also be noted that PLM systems are often uniquely integrated to the business processes of an organization, and as such the concrete benefits of PLM are rarely the same from one organization to another (Silventoinen et al., 2009). Still, some general benefits of PLMs – and by extension PDMs – can be listed, such as (Stark, 2005; Liu & Xu, 2001; Hadaya & Marchildon, 2012):

- Faster and less complex access to product information
- Generating more innovative product ideas and delivering them to markets faster
- Improving business processes
- Aiding collaboration between disciplinaries and teams
- Better overall quality on products through less defects and mistakes
- Enhancing project management via more precise project schedule
- Promoting the use of previous product knowledge and utilizing modular product structures
- Better recycle processes for products
- Improving relationships with supply chain partners

Of course, not all of these benefits can be realized if certain functionalities of PLMs are not utilized. For example, if an organization only uses their PLM as a glorified data bank for CAD structures and nothing else, it could be near impossible to gain the benefit of improved project management through it. In addition to the generic benefits, other demonstrable benefits have been identified in case studies (Saaksvuori & Immonen, 2008) or empirical PLM studies (Schuh et al., 2008). Saaksvuori and Immonen divided the benefits into three categories of "*saving time, improvement in quality, and reduction of tied-up capital*". Better access to product structures, reduction in overlapping work, and historical data on product information among others saved time, electrical acceptance processes, easy access to standards, and improved information security etc. improved the quality, and standardization of product items, management of smaller stock inventories, and improved production planning via correct product structures reduced the tied-up capital within the case organization. In the case of the empirical study conducted by Schuh et al. (2008), the benefits were too numerous to list comprehensively, but improved the processes of idea management, requirements management, product structuring, product program planning, change management, project controlling, risk management and quality controlling directly for example by higher innovation productivity, fostering continuous improvement, improving decisions-making, identifying quality problems earlier, and reducing development costs through modular products among others. As is apparent, the implementation and correct utilization of a PLM system offers numerous benefits which have a direct effect on various processes and not just the ones in product design for example.

There are also clear challenges in utilizing PLMs/PDMs. While the PLM literature often focuses on the issues related to the implementation of a PLM/PDM system from scratch – such as the lack of training on the use of the system, initial cost of implementation, embracing product engineers as implementation team members, or the ever-elusive topic of customization – there is not a clear consensus on what the most prominent challenges are in the *use* of these systems (Hewett, 2010; Saaksvuori & Immonen, 2008). Liu and Xu (2001) refer to the usability of a PDM system to being one of its greatest challenges, as most PDMs do not have the most user-friendly interface. One explanation for the low usability is arguably the fact, that since PDMs evolved from systems that were strictly for the use of engineers, to systems that are being used throughout the organization, the engineer-centric viewpoint to user interfaces – high functionality overall, including usability – has stuck with the systems. The challenge with usability is also not just related to bad user-interfaces, but also to such things as hard-to-use operations resulting in a steep learning curve (Liu & Xu, 2001). Additionally, in a case study by Kropsu-Vehkapera et al. (2009) four high-technology organizations' use of PLMs/PDMs were evaluated and the contender for most problematic issue was how to get the employees to comprehend product data coherently and to utilize standardized processes to avoid faulty or incomplete data. Other issues were the lack of a technical product structure and the lack of nominating a product data owner/responsible. Unsurprisingly, the biggest identified issues on the use of PLMs/PDMs are somewhat human centric; either based on the usability of the system via non-user-friendly interfaces or steep learning-curves or based on the users' (miss)understanding relating to product data, managing its quality over time, and lack of a data governance network (Liu & Xu, 2001; Kropsu-Vehkapera et al., 2009).

2.1.5 Data quality and governance

In modern product data- and life cycle management, arguably one of the biggest issues is keeping the quality of data high. While at first glance the topic might seem trivial – *just use accurate data and keep it up to date?* – there are many nuances to data quality (DQ), such as the fact that the same data might be used for different purposes by multiple users resulting in a situation where from the perspective of the original intended use the data's quality might be high, but from the perspective of another could be lacking (Tayi & Ballou, 1998). The management of data quality is also an intricate concept, as it is not only interested in data cleansing or improvement, but also on the gathering of the data, measuring its quality and continuously monitoring that the DQ also stays high (Ehrlinger

& Wöß, 2022). A prerequisite to understanding DQ management is to understand the concept of data quality as well as the measurable dimensions of it.

Data quality as a concept goes all the way back to the 1950s where data issues were studied in relation to product data, but it was not until the 1980s where the first definition of data quality was coined as "the degree to which a set of inherent characteristics fulfil the requirements" (Deming, 1982). From then on, the concept has evolved to have multiple different definitions over time, but the most fitting and modern view is, that DQ is dependent on the real-life use of the data, and as such when the data is fit for use – in any given scenario – it is of high quality (Wang & Strong, 1996; Wand & Wang, 1996). Of course, having data that is perfect – i.e., accurate, timely, and consistent at all times from any user's perspective – is entirely impossible and as such there should not be any efforts to reach that. The focus instead should be on having data that is accurate enough, timely enough, and consistent enough from the relevant users' perspective (Orr, 1998).

In order to manage the quality of data, the *dimensions* of DQ must first be understood, as they give a description and a reference frame for data quality measurement which is an intrinsic step in DQ management. The role of DQ dimensions is to "describe and classify measurable aspects of data quality" and similarly to present the characteristics of high-quality data (Silvola, 2018). The original – and the most prominently used – four main dimensions to DQ are accuracy, timeliness, completeness, and consistency (Ballou & Pazer, 1985). Additional dimensions have been presented to accompany the original four, such as the numerous ones introduced by Wang and Strong (1996), which together offer a broader view to DQ than the conventional four-dimensioned view, as seen in table 1. In this model each DQ dimension correlates to one of four DQ categories: intrinsic DQ, accessibility DQ, contextual DQ, and representational DQ. The dimensions are all from the data consumers' – i.e., anyone who sees, edits, creates, or interacts in any way with the data – perspective. Intrinsic DQ is of course interested in the accuracy and believability of data, but also on the objectivity and reputation of it. Contextual DQ focuses on the context of the data usage, where important dimensions are the added-value, relevancy, timeliness, completeness, and appropriate amount of data. To combat the issue of low-quality un-contextualized data, the contextual dimensions could be parameterized for each task, resulting in data that specifies which type of task it is useful for. Representational DQ dimensions are interpretability, concise and consistent representation, and ease to understanding, which either relate to the format or meaning of

the data. As such data must be in the correct format, interpretable and consistent (e.g., component measurements are reported with the metric system in a clear and concise way in European databases rather than with empirical system) to be considered high-quality by the representational dimension. Accessibility DQ dimensions relate to the accessibility and access security of data, and since the widespread use of numerous IT systems has only become more important (Wang & Strong, 1996). In addition to Wang and Strong's DQ dimensions, a number of other potential dimensions have been identified and introduced in literature (e.g., Shanks et al., 2000; Kahn et al., 2002), but still the most widespread dimensions – at least in data quality measurement – are the original four: accuracy, timeliness, completeness, and consistency.

Table 1: The categories and dimensions of data quality (modified from Wang and Strong, 1996)

DQ Category	DQ Dimensions
Intrinsic DQ	Accurary, Objectivity, Believability & Reputation
Accessibility DQ	Accessibility & Access security
Contextual DQ	Relevancy, Value-Added, Timeliness, Completeness & Amount of data
Representational DQ	Interpretability, Ease of understanding, Concise representation & Consistent representation

Like the multiple interpretations on DQ dimensions, *data quality management* (DQM) has gone over a few revisions as well. The most common definition for it comes from the Data Management Association (DAMA), that define data quality management as the analysis, improvement, and assurance of data quality (Otto & Österle, 2016). In surrounding literature, the methods for DQM are also numerous, as methodologies such as total data quality management (TDQM), methodology for information quality assessment (AIMQ), and data quality assessment methods have been introduced over the years (Wang, 1998; Lee et al., 2002; Pipino et al., 2002; Maydanchik, 2007). The different perspectives to DQM of course have different emphases, omit certain activities, and include some additional ones, but even then, they often are not contradictory. As demonstrated by Ehrlinger and Wöß (2022) in data quality literature the following four characteristics can often be found in nearly all DQM methodologies: state reconstruction,

DQ measurement or assessment, data cleansing or improvement, and the establishment of continuous DQ monitoring. As such, these four activities could be called as the "core activities" of data quality management and can be used as a starting point to a general DQM process.

The first core activity of DQM is the reconstruction of a current state, where "contextual information on organizational processes and services, data collections and related management procures, quality issues and corresponding costs" is collected (Batini, et al. 2009). This activity can also be skipped if sufficient previous documentation already exists, although the timeliness and extensiveness of it should be evaluated or at least kept in mind. The second core activity is the DQ measurement or assessment depending on which terminology is used. Both the measurement and assessment of data quality have been described as the most problematic concepts in the literature as the question on how to measure or assess the quality of data is often difficult to answer (Sebastian-Coleman, 2012). This is the reason why the dimensions of DQ are so important to identify, as they give measurable values and metrics that can be used to assess the DQ. As explained by Batini et al. (2009) the measurement phase can be further divided into five steps:

- *Data analysis*, which examines data schemas and performs interviews to reach a complete understanding of data and related architectural and management rules
- *DQ requirements analysis*, which surveys the opinion of data users and administrators to identify quality issues and set new quality targets
- *Identification of critical areas*, which selects the most relevant databases and data flows to be assessed quantitatively
- *Process modeling*, which provides a model of the processes producing or updating data
- *Measurement of quality*, which selects the quality dimensions affected by the quality issues identified in the DQ requirements analysis step and defines corresponding metrics; measurement can be objective when it is based on quantitative metrics, or subjective, when it is based on qualitative evaluations by data administrators and users.

The third core activity of DQM is the cleansing of data. In this process the inaccurate, flawed, or unfinished data is fixed and corrected through different automated or manual methods. Data cleansing can range from correcting a few dates on an excel sheet to

running highly sophisticated algorithms that correct and format entire databases based on preset requisites. The fourth core activity of DQM is the monitoring of data quality. In this phase, the focus is not only on the monitoring aspect per se, but also on creating iterative procedures to keep monitoring and constantly evaluating the quality of data (Ehrlinger & Wöß, 2022).

Having a thorough DQM process is often overlooked in many organizations as a waste of resources, but unsurprisingly the effects of low-quality data are numerous and, in some cases, even financially devastating (Wang & Strong, 1996). First off, as stated by Moges et al. (2016), if an organization utilizes data that is of bad enough quality, the first direct result is poor decision making. This is only natural, as the more accurate, timely, and specific the utilized data is, the more accurate and better decisions can be made with it. In addition to poor decision making, negative effects of poor data quality include lessened customer satisfaction, increased running costs, lower performance, lower employee satisfaction, and increased operational costs (Haug et al., 2011). Poor-quality data might even affect the organizational culture, as trusting the organization and its decisions becomes more and more difficult. Of course, the costs and negative effects due to poor-quality data do not end there, as Eppler and Helfert (2004) collected a list of 23 different costs that result from low quality data. The list contains costs such as "*excess labor costs*", "*data re-input costs*", "*time costs of viewing irrelevant information*", "*costs due to tarnished image or loss of goodwill*", and "*costs due to increased time of delivery*". So, as the results and effects of having poor quality data in use are as numerous, it could be perceived to be justified to conduct DQM in at least some degree.

While data quality management is a good tool for improving data quality, it alone is often not enough; guidelines and processes to *govern* data quality management are needed. According to Thomas (2006) data governance is important, since data is incapable of managing itself, it is entirely reliant on the people and tools that are connected to it, therefore making data governance not only the governance of data itself, but its related technology and people as well. In their comprehensive literature review on data governance, Abraham et al. (2019) take this definition even further: "*Data governance specifies a cross-functional framework for management data as a strategic enterprise asset. In doing so, data governance specifies decision rights and accountabilities for an organization's decision-making about its data. Furthermore, data governance formalizes data policies, standards, and procedures and monitors compliance*." While other

definitions for data governance – such as Newman and Logan's (2006) – have been presented, the one used by Abraham et al. (2019) is the most comprehensive and has the focus of data being an asset from a business' point of view. Likewise, several frameworks for practicing data governance have been presented, but the most notable one comes from Khatri and Brown (2010), where the decision domains of data governance have been separated into five parts. These five domains are data principles, data quality, metadata, data access, and data life cycle, as shown in figure 5.

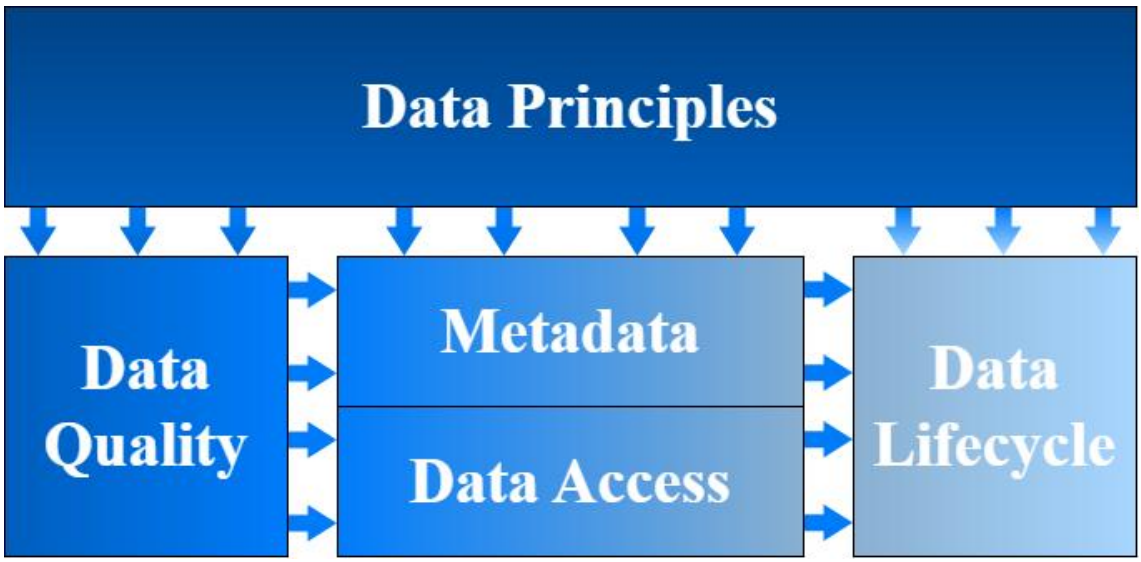

Figure 5: Data governance decisions domains for data governance (modified from Khatri and Brown, 2010)

In the framework presented by Khatri and Brown (2010) the decisions domains indicate who holds the decision rights and accountability in relation to an organization's data assets. The first decision domain, data principles, acts as the base for all other decisions domains by defining the boundaries of data usage as an asset. Data principles also set the company's standards for the second decision domain; data quality, which in turn create the basis for both how the data is described (à la metadata) and how it is accessed (à la data access) by data consumers. Then finally, the decisions relating to the lifecycle of data – i.e., the production, retention, and retirement of data assets – are handled in the fifth domain. The different data governance roles – such as data custodian, chief information security officer, data owner, etc. – are then assigned to each decision domain (Khatri & Brown, 2010). A complete framework for the decision domains and potential roles or accountabilities for each data governance domain can be seen in table 2.

Table 2: Domain decisions and potential roles or accountabilities for each data governance domain (modified from Khatri and Brown, 2010)

Data Governance Domains	Domain Decisions	Potential Roles or Accountabilities
Data Principles *Clarifying the role of data as an asset*	• *What are the uses of data for the business?* • *What are the mechanisms for communicating business uses of data on an ongoing basis?* • *What are the desirable behaviours for employing data as assets?* • *How are opportunities for sharing and reuse of data identified?* • *How does the regulatory environment influence the business uses of data?*	• *Data owner/trustee* • *Data custodian* • *Data steward* • *Data producer/supplier* • *Data consumer* • *Enterprise Data Committee/Council*
Data Quality *Establishing the requirements of intended use of data*	• *What are the standards for data quality with respect to accuracy, timeliness, completeness, and credibility?* • *What is the program for establishing and communicating data quality?* • *How will data quality as well as the associated program be evaluated?*	• *Data owner* • *Subject matter expert* • *Data quality manager* • *Data quality analyst*
Metadata *Established the semantics or "content" of data so that it is interpretable by the users*	• *What is the the program for documenting the semantics of data?* • *How will data be consistently defined and modeled so that it is interpretable?* • *What is the plan to keep different types of metadata up-to-date?*	• *Enterprise data architect* • *Enterprise data modeler* • *Data modeling engineer* • *Data architect* • *Enterprise Architecture Committee*
Data Access *Specifying access requirements of data*	• *What is the business value of data?* • *How will risk assessment be conducted on an ongoing basis?* • *How will assessment results be integrated to the overall compliance monitoring efforts?* • *What are data access standards and procedures?* • *What is the program for periodic monitoring and audit for compliance?* • *How is security awareness and education disseminated?* • *What is the program for backup and recovery?*	• *Data owner* • *Data beneficiary* • *Chief information security officer* • *Data security officer* • *Technical security analyst* • *Enterprise Architecture Development Committee*
Data Lifecycle *Determining the definition, production, retention, and retirement of data*	• *How is data inventoried?* • *What is program for data definition, production, retention, and retirement for different types of data?* • *How do the compliance issues related to legistation affect data retention and archiving?*	• *Enterprise data architect* • *Information chain manager*

2.2 Substance compliance

As a field of study substance compliance can be defined as the practice of complying with material compliance regulations such as RoHS, REACH or California proposition 65. Within this criterion also fit the identification of environmental product related regulations, gathering of product composition data, and then using various means to comply with each applicable regulation (Hsu & Hu, 2009; Buckreus et al., 2021). Substance compliance is defined mostly by its regulations, which are numerous and vary depending on what kind of products developed and where they are manufactured in or

exported to. For the purposes of the theoretical framework, the terminology of substance compliance is presented in addition to the practicalities of managing substance compliance, as well as connections to product lifecycle management and product development.

2.2.1 Defining substance compliance

Due to ever-growing concern over the environment and its changing nature, organizations all over the world are facing pressure to join the "green" movement and operate in a more sustainable manner. This has led to numerous changes in the way organizations conduct their business, from green management methods, favoring green innovation in product design, to complying with environmental regulations and expectations (Duarte & Cruz-Machado, 2013; Wiley et al., 2010; Bortree, 2009). The push to adopt more environmentally healthy practices in organizations is either mandatory (e.g., complying with regulations and laws), voluntary (e.g., trying to create a more environmental marketing image) or often times both to some degree. It is also clear, that there is a financial incentive to be more environmental, as violations to environmental standards – even to those that are not lawfully binding – can lead to direct as well as indirect costs by losing an operating license, decreasing the organization's public image, or simply getting a monetary fine for example (Buckreus et al., 2021). As such, the motivation for organizations to be sustainable and environmentally *compliant* (i.e., conforming to a set of rules) can be deemed high and constantly growing.

Substance compliance has the aim of ensuring that materials used within manufactured products abide by certain standards and environmental requirements such as the RoHS (Restriction of the use of certain Hazardous Chemicals) or REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) directive (Scruggs et al., 2015; Buckreus et al., 2021). The directives can be country specific, and they might apply only to certain industries, but the general aim is the same; adhere by the requirements that are valid to the product that you are manufacturing and selling in the given areas. The literature concerning substance compliance is scarce to the point that there is not even a consensus on what is the correct terminology. As pointed out by Buckreus et al. (2021) compliance is understood as the umbrella term that consists of other sub-types such as material compliance, product compliance, and environmental compliance, but those subtypes are not clearly specified. Environmental compliance could be argued to be related to any activity concerning adhering to any environmental requirements, while

substance compliance or material compliance are most of the time seen as related to the manufacturing of products, where the used materials and substances adhere to the regulations (Wu, 2009; Buckreus et al., 2021). The two terms of material- and substance compliance are used interchangeably in the literature, and both are also incredibly close to hazardous substance management, which also has the ultimate aim of making products and supply chains adhere to the environmental legislations such as RoHS or REACH (Hsu & Hu, 2009). From now on the term substance compliance is used, as it adequately describes the act of complying with regulations related to the substances used in the manufacturing products.

While the literature concerning the terminology of substance compliance is unconclusive, the legislations and standards themselves are clear. Numerous regulations exist, but as demonstrated by Buckreus et al. (2021), product manufacturers regard the regulations of REACH, RoHS, and POP (Stockholm convention on Persistent Organic Pollutants) as the three most relevant for substance compliance. Other well-known regulations are the California proposition 65, the battery directive, WEEE (waste electrical and electronic equipment directive), and U.S. conflict minerals regulation. It must also be mentioned that historically environmental requirements and standards have been on a steady rise and do not seem to be slowing down, as seen on figure 6 (Buckreus et al., 2021).

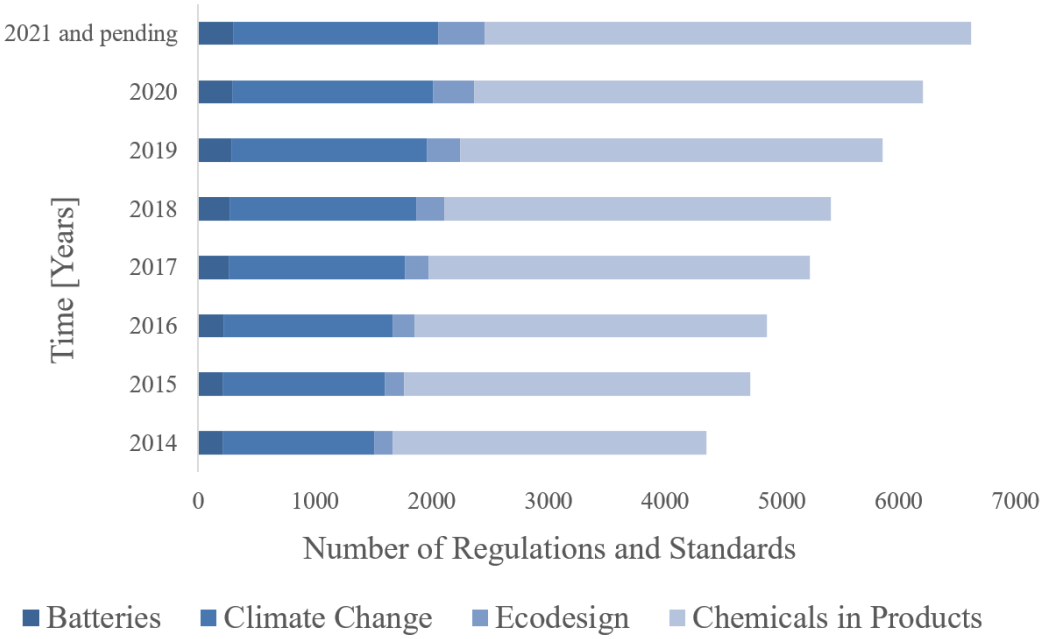

Figure 6: Development of environmental requirements and standards over the years (modified from Buckreus et al., 2021)

Stockholm Convention on persistent organic pollutants (or POP for short) is a legislation that seeks to reduce and eliminate production, use, and release of substances which have been categorized as persistent organic pollutants (United Nations Environment Programme, 2001). The legislation was approved at the Stockholm Convention 2001 and entered into force in 2004. Originally there were 12 different POP substances, and while new ones have been identified, the key concern is still the original 12 (Ashraf, 2017). These compounds are highly toxic that tend to be transported far from their sources, have long persistence in the environment, and accumulate in the food chain. The legislation states that manufacturers must ensure no use, sale, or import of any prohibited substances, ensure restricted substances are used according to the restrictions, collect and maintain evidence of compliance, and be prepared to provide declarations of compliance to importers, distributors, and professional customers (United Nations Environment Programme, 2001). Additionally, as new pollutants are constantly being added to the list of prohibited or restricted substances, manufacturers should have iterative checking procedures in place for not violating POP regulation.

The *registration, evaluation, authorization, and restriction of chemicals* (REACH) regulation aims to reduce the use of hazardous chemicals with the use of four elements: registration, evaluation, authorization, and restriction (Williams et al., 2009). According to the regulation, manufacturers that are either located or export to the European union are required to do the following three steps. First is to offer basic information on whether or not the article – i.e., a physical manufactured product, which is defined by its solid shape rather than its chemistry – contains any hazardous substances or mixtures and if it does what is the identity of the chemical and what are the hazardous properties of it. This first step is also a requirement to be able to push a product to the EU markets. The second step is to communicate with the whole supply chain of the manufactured article on the proper use and handling of the product if it contains substances that are on the candidate list for Substances of Very High Concern (SVHC). The third step is to either immediately stop the production of a SVHC once it is moved to the authorization list – i.e., a list that defines requirements for SVHCs that have restrictions on use applications – or to get a use-specific authorization for prolonged use. Additionally, there are specific restrictions set for certain substances, which are prohibited from use completely or have restrictions when used in certain pre-defined applications (Imaizumi, 2016; Scruggs et al., 2015; Williams et al., 2009). Like with the POP regulation, REACH is also updated regularly,

as historically new substances have been added to the regulation roughly every six months.

Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) aims to reduce hazardous substances in the end-of-life of electrical and electronic equipment by limiting the use of certain substances in manufacturing such as lead, mercury, or cadmium (European Commission, 2011). The directive has many similarities to the WEEE directive (Waste Electrical and Electronic Equipment), as it too has the similar goal of limiting the hazardous waste at the EOL of electrical and electronic equipment, but unlike RoHS, WEEE focuses on the EOL waste management aspect rather than restricting the hazardous substances in manufacturing of the product altogether (e.g., Cole at al., 2019). Currently RoHS contains ten substances that are restricted, where any substance can only be present at a concentration of 0,1% or 1000 parts-per-million – with the exemption of Cadmium, which has a limit of 0,01% or 100ppm – in any homogeneous material used within the product. The regulation defines homogeneous material as a material that cannot even theoretically be separated through mechanical means, which means that individual screws, gold wires, and silicon for example are defined as homogeneous materials, while a sub-assembled circuitry board is not (European Comission, 2011; Cusack & Perrett 2006). RoHS also specifies some exemptions from the list – such as lead used in resistors – where the restrictions are altered for certain use-cases. It is also important to note, that RoHS compliance is a requirement for receiving the CE marking and to enter the EU markets, and like the POPs and REACH regulations, RoHS has historically also been amended and updated to include new substances (George & Pecht, 2016).

California proposition 65, or also known as the Safe Drinking Water and Toxic Enforcement Act of 1986, places two separate requirements to manufacturers. The first is that manufacturers are not allowed to knowingly poison drinking water with substances that are known to cause cancer or reproductive harm. While an important requirement in its own right, electronic manufacturers are more often than not concerned with the second requirement, which is that manufacturers are prohibited from knowingly exposing anyone in the state of California to substances that are known cause cancer or reproductive harm without providing a clear warning first (Barsa, 1997). In contrast to POP, REACH or RoHS, the California proposition 65 is interested in whether or not anyone is exposed to harmful substances because of the product and if they have been warned first, rather than

focusing on the substances within the product. California proposition 65's scope is not only the consumers that are liable to be informed of harmful substances, but so are practically anyone who come into contact with the product and/or its chemicals, including organizational employees, people in the supply chain, or the general public. Still, as the proposition does not restrict the use of harmful chemicals, the general focus – as seen through the eyes of the manufacturer – is to present a warning sign indicating that some chemicals within the product are known to cause cancer or reproductive harm. The list of harmful chemicals specified in the proposition is also comprehensive, since as pointed out by Kukla (2010) there were already 750 chemicals listed in 2006, and since then the number has only continued to grow. This has resulted in a situation where most manufacturers that have any connection to the state of California either conduct iterative proposition 65 compliance, or like demonstrated by Kukla (2010), place prop. 65 warning signs as a precautionary measure.

Full material declaration – FMD for short – is also an important aspect to consider even though it is not a regulation itself. As the name states, FMD is a full disclosure of all materials used in all components of a product, that is visible to all supply chain actors (Schenten et al., 2018). The aim is to give a comprehensive breakdown of the product and its components down to the homogenous level, which means that each component would have a declaration stating which chemicals, substances, and materials are used in it and by how much (Wu, 2018). Collecting FMD data in itself is not a regulation or even something organizations need to comply with at all, but rather a way of making sure that the components are compliant with other regulations and standards. As such, FMDs could be perceived to be more of a risk mitigation tool. In a way providing FMD data through the supply chain can be seen as the golden standard, as theoretically being able to provide correct and comprehensive FMD data means that the organization is able to provide nearly any other type of substance compliance regulation data through it. The means of using FMD data is relatively new method to stay compliant, and as such the topic is not heavily discussed in literature either. So much so, that FMD is in some cases also known as *full material disclosure* and does not have a standard definition (Schenten et al., 2018; Wu, 2018).

2.2.2 Substance compliance management

If substance compliance is defined as being compliant to the environmental product-related regulations and standards, substance compliance management can be defined as

the act of identifying the regulations, acting upon them, and thus staying compliant in practice. Since the literature on substance compliance is limited, there is no clear consensus on what the practical steps are to being substance compliant. Still practical steps for individual regulation compliance have been presented, such as the systematic steps to be RoHS compliant by George and Pecht (2016). In their study the steps to compliance are to "plan and design a product based on RoHS compliance requirements, gather information on lead-free suppliers, develop and optimize lead-free processes, and conduct tests to ensure the durability of these lead-free products". George and Pecht (2016) also describe how the "coordination with regulatory authorities and customers" is important to the entire compliance process. Goosey (2007) also expressed how the steps of requesting material information through the supply chain, conducting thorough risk assessment for components and individual suppliers, and being able to demonstrate a commitment to RoHS compliance are mandatory to ensure compliance. A more comprehensive view on what is needed to stay compliant can also be seen in the IEC 63000:2018 standard, which heavily affects substance compliance management (Ottinger & Leonova, 2020). In situations, where a company has to be compliant to multiple regulations – such as REACH and RoHS simultaneously – Bachmann (2010) suggest a 15-step procedure, where the focus is on first identifying legal implications and requirements, then identifying the compliance objective both internally and in relation to suppliers, then instructing and working with suppliers to build a list of declarable substances, and finally evaluating the provided information and suppliers' rate of return. By using the three separate best practices on substance compliance management by George and Pecht (2016), Goosey (2007), and Bachmann (2010), a general substance compliance plan can be theorized, as visualized in figure 7.

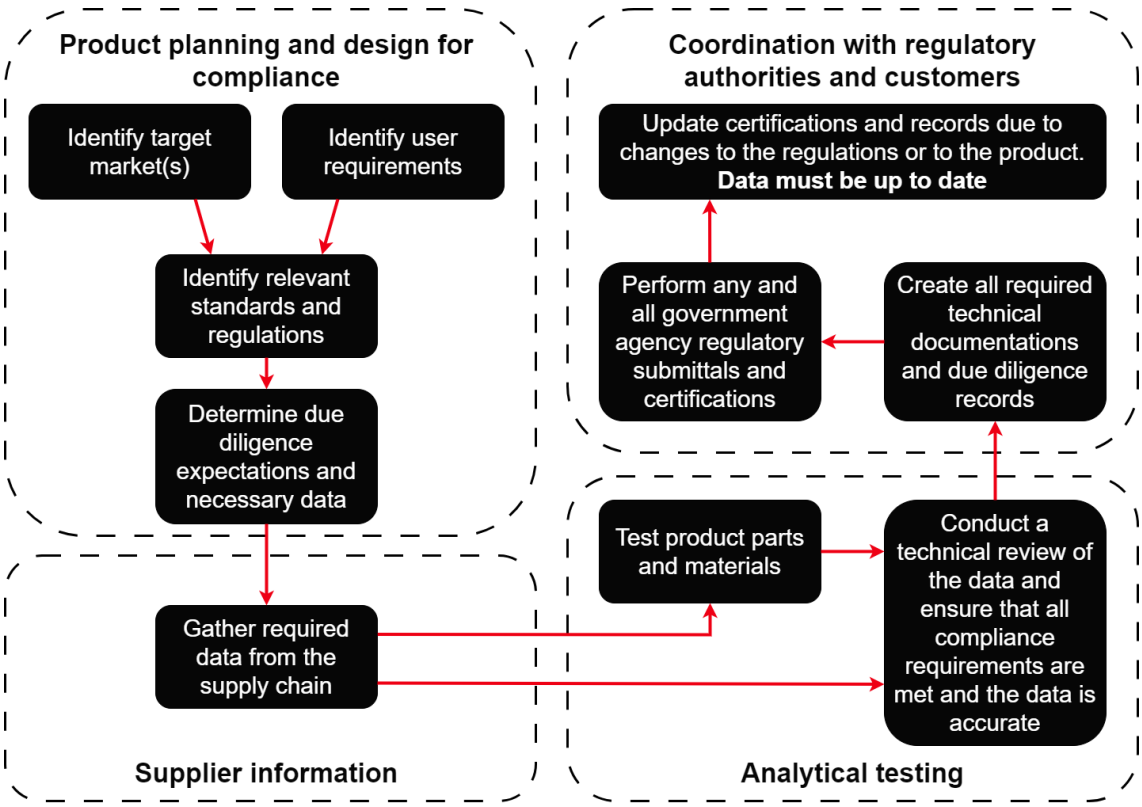

Figure 7: Generic substance compliance plan (illustration based on George & Pecht, 2016; Goosey, 2007; Bachmann, 2010)

Once the overall plan in regard to substance compliance management is clear, the only thing left is to naturally to put in the effort and complete the steps of the plan. Generally, the management of substance compliance is handled either externally through compliance service providers – like compliance consultants or environmental regulation lawyers for example – or internally with compliance managers/specialists utilizing substance compliance systems. It is also not unusual to see organizations utilize both, as some compliance system providers have shifted into the SaaS (i.e., software as a service) model (Butler & McGovern, 2012). While some organizations do not fall into either camp of substance compliance management – for example an organization utilizing only Excel spreadsheets as the main compliance management method – it could arguably be wise to shift to a dedicated compliance system or service provider, as managing thousands of substances manually through Excel can lead to complications or errors, which ultimately leads to financial fines or even not being able to enter certain markets (George & Pecht, 2016).

Environmental compliance management systems (ECMS) are information systems that are designed to help with different environmental compliance processes, including substance compliance (Butler & McGovern, 2012). There are plenty of commercial

options available, and while the end goal is the same – to help an organization comply with environmental regulations – the way the different systems help may differ (e.g., Greensoft Technology, 2022; Sphera, 2022; Qualityze, 2022).

In stark contrast with the somewhat plentiful nature of commercial systems, scientific literature on the subject of environmental compliance management systems is scarce. Still, some examples of ECMS or certain functionalities of such systems have been presented, for example by Butler and McGovern (2012) or Zhou et al. (2009). In the theoretical framework for a high-functioning ECMS Butler and McGovern (2012) present that an ECMS should be able to handle compliance requirement gathering, compliance management, and compliance knowledge management. Compliance requirements gathering refers to the feature of identifying applicable regulations, expressing ways to comply with them, and offering legal expertise/knowledge on the regulations. Compliance management process on the other hand refers to the functionality that aids in the material compliance data gathering by for example allowing its users to see the effects of regulations on product components and structures dynamically, offering task coordination within the compliance process, and cataloging and preserving compliance related documentation for the given grace period. And finally, compliance knowledge management refers to the functionality that allows its users to share, view, and create compliance related knowledge for example by an audit trail of supplier declaration, comprehensive search features, and the ability to create contexts for the effects of compliance issues (Butler & McGovern, 2012). Through these functionalities, a theoretical overarching ECMS architecture can be presented, as visualized in figure 8. Butler and McGovern (2012) also argue, that in 2012 there existed no proper highly functional ECMS, as none of the identified substance compliance management systems were able to perform all the needed functions of a proper ECMS.

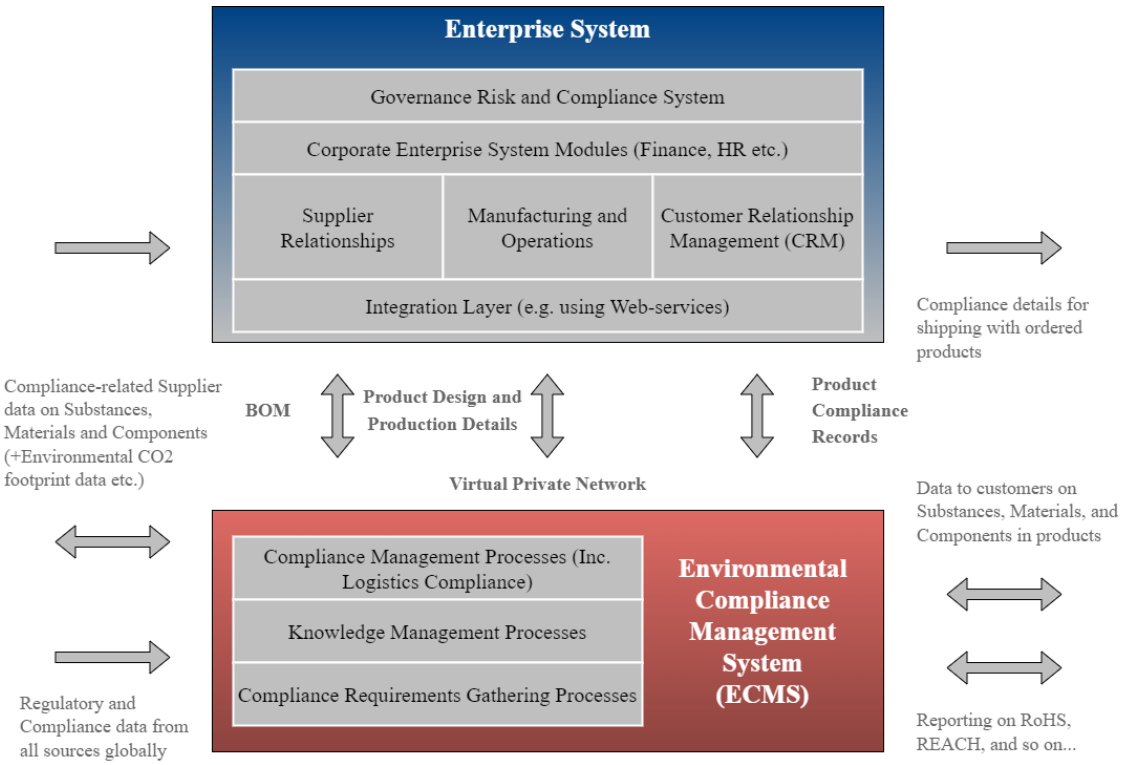

Figure 8: Overarching ECMS architecture (modified from Butler and McGovern, 2012)

2.2.3 Substance compliance's interoperability with PLM

Environmental compliance management systems – and any other systems with the main intent of managing the process of substance compliance – can be seen as their own separate system, but they are still entirely reliant on more widespread enterprise systems. The reason for this is obvious: ECMS' require at least comprehensive product material data and supply chain information that is timely, accurate, and reliable – i.e., of high quality – in order to see if the product materials/substances adhere to environmental regulations (Miehe et al., 2015; Bachmann, 2010). This means that ECMS should be connected or integrated with systems that can provide the required data, and as such the integration with either an ERP system or a PLM system can be seen as reasonable (Takhar & Liyanage, 2018). Additionally, as pointed out by Butler and McGovern (2012) one of the major functionalities of ECMS is the importation of a product's bill of materials and the following analysis of the technical product structure in regard to the environmental regulations. Zhou et al. (2009) also mention, how importing a product BOM from another system and modifying it into a "compliance BOM" is one of the key features of a RoHS compliance management interoperable system. Arguably this could favor the integration of a PLM system as the integrated database for an ECMS, as PLMs excel in product structure and configuration management, life cycle monitoring and management, as well

as doubling as a data vault and document management system (Stark, 2005). Still, as ECMS are also heavily reliant on high-quality supply chain data, an integration with an ERP system could be deemed as functional, due to ERP systems having more focus on the manufacturing and supply chain management aspect (Peltonen, 2000). In either case, it has to be understood that even a theoretically high-functioning ECMS should be integrated or connected to an enterprise-wide system, due to its requirements.

Consequently, substance compliance management also has direct connections to product data quality. As expressed by both Miehe et al. (2015) and Bachmann (2010), high quality product data is crucial for substance compliance management. If product DQ is not up to high enough standards, it might mean that errors or complications come up in the substance compliance management process. An example of such an event could be, that the material composition of a component in the BOM has not been updated after choosing to replace it with physically similar looking, but materially differing component, resulting in an erroneous substance compliance declaration if not corrected. It could also be argued further that Wang and Strong's (1996) other dimensions for DQ can also affect substance compliance, as for example accessibility, believability, and accuracy of product data can have an effect to the management of substance compliance. Bachmann (2010) seems to follow this notion by mentioning how "*only accurate, reliable and timely information modelled in sustainable processes will guarantee and improve image and legal compliance*".

Substance compliance is also closely tied to product development and especially in the management of the product's lifecycle. As explained by Hornberger et al. (2014) compliance must be taken into account from the first stage of product development to the final moments of the product's life cycle. Substance compliance should not be tacked on already built products but should rather be a constant perspective in the design of the product as the choice of materials and supply chains is easier to change and identify in the early stages of product development. In some literature, the philosophy of Design for Environment – which is a subset of Design for X where different perspectives are taken into account in the product design phase – is also connected to substance compliance reinforcing the idea that substance compliance should be a part of the product design phase (Shangguan, 2004).

2.3 Project Change management

A significant amount – up to 60 percent – of change programs either fail completely or fail to reach the set goals and outcomes (Beer et al., 1990; Hayes, 2022). As such, it is important to those carrying out change projects – such as the integration and deployment of two information systems – to successfully manage the process. To aid in such endeavors, the field of study of *change management* has risen. Change management has been defined as "*the process of continually renewing an organization's direction, structure, and capabilities to server the ever-changing needs of external and internal customers*" (Moran & Brightman, 2001). In this definition the organizational aspect is highlighted, as change management is essentially focused on delivering organizational change. As pointed out by Gill (2002) change management is not only interested in managing – i.e., planning, organizing, directing, and controlling – the process of change, but also offering leadership. The field of study is seen as hugely people-centric, and as such focuses largely on how to successfully plan, implement, and sustain change by focusing on the people and stakeholders that are connected to the change.

2.3.1 Change management process

Overall multiple different change management process models and theories have been presented. The first one was born from the *force field* theory of Lewin (1951), where the change was described as something that had to be achieved by shifting the current status quo. According to Lewin, the current situation in a change process at any given time is the equilibrium of two opposing forces: one pushing for the change and one pushing back against it. While change efforts at the time were usually seen as something that had to strengthen the forces for change, Lewin proposed that another way of achieving change successfully would be to lessen the forces that oppose it instead. A visualization of the mode can be seen in figure 9. By developing the force field theory further, Lewin arguably created the first change management process theory; the three-stepped process of change (Lewin, 1946). The model focuses largely on the group dynamics and how to achieve a planned change in it by dividing the act of change into three clear steps.

Figure 9: Lewin's forcefield model (modified from Lewin, 1951)

According to Lewin (1946) in the first step of the change management process the current status quo must be unfrozen, i.e., the balance of the driving and resisting forces for change must be destabilized so that a change can happen. As pointed out by Sarayreh, Khudair and Barakat (2013), the methods for unfreezing differ greatly between projects and situations, and they may prove to be incredibly difficult. In practical terms the first step can be seen as for example alerting the organizations employees and management of a needed change and motivating different parties to change through a clear vision (Hayes, 2022). The second step consists of the act of *moving* the current state to a new level. In this step the actual changes in the organization, people, and processes are conducted and a new way of doing things is adopted (Lewin, 1946). In practical terms this might mean for example introducing a new process for an IT system usage and starting to adhere to it or reforming the organizational structure and starting to utilize the benefits the new structure offers. In the third and final step, the current state is frozen back in place in a new equilibrium. This means that the newly learned ways of working are solidified as the *de facto* way of doing things. The third step can also include gathering feedback in a continuous manner which can help embed the new behaviors and to gather data on the effectiveness and consistency of the change, further helping the overall change efforts (Hayes, 2022). In entirety, Lewin's three-stepped change management model can be boiled down to unfreezing the current state of behavior, moving it to a new level, and then freezing it again to solidify the changes. The inherent simplicity has drawn many change leaders to utilize the model, but at the same time the mode has garnered critique by oversimplifying the change process to a one-dimensional approach, which does not factor in many dimensions of change needed to realize a full change process (Rosenbaum et al., 2018).

Another widely regarded model for change management came from Kotter's (1996) publication *leading change*, where the change management process was divided into the following eight steps (Kotter, 1996; Smith, 2005; Appelbaum et al., 2012):

1. *Establish a sense of urgency about the need to achieve change – people will not change if they cannot see the need to do so.*
2. *Create a guiding coalition – assemble a group with power energy and influence in the organization to lead the change.*
3. *Develop a vision and strategy – create a vision of what the change is about, tell people why the change is needed and how it will be achieved.*
4. *Communicate the change vision – tell people, in every possible way and at every opportunity, about the why, what and how of the changes.*
5. *Empower broad-based action – involve people in the change effort, get people to think about the changes and how to achieve them rather than thinking about why they do not like the changes and how to stop them.*
6. *Generate short-term wins – seeing the changes happening and working and recognizing the work being done by people towards achieving the change is critical.*
7. *Consolidating gains and producing more change – create momentum for change by building on successes in the change, invigorate people through the change, develop people as change agents.*
8. *Anchor new approaches in the corporate culture – this is critical to long-term success and institutionalizing the changes. failure to do so may mean that changes achieved through hard work and effort slip away with people's tendency to revert to the old and comfortable ways of doing things.*

Kotter's (1996) eight-stepped process model for change has been hailed as one of the best starting points for new change managers, but as stated by Appelbaum et al. (2012) it should not be treated as a one-size fits all mode that guarantees success for change projects. Rather, the model should be tailored to the correct context and used accordingly. Appelbaum et al. also further argue, that while completing each of the eight steps of the model is important to the successfulness of it, the order to undertake them is still under investigation in the empirical literature.

While Lewin's (1951) and Kotter's (1996) process models for change are still regarded as good and functional models for achieving change, Hayes' model (2022) took the best of both worlds and introduced a practical change management process that is backed up by theoretical change management literature. Hayes' change management process model builds upon Kotter's model and divides the change process into seven activities (Hayes, 2022):

1. *Recognizing the need for change and starting the change process*
2. *Diagnosing what needs to be changed and formulating a vision of a preferred future state*
3. *Planning how to intervene in order to achieve the desired change*
4. *Implementing plans and reviewing the progress*
5. *Sustaining the change*
6. *Leading and managing the people issues*
7. *Learning*

Unlike in Kotter's change management model (1996), Hayes' model functions in slightly less linear style. While the first five steps can be executed in a linear fashion, in practice the use of the model is often iterative, as some of the steps can be addressed more than once, for example the diagnosis of change can be revisited multiple times to pinpoint the correct issue (Hayes, 2022). Additionally, the steps of *leading and managing the people issues*, and *learning* can and should be conducted throughout the whole process in parallel to the other steps. A visualization of the whole process can be seen in figure 10.

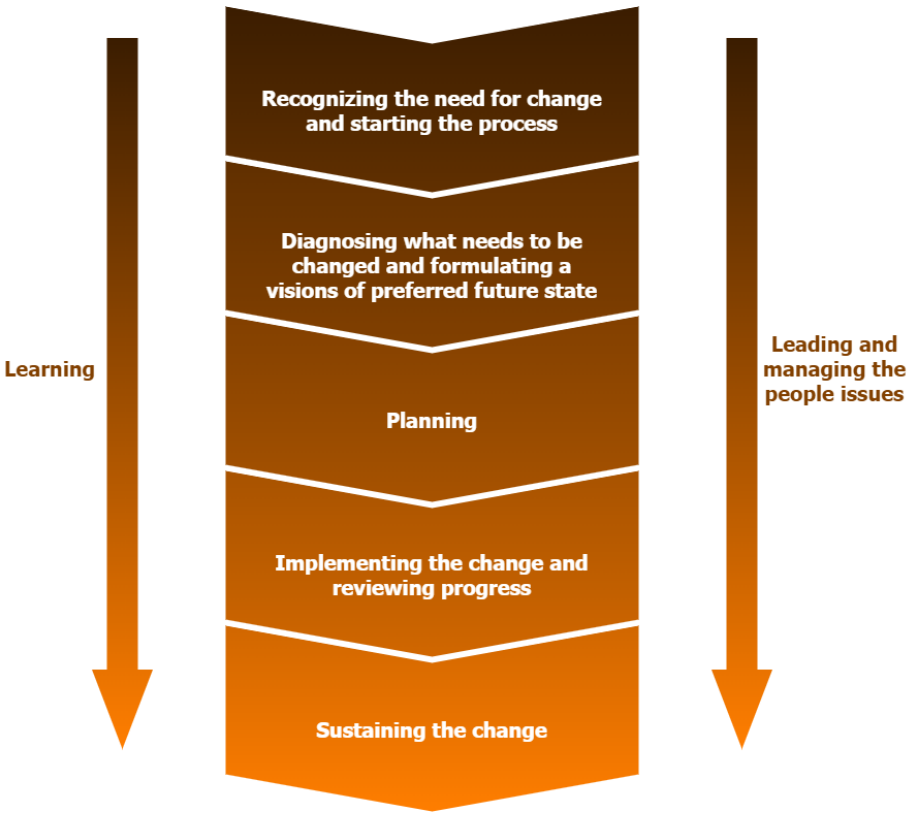

Figure 10: Process model for organizational change (modified from Hayes, 2022)

With all the different change management models, it must be mentioned that while some are more effective at delivering successful change in some specific circumstances, none of the models are perfect examples of how to conduct change. In his comparative analysis of eight different change management models, Galli (2018) argues that ultimately the choice of which model of change to utilize depends entirely on the organization and its current situation. Still, he pinpoints that the aspect of leading people issues is instrumental for change management, as the topic is extremely human-centric and strong communication is often the key. Additionally, the willingness for change must be there for it to work at all, and that change should be addressed proactively rather than reactively. Cameron and Green (2019) share the same view of picking different change models depending on the circumstances and the importance of dealing with people issues. As such, while Lewin's three-stepped change model (1951) could be a quick and practical tool to implement a system integration project, it lacks the depth required for a thorough analysis. Kotter's eight-stepped plan for leading change (1996) on the other hand is an excellent starting point, but ultimately lacks in the key aspect of change management: dealing with the people issues (Galli, 2018). Other models such as the ADKAR model (Hiatt, 2006) or Bullock and Batten's model for planned change (1985) could also in

theory be used in the integration of a PLM system with substance compliance management system, but as Hayes' change management model (2022) addresses the relevant topics for change management while combining theoretical literature of the previous models with a concrete practical view of organizational change, it could be deemed as the proper starting point for an analysis of integrating two systems and processes. Furthermore, as the research objective is to analyze an ongoing change project which has already moved on to the implementation phase, it could be argued that the four most essential steps to utilize in the change management model are the steps of implementing change and reviewing the progress, managing the people issues, learning, and sustaining the change.

2.3.2 Implementing change

The implementation of change can be theorized in many ways and can include a plethora of various dimensions. Hayes (2022) states that the implementation stage of the change management process can be divided into the two separate parts. The actual implementation – including aspects such as clear communication, stakeholder management, adoption of fair management practices, and aligning the views and building coordination – and the monitoring and reviewing, which help keep the change on track by validating whether or not that change plan is still functional. The leading of people issues and focusing on leadership during the implementation phase of change management has also been heralded as a key point in successful change projects (Hayes, 2022; Gill, 2002).

As pointed out by multiple change management models, the communication and the way the change is being communicated is an extremely crucial point in nearly any change project (Mento et al., 2002; Van Hau & Kuzic, 2010; Hayes, 2002). The way the change is communicated has a great impact on how the change is perceived and could thus increase the resistance to change. The same is true if the change is communicated badly or if there is room for interpretation by anyone that is affected by the change, and as such the way the change should be communicated should be clear, concise, and unambiguous (Hayes, 2022). As mentioned by Mento et al. (2002) the communication should be honest, even if it could be the herald of negative changes, as it gives people time to react to the change rather than get in the crosshairs after the change has already been realized. It is also important to note that the communication should also not be just a one-time-deal, but rather constant and notify the affected parties when changes to the plan occur. The

importance of proper communication is further highlighted in information system and enterprise system implementation projects as in the study by Van Hau et al. (2010) 100% of the respondents of the successful ERP implementation projects reported effective communication being a factor in the successfulness of the project.

Like the aspect of clear communication, stakeholder management has been identified to be a key issue during change project implementations. During the implementation – especially in information system related change projects – it is important to identify the stakeholders involved and affected by the change and to analyze their relation to the ongoing change efforts (Ćirić & Raković, 2010). Importantly, after identifying all the stakeholders, they should be analyzed in relation to their power or influence over the change project and their attitude towards it, as to figure out which stakeholders are the most influential and which could mount the most resistance (Grundy, 1998). After the stakeholders, their influence, and attitudes towards the change have been identified, a number of different strategies can be conducted to increase the forces for change. In example – as demonstrated by Grundy (1998) – increasing the influence of a stakeholder who holds little power but has a strong positive attitude towards the change could increase the successfulness. Vice versa, decreasing the influence of a stakeholder with negative attitudes could also help. Similarly, affecting different stakeholders' attitudes towards the change should have an impact on the change resistance. Other strategies with influential stakeholders involve building a coalition of supportive stakeholders with a uniting vision, dismantling existing coalitions who have negative attitudes towards the change, and bringing entirely new stakeholders with positive attitudes into the situation (Hayes, 2022).

Reviewing and monitoring the change progress is also an important aspect within change projects. While Hayes' model combined the phases of implementation and reviewing/monitoring into one, some change management models particularly point out the importance of reviewing and monitoring as a step of its own (Mento et al., 2002). Still, whether it is a phase of its own or not, the basic idea is to create and utilize metrics to monitor the change efforts, its effects on situations and people, and reviewing whether the change plan is still valid at any given time (Hayes, 2022; Mento et al., 2002). The metrics and methods are depended on the circumstances of the change project, but the crucial part is to conduct the reviewing and monitoring throughout the process, not just at the end. This way, the change process can become iterative, and the original change plans can be revisited throughout the project and the goals, methods, and the metrics

themselves can be improved during the process. Mento et al. (2002) also highlight the importance of using milestones, as in addition to helping with monitoring the progress, they also double as motivational aspects for the people driving the change forward.

Lastly, the leading and managing of people issues should be taken into account when implementing change. Change management at its core is a very human and people centric subject, and as such the focus should not only be put on the management of change, but also the *leadership* of change (Gill, 2003). Hayes (2022) divides the role of leadership into the following seven tasks:

1. *Sense making: Make sense of the world and identify the opportunities and threats that require attention*
2. *Visioning: Identify a vision of what a more desirable state of affairs might look like and what needs to be done to move towards this better future*
3. *Sense giving: Communicate the vision to a wider audience and respond to feedback as required to win commitment to the change*
4. *Aligning: Promote a shared sense of direction so that people can work together to achieve the vision*
5. *Enabling: Remove obstacles and create the conditions that empower others to implement the change*
6. *Supporting: Recognize and respond to the concerns of those affected by the change*
7. *Maintaining momentum and sustaining the change: Show commitment and 'walk the talk' – demonstrating that they are prepared to change their behaviour as well – to keep people focused on the change*

As Hayes (2022) sees the act of managing people issues and leading change as an ongoing effort alongside the entire process of change, not all seven tasks are necessarily relevant to the implementation phase of a change project. Arguably the tasks of sense giving, aligning, enabling, and supporting are often times used within the implementation of a change project. The aspects of motivating, inspiring and aligning can be seen especially important, as these tasks are often heralded as crucial for the success of effective leadership in change management projects (Gill, 2003; Kavanagh & Ashkanasy, 2006; Hayes, 2022). Additionally, the aspect of reaching, celebrating, and delivering "quick

wins" – i.e., acknowledging reaching minor milestones – can help keep the momentum of change implementation going (Kotter, 1996; Hayes, 2022).

2.3.3 Sustaining change

While the stages of diagnosing, planning, and implementing change are without a doubt crucial for a change to be realized, it is all for nothing if the gains of the change are not attained i.e., the change is not sustained. Already in the first widespread change model developed by Lewin (1946) the importance of making the change long-term is described. In Lewin's model this meant the act of "freezing" the new equilibrium to harden the newly learned ways of doing things into the new norm. Since then, the theory of sustaining change has been explored and deepened and the term *sustainability* has been coined. According to the NHS Modernisation Agency (2002) sustainability in the context of change management is defined as the state where "*new ways of working and improved outcomes become the norm*" and where "*the thinking and attitudes behind them are fundamentally altered and the systems surrounding them are transformed in support*". The key point in the definition being, that a change is sustained once it becomes the new norm, and the ways of working are irreversibly transformed.

While the surrounding literature has identified a plethora of issues that affect sustainability in change management projects, there seems to be a lack of a clear consensus on which the main issues are. Buchanan et al. (2005) made a thorough review on the literature on sustaining change and – while arguing that more studies need to be conducted towards the subject – defined a state of decay for change efforts that naturally realizes if efforts to combat it – i.e., sustainable actions – are not taken. They point to three issues that could affect how, if, and when said decay could happen: (1.) *the substance of change*, (2.) *the implementation process*, and (3.) *the temporal dimensions* (Buchanan et al., 2005). The substance of change – i.e., the way the change is perceived – can have a big impact on how sustainable the change is long-term. An example of this is when a change is seen instrumental, it becomes more sustainable, than if the same change would be perceived as trivial. The implementation process also affects sustainability, as some methods of implementing change can foster greater sustainability than others. And the temporal dimensions (the timing, sequencing, and pacing of the change process) similarly can have a great effect on how the change is sustained. A strict schedule might make the change efforts rushed, but on the other hand a more relaxed timetable – especially with delays – can divert the efforts elsewhere and decrease

sustainability altogether (Hayes, 2022). In an expanding research, Buchanan et al. (2006) further identified ten practical recurring issues found in change projects and introduced ways to combat said issues. These issues and ways to address them can be seen in table 3.

Table 3: Ten practical issues affecting change sustainability and ways to address them (modifed from Buchanan et al., 2006 and Hayes, 2022)

Issue	Ways to address
1. Those who iniated the change move on to another organization:	. *Design career development and reward policies to motivate and retain key change agents.* . *Choose successors with similar competences and aspirations.*
2. Accountability for development becomes diffused:	. *Establish clear project and line management responsibilities.* . *Ensure appropriate and visible rewards for those responsible for driving change.*
3. Knowledge and experience of new practices is lost through turnover:	. *Develop retention strategies to minimize such losses.* . *Develop a 'buy-back' policy to involve leavers in induction and training for new staff.*
4. Old habits are imported with recruits from less dynamic organizations:	. *Strengthen the induction and training regime for recruits.*
5. The issues and pressures that triggered the change iniative are no longer visible:	. *Communicate in a way that keeps these issues in the forefront of staff thinking.* . *Identify new reinforcing issues and pressures.*
6. New managers want to drive their own agenda:	. *Support where appropriate but also ensure that they are given an explicit remit to work with and not dismantle particular changes introduced by their predecessors.*
7. Powerful stakeholders are using counter-implementation tactics to block progress:	. *When reason fails, develop a 'counter-counter-implementation' strategy to reduce their influence.*
8. Pump-priming funds run out:	. *Start to revise budget allocations well in advance, so that the extra costs of new working practices can be absorbed gradually in a phased manner.*
9. Other priorities come on stream, diverting attention and resources:	. *Develop a time-phased change implementation strategy to provide periods of planned stability between change projects.* . *Avoid diverting resources behofre iniatives are embedded.*
10. Staff at all levels suffer iniative fatigue and enthusiasm for change falters:	. *Beware the 'bicycle effect' where a lack of forward momentum leads to a crash. Relaunch with new focus, themes and goals.* . *Sell the benefits and clarify what's in it for them.*

Another topic to take into consideration when trying to make change stick, is the aptly named “spreadability” as coined by Hayes (2022). According to Hayes, spreadability refers to the act of spreading – i.e., applying or adopting – the already implemented and sustained change efforts into other parts of the organization. While other change

management models often forego the issue of spreading change to other parts of organization, it is indeed an important aspect to consider, as often times change is not implemented organization-wide, but rather at a specific sector or team within it. And if the change efforts are only contained within that specific part, then in other parts it could be seen as if change was never even realized. Hayes (2022) also points out how close spreadability is to the topic of innovation and more specifically to the spread of innovation, and as such the theories surrounding innovation spread are largely applicable to the spreadability of change. Keeping that in mind, the five attributes that affect the spread of new innovations described by Rogers et al. (2019) are applicable to sustaining change. These attributes are *relative advantage, compatibility, complexity, trialability,* and *observability.* Relative advantage refers to the gab born from how big of an advantage the innovation has over the previous method of working. Compatibility on the other hand refers to the rate at how well the innovation can be integrated to the current ways of working. Interestingly, the perceived compatibility plays a huge role compared to the actual compatibility. Complexity has a negative impact on the rate of adoption and means the perceived difficulty in using and understanding the innovation. Trialability – or testability as it is referred in some literature (Hayes, 2022) – is the rate at which the innovation can be experimented on, especially before commitment is being done to the change. And finally, observability refers to the visibility of the innovation, as the rate of adoption can be higher when people are able to witness the gains of the innovation with their own eyes (Rogers et al., 2019). Furthermore, Klein and Sorra (1996) cite that a strong implementation climate – i.e., a climate where innovations and change efforts are more likely to spread – can be cultivated by establishing the necessary skills for people to use the innovation, offering incentives for the use of the innovation, and clearing the way of any potential obstacles in the way of adopting the innovation. By keeping an eye out for these attributes and trying to either maximize or minimize them can help spread the change efforts to other parts of the organization.

2.4 Synthesis of literature review

The aim of the literature review was to answer the first two research questions that were set at the beginning of the thesis, the first of which was:

RQ1: What connections does substance compliance have with product lifecycle management?

As substance compliance requires large amounts of information on product materials and the supply chain, a connection or integration with either an enterprise resource planning system or product lifecycle management system can be seen as favorable (Takhar & Liyanage, 2018). Of course, the connection of substance compliance and PLM through supply chain information and material data is obvious, but the entire product structure management functionality can be seen important to substance compliance as well, as building "*compliance BOMs*" using traditional bill-of-materials is an important step in the systematic compliance management systems (Zhou et al., 2009). Additionally, the product structure can define how a product is perceived from the eyes of the key standards and regulations. As an example, California Proposition 65 is interested in whether any stakeholder – from manufacturing engineers to customers to recycling employees – during the lifecycle of the product comes into contact with the specified materials or substances. So, if a product containing some of these materials is structured in a way where the stakeholders do not come into contact with the harmful substances through perceivable ways, the product could be deemed compliant from the eyes of California Proposition 65. Similarly with the REACH regulation, if a component or application as a whole has a certain pre-defined application – such as being used in space – it is subject to different restrictions and as such the product structure management can be perceived as helpful for the entire process (Scruggs et al. 2015).

Data quality and its management are also heavily present in both PLM and substance compliance. While managing product data and the quality of it is one of the key aspects in PLM, the need for high quality product data is equally as high in substance compliance (Tayi & Ballou, 1998; Miehe at al., 2015). Without high quality data – i.e., data that is accurate, timely, complete, and consistent – substance compliance cannot be managed, as incorrect or uncomplete product data can be seen as actively harmful for compliance processes, as it might for example lead to wrongful declarations (Bachmann, 2010). As such, it could be determined that the processes of data quality management and data governance are important to not only in the eyes of product lifecycle management, but substance compliance as well. Additionally, it is important to factor in the perspective of substance compliance from the start of a product's lifecycle, as the earlier the compliant materials and suppliers are thought of, the better (Hornberger, 2014).

The second research question aimed to question what to consider when implementing a PLM integration project. The aim was not only on how an integration project involving a

PLM could be implemented in theory, but also how to sustain the benefits resulted from the integration as well. In whole, the research question was defined as follows:

RQ2: How can a PLM integration project be implemented, and the changes sustained?

When implementing a PLM integration, the topic of PLM maturity – as described by Nolan (1979) – should be taken into consideration. PLM maturity describes the current state of a PLM implementation, and mirrors this current state to a full implementation, where the PLM is utilized near perfectly. But of course, as perfect implementation can nearly never be fully realized, a more practical framework by Batenburg et al. (2006) can be used to improve the implementation of a PLM system. In this framework, the main goal is to create an actionable PLM roadmap to improve PLM maturity, which is done by five iterative steps. The steps are analyzing the current PLM maturity and alignment, benchmarking maturity, identifying the desired PLM maturity and alignment, identifying items to be improved, and defining the PLM roadmap.

The integration involving PLM of course also contains technical aspects. As the role of a PLM system is to work as a data vault and improve data- and process management, it is naturally important that the data that is used in the integration is of high quality (Liu & Xu, 2001). As such, the data quality of the PLM should be identified, and processes that manage the quality of data should be put in place if none already exist. The overarching topic of data quality management can be seen as important, and the four core activities as described by Ehrlinger and Wöß (2022) should be utilized. These core activities are state reconstruction, data quality measurement or assessment, data cleansing or improvement, and the establishment of continuous data quality monitoring. Additionally, it is not enough to only prepare the data for the integration, as the responsibilities to govern it should be taken into consideration as well. Data governance defines "*a cross-functional framework for management data as a strategic enterprise asset*" and accountabilities as well as rights to decision-making while also formalizing data policies, standards, procedures, and monitoring compliance (Abraham et al., 2019). One of the more notable frameworks for practicing data governance was created by Khatri and Brown (2010) where the decision domains for data governance are split into five parts of data principles, data quality, metadata, data access, and data life cycle. Each data governance domain has its own questions that need to be addressed, and from these the potential roles and

accountabilities can be identified for each domain, such as data owner, data steward, or technical security analyst.

As for the final technical aspects for PLM integration implementation, it is also important to factor in the most notable problems in the use of the systems, as these might affect the implementation. The usability of a PLM can be seen as one of the more notable problems, as it is not uncommon for a PLM to have un-friendly user interfaces where hard-to-understand functions are used, and the learning curve for utilizing the system at an acceptable rate is exceptionally steep (Liu & Xu, 2001). Kropsu-Vehkapera et al. (2009) similarly identified the comprehension of product data as an issue, as not understanding the technical structure of a product for example can negatively affect how a PLM can be utilized. Other identified issues that need to be taken into consideration are the utilization of standardized processes, lack of technical product structures, and lack of nominating a data owner or responsible (Kropsu-Vehkapera et al., 2009).

While focusing on the technical perspective on an integration project is never a bad idea, it is also important to factor in how the project as a whole is being managed and implemented. Multiple different perspectives could be utilized for analyzing the project, but as explained by Garetti et al. (2005) "*change management is strictly related to a PLM project, due to the large amount of change involved in project implementation*". As such, the perspective of change management can – and should – be utilized in the implementation of a PLM integration and to further sustain the benefits brought in by it. Multiple change management models and frameworks have been introduced in literature, such as Lewin's force field model, Kotter's eight steps for leading change, and Hayes' change management process model among many others (Lewin, 1951; Kotter, 1996; Hayes, 2022). The choice of which one to use depends on the situation and the organization, and ultimately as the PLM integration project requires practical recommendations on how to implement and sustain change not just from the strategic perspective, but also from a human-centric perspective, the change management process model from Hayes can be seen as applicable. Hayes' model is divided into seven activities, and when taking into consideration that the focus is on analyzing the implementation and introduction of a PLM integration, the most important steps can be perceived to be the implementing of change and reviewing the progress, managing people issues, learning, and sustaining the change (Hayes, 2022).

When implementing a change project, from the perspective of change management some of the most important factors are communication, stakeholder management, monitoring and reviewing change progress, and leading and managing of people issues (Hayes, 2022). In an integration project the way the communication is being handled – both internally on how things are going to change as well as externally on different stakeholders on the aims and goals of the project – can affect how well the project can be implemented. As pointed out by Mento et al. (2002) communication needs to always be honest and straightforward no matter what, as even in the face of negative news it is crucial that the points are not misunderstood, and people have enough time to prepare for the implementation. Stakeholder management can also be perceived to be important in integration projects, as identifying the different stakeholders and analyzing their influence over the change can yield good ideas on how to better implement change (Ćirić & Raković, 2010). In practice this could for example mean identifying the internal employees who have influence over others and analyzing how they might react to the introduction of a new integrated system interface. Based on the analysis different strategies on how to introduce the integration to different people can be conducted.

Reviewing and monitoring the integration implementation progress is also important to factor in. The creation and utilization of metrics to monitor the change efforts as well as its effects on situations and people and reviewing whether the change plan is still valid at given times can be seen crucial to stay on path to successful change (Hayes, 2022; Mento et al., 2002). The importance of using milestones both as a project completion metric and a motivational factor is also highlighted. In an integration project setting milestones for project completion and utilizing additional metrics for checking whether the preliminary project plan is still valid could be seen as practical methods of reviewing and monitoring the change efforts. Leading and managing of people issues also come into play when an integration moves on to the implementation stage, as somebody has to take the role of leadership in various aspects. From the overall seven leadership tasks described by Hayes (2022) the last five steps of sense giving, aligning, enabling, supporting, and maintaining and sustaining the change can be perceived to be important in the implementation phase of an integration project. In other words, there must be someone in the organization that not only provides support for the people affected by the integration, but to also actively removes obstacles in the face of change, aligns people to work together, communicates a clear vision of change for the employees, and shows commitment to the change by embracing it headfirst.

Sustaining the benefits of a successful implementation of an integration can be seen as important as the implementation itself. If actions are not taken to take up the continuous use of an integration, the change efforts will face – as coined by Buchanan et al. (2005) – a state of decay where benefits of the implementation slowly but surely wash away. As such, special care should be put on the sustainability of change, where the new ways of working and doing become the new norm replacing the old habits (NHS Modernisation Agency, 2002). Buchanan et al. (2005) identified ten issues related to change sustainability and devised practical ways to combat with each one, which should all be more or less taken into account in an integration project during and after the implementation phase. The "*spreadability*" of change as coined by Hayes (2022) is also an important aspect in sustaining the benefits from an integration project. The term refers to the act of spreading, applying, and/or adopting the newly changed ways of working to other parts of an organization. In practical terms in an integration project this could be seen as how the use of the new integration can be spread into other teams from the team that implemented it. By looking at *spreadability* from the eyes of innovation research, five attributes that affect it can be identified: relative advantage, compatibility, complexity, trialability, and observability (Rogers et al., 2019). If these aspects are considered in the way the use of the integration is spread throughout the organization – i.e., by showcasing the advantage the use of the integration brings in relation to previous ways of working and demonstrating how uncomplex it is – the entire process should proceed faster, and the gains of the change efforts can be attained and sustained in the long run.

3 RESEARCH METHODS AND PROCESS

Here the study's case context, research design, data collection methods, and data analysis are presented. Case context covers the important background for the study by introducing the case company, explaining the larger stakeholders of the integration project, and explaining the current timeline. Research design describes the overall design on how the study was conducted, what study methods were chosen, and the relevant steps related to the study method. After that data collection goes further in depth on the research by explaining the data collection methods that were used within the thesis. And then finally, the data analysis methods are presented.

3.1 Case context

The case organization studied in this master's thesis is a European electronics manufacturer company, with a long history of being in the field. While not legally recognized as a small or medium sized enterprise, from the perspective of product development or daily operations it could be classified as one. The motivation to participate in the study in the organization's side came from the fact that, at the time of writing this thesis they were implementing a unique integration of substance compliance with a PLM system, and as such had a profound interest in documenting and improving its development, implementation and introduction.

From the case company's perspective, the integration project was done in cooperation with a third-party product lifecycle management system development organization, which is named in this thesis as *PLM developer*. This third party oversaw the development and testing of the software involved in the integration and had a great amount of interest in the success of the project. Another third-party organization, known for its substance compliance expertise, was also involved in the integration project working mostly in a counseling position. This compliance management organization – from now on named as *Compliance Counselor* – also had close ties to a larger global substance compliance solution provider known for the compliance management software and services, for which are also utilized within the case company. This fourth organization – aptly named *Compliance Provider* – also had direct and undirect communication to the PLM developer, due to the technical implementation of the two organizations' systems. The case company, PLM developer, and compliance counselor formed the primary triangle of

stakeholders in the project, with the compliance provider serving as an additional fourth stakeholder, that was less active on the day-to-day development of the integration. A visualization of the different organizations taking part in the integration project can be seen in figure 11.

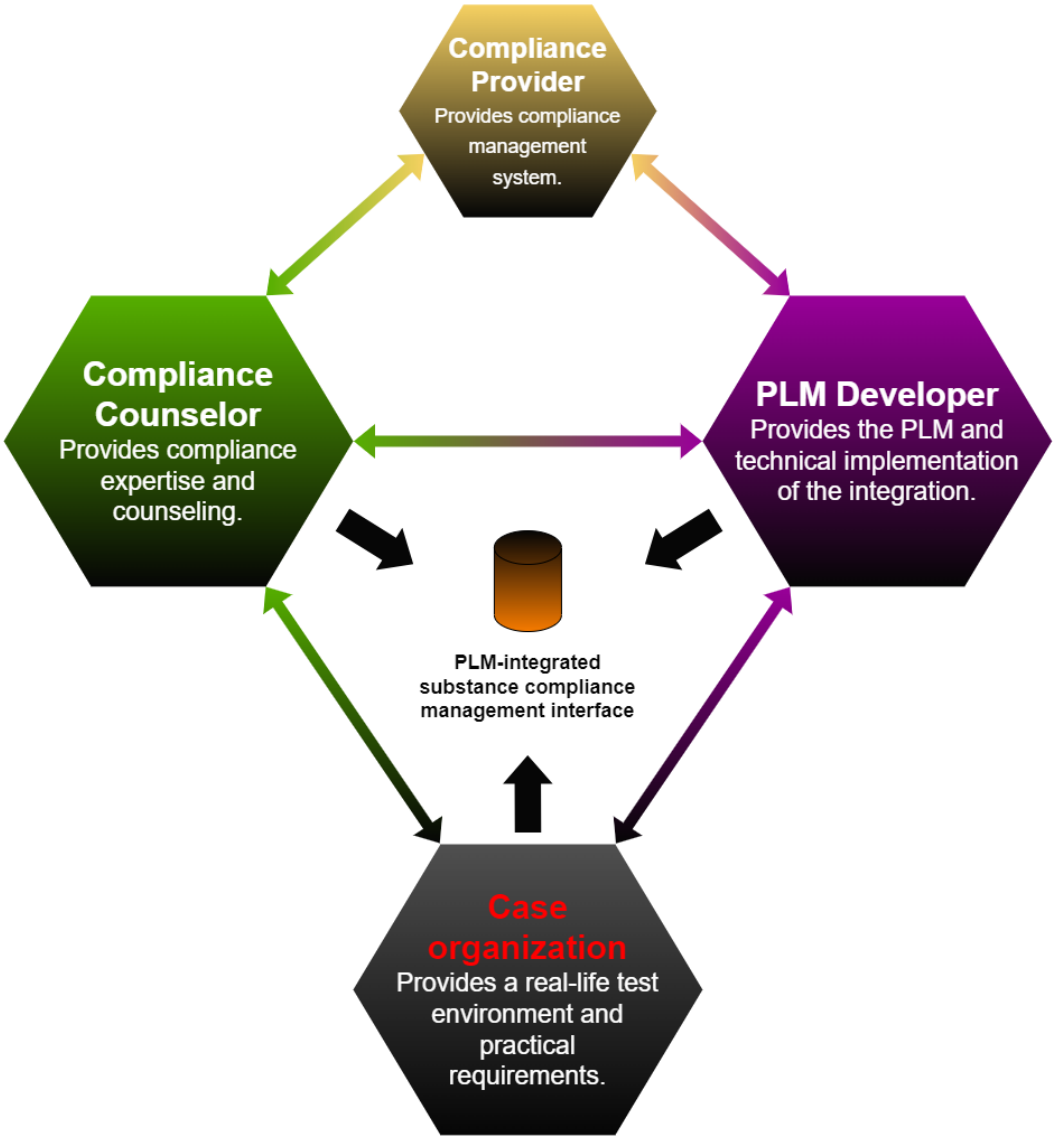

Figure 11: Visualization of the different organizations taking part in the integration project.

If the timeline of the project was considered from the perspective of Hayes' change management model (2022), the project was – at the time of writing this thesis – at the implementation stage. The recognition that a change is needed had come to fruition, the diagnosis of what needs to be changed had also been done, and while the planning in software development projects is often an iterative and ongoing endeavor, the initial planning for change had also been completed. The implementation of the integration was still an ongoing effort, as the software was being prototyped and tested in the case

organization's test environment. Reviewing progress was similarly ongoing, but the processes and plans for how to sustain the changes from the integration project were still largely undone.

3.2 Research design

The master's thesis study was conducted as a case study to research the phenomenon of integrating a substance compliance management system to a product lifecycle management system. The case study method was chosen since the integration project was a development project that was first of its kind, and as such no previous literature had studied the topic or given prior research studies to fall back on. And, as explained by Eisenhardt (1989), case studies excel due to their strong theory-building approach and independence from previous research and are "particularly well-suited to new research areas or research areas for which existing theory seems inadequate". Eisenhardt also devised an eight-stepped plan on how to conduct case study research, which is still often used in case studies. Still, for the purposes of this master's thesis, a more modernized and condensed version by Patton and Appelbaum (2003) was used, as it functionally included the same steps as Eisenhardt's case study approach but in a more streamlined way. These five steps are: (1.) determine the object of the study, (2.) select the case, (3.) build initial theory through a literature review, (4.) collect and organize the data gathering, and (5.) analyze the data and reach conclusions. A more detailed explained to each step can be seen in figure 12, where Patton's and Appelbaum's (2003) case study roadmap is presented.

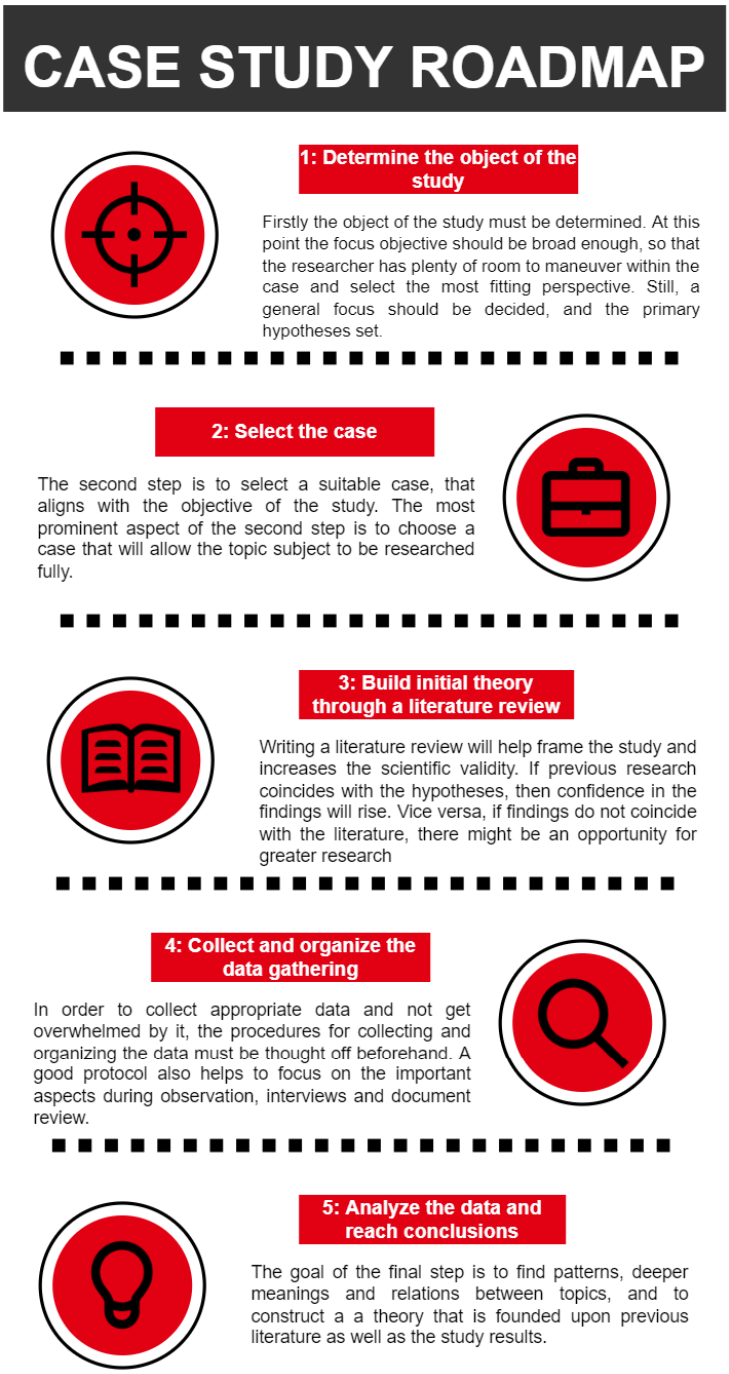

Figure 12: Case study roadmap (modified from Patton and Appelbaum, 2003)

3.3 Data collection

As is common on case studies, the data collection and gathering in this master's thesis focused on qualitative data. While combining qualitative and quantitative data simultaneously could give a broader and clearer picture, utilizing only qualitative data is justified as the studied phenomenon is not easily comparable to other cases as it is connected to a development project first of its kind. As is tradition in case studies, combining different data gathering methods results in better outcomes while also

providing more scientific validity (Patton & Appelbaum, 2003; Yin, 2009). As such, the data collection within the thesis was threefold. Firstly, on-site observations were made based on a five-month-long period spent in the product services team at the case organization's office. Secondly, two sets of semi-structured interviews were utilized to gather data on the current understanding and use of PLM and substance compliance. And thirdly, a single use-case analysis conducted through an active participation observation session was conducted to gather data on the state of the integration.

Observation – or more specifically participant observation – is the qualitative data collection method where data is collected through observing and recording ongoing activities, participating in informal discussions clarifying questions in the setting, and potentially taking part in the activities to gain understanding (Kaplan & Maxwell, 2005). The method is often not used as the primary data collection method, as relying on it alone might not produce enough viable qualitative data, and it might be prone to multiple biases. Still, observation is a fantastic data collection method as a confirmatory or auxiliary research complementing other types of data collection methods (Jamshed, 2014). In the context of this study, participant observation was done through a five-month-long internship at the case organization's office. The aim of these five months was to get a rough initial view and understanding on the processes of substance compliance and product lifecycle management in the case company.

Semi-structured interviews – the most common method in qualitative research (Alvesson & Deetz, 2011) – are interviews, where there is a prepared structure to the questions and interview process, but the questions could be open-ended in nature, allowing for more explorative answers (Qu & Dumay, 2011). The questions often circle around one or more broad themes and aim to allow the interviewee to answer in their own terms and words, which often times results in more extensive answers than found on questionnaires for example. Semi-structured interviews also allow for spontaneous follow-up questions to further try to show light to a concept or answer an interviewee presented. Of course, since the nature of semi-structured interviews is ever flowing, it is important to be flexible in the data gathering process, while simultaneously keeping an eye on the studied phenomenon (Qu & Dumay, 2011).

In this study, the interviewing process was split into two separate interviews. The first interview focused on building a qualitative current state analysis of the case

organization's internal use and understanding of both the product lifecycle management system as well as substance compliance in different teams. The interviewees in the case company were the PLM manager, compliance manager, and other employees who either used or based on literature should have used the PLM and/or substance compliance system. In total, nine employees from six separate teams were interviewed. The interviews were designed to take roughly 60 minutes each, but due to the nature of semi-structured interviews, the durations varied slightly.

The second interview similarly focused on getting a qualitative view, but this time on the on-going integration project. The perspective was on how the project had so far been conducted and tried to provide understanding on the motivations and goals of the different project stakeholders both internally and externally. Additionally, the interview also aimed to shed light on how the project was seen through the eyes of change management and were there any ideas or plans on how to sustain the change efforts coming from the integration. The second interview had five participants, three from the case organization, one from the PLM developer, and one from the compliance counselor. As in the first interview, the questions asked were open-ended, had a semi-structured framework, and ranged from 45 minutes to 75 minutes. A complete table of the participants in both interviews can be seen in table 4. Additionally, both interview question sets can be seen in full in the appendix 1 and 2.

Table 4: A full list of all participants in both interviews.

Interviewees for current state analysis
Production Development Engineer
Sourcing Manager
Principal Mechanics Engineer
Compliance Manager
Principal Hardware Engineer
Senior Industrial Engineer
PLM Solution Specialist
Sustainability Manager
Head of Strategic Sourcing

Interviewees for integration project analysis	
PLM Solution Specialist	Internal
Compliance Manager	Internal
Head of Product Services	Internal
Product Manager – PLM Developer	External
CEO – Compliance Counselor	External

Lastly, the technical implementation of the integration was analyzed through a participative observation session. In the session the functionalities of the first prototype of the minimum viable product of the PLM-integrated interface were examined with the help of the case organization's compliance manager. The examination process started

with a step-by-step introduction on how to use the system and showcasing the biggest functionalities it offers, during which clarifying questions and informal discussion on the use of the interface were made. The focus point on the session was to discover how the system works, what can be done with it, and how it improves the current processes for substance compliance in the case organization. Data collection on the technical implementation of the system also combined on-going meetings on the development of the interface as well as documents related to the integration.

3.4 Data analysis

As most of the data gathered in the study was qualitative, a proper qualitative data analysis method was to be chosen. From the plethora of options, the method of inductive content analysis was chosen. Content analysis is a method that can be used with both qualitative and quantitative data, and the inductive content analysis is a subsection of that method focusing on qualitative data (Elo & Kyngäs, 2008). Furthermore, inductive content analysis perfectly suits the scope of the study, as it excels in cases where former knowledge about the studied phenomenon is scarce, fragmented, or nonexistent (Lauri & Kyngäs, 2005). As such, the data analysis method was perfect for the context of this study, as earlier literature and knowledge on the topics of substance compliance and integrating it into a PLM system are extremely scarce.

The process of inductive content analysis is split into three main phases of preparation, organizing, and reporting. Preparation refers to the phase where the unit of analysis is selected. The unit can be a word, theme, or concept, depending on what suits the case best (Polit & Beck, 2004). It is also important to make sense of the data and the whole in this phase, as without it can be troublesome to form insights or theories from the data. After the preparation phase comes the organizing phase, where in an inductive approach the process is divided into five steps: open coding, coding sheets, grouping, categorization, and abstraction (Elo & Kyngäs, 2008). With open coding and coding sheets the aim is to inspect the data, create notes and headings based on the data, and generate categories through coding sheets. Following the coding, grouping of all the different categories is done where similar or close-enough categories are combined into bigger and more suitable sets. These sets are then categorized in order to "*provide a means of describing the phenomenon, to increase understanding and to generate knowledge*" (Cavanagh, 1997). The final step in the organizing phase is abstraction, where main category, generic

categories, and sub-categories are named and connected. Once the data has been analyzed the final step is to report the analyzing process and the results. A complete figure of the inductive content analysis process can be seen in figure 13. The inductive content analysis method was utilized with all three types of data, as while the methods used for gathering said data varied, the process neatly combined the data into one understandable big picture.

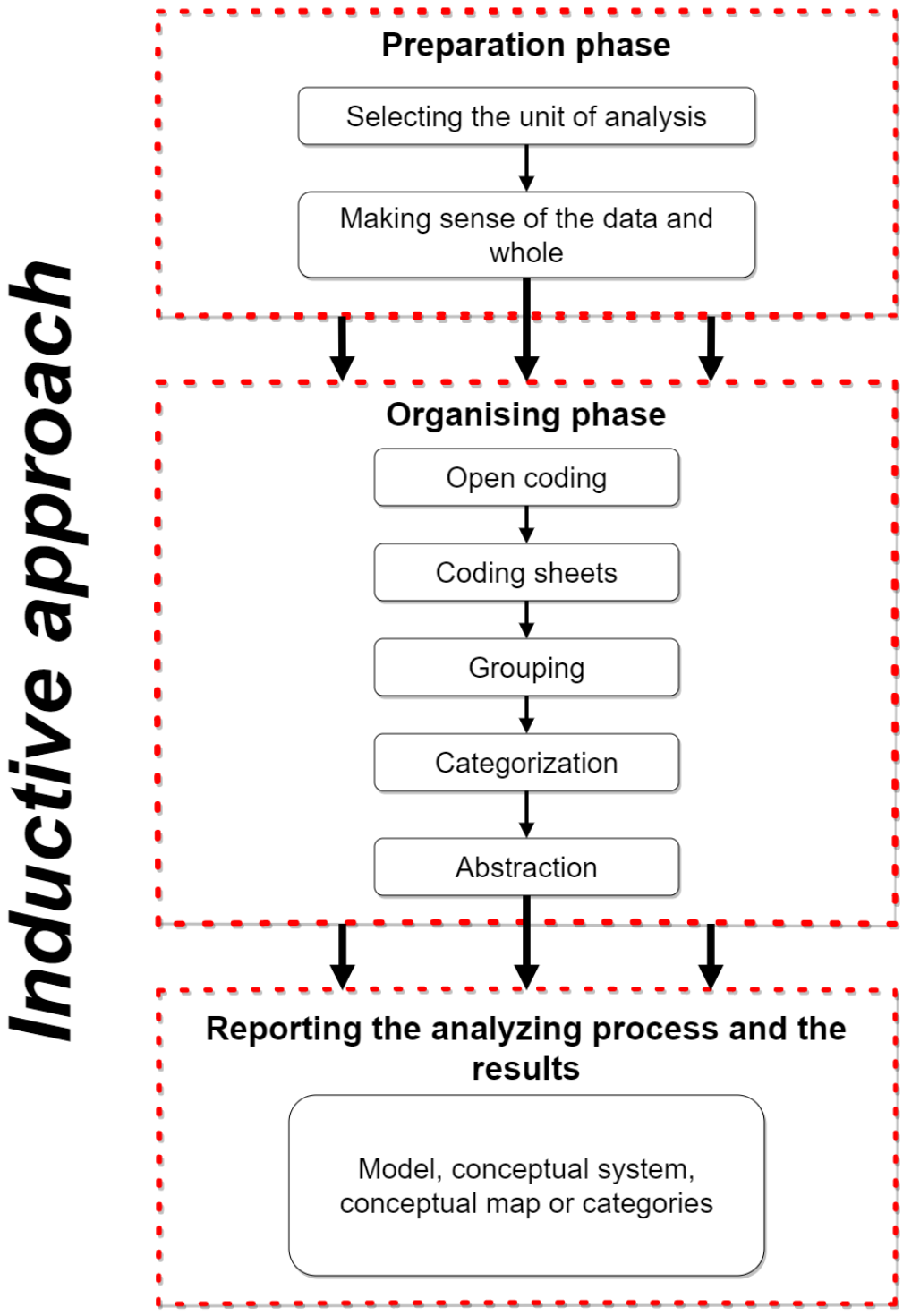

Figure 13: The inductive content analysis process (modifed from Elo and Kyngäs, 2008)

In practice, the data analysis in this master's thesis followed the process of the inductive content analysis closely. Firstly, in order to prepare for the data analysis, the gathered interview recordings and observation notes were watched and read multiple times to get a more thorough big picture of the results. After that, the organizing phase started by going through each interview recording individually and taking notes of the most important answers and comments. These answers and comments in individual interviews were then collected under suitable categories of for example perceived product data quality. After going through each interview recording, the most notable and important categories and answers to them from the different interview recording notes were combined to give a collective – and arguably varying – view of the topics. Then the smaller categories and answers were either combined to the larger ones or disregarded as irrelevant to the study. Once the answers from the interviews and observation notes were grouped and categorized, three major categories with eight distinct sub-categories in total were created. These categories were then named and the main structure of the findings from the current state analysis was created.

4 CURRENT STATE ANALYSIS RESEARCH FINDINGS

In this chapter the current state analysis research findings on the two types of interviews as well as the technical analysis are presented. Findings from each data collection are separated into their own sub-section after which a summary of the research findings is presented. Observations made during a five-month-long internship were also combined with the findings of each section to enrich the results and add further points of interest. In the first subsection – titled current understanding and use of PLM and substance compliance – the results from the first interview are presented. This interview focused on the understanding and use of product lifecycle management as well as substance compliance within the case organization. Overarching categories identified from the first interview were the use of product lifecycle management system, perceived product data, and substance compliance processes and understanding. The second sub-section titled integration project analysis findings covers the results from the second interview where the integration project was analyzed. Important stakeholders not only within the case organization but also outside of it were interviewed, namely the product manager from the PLM developer organization and CEO from the compliance counselor organization. The most important categories identified were the project goals, motivations and planning, project challenges, and internal change management. A complete list of all the participants in both interviews is visible in table 4, and the interview questions are also visible in appendix 1 and 2 respectively. And finally, the findings from the technical system analysis – i.e., how the integrated compliance interface works – that was conducted through a participatory observation session with the case organization's compliance manager are presented in the third heading. It is also important to note, that the current state analysis research findings from the two types of interviews describe a subjective view of the topics of PLM, substance compliance, and the integration project, and as such paint a picture of how different employees in various teams perceive things to be rather than how they objectively are.

4.1 Current understanding and use of PLM and substance compliance

4.1.1 Use of product lifecycle management system

The current lifecycle management system within the case organization has not been in use for long. Initially, around two years before conducting the interviews the first PLM

system was implemented. Before this, the product structures, change notifications, specifications, and other product data were scattered in the ERP system, CAD modeling software and personal files of employees. As pointed out by one interviewee, the situation then was not entirely optimized. The process before PLM was excruciatingly slow, carried a high potential for risks, and was dependent on key employees knowing where each kind of product data was located. Fortunately, the decision to implement a functional PLM was made. After implementing the PLM system, it was firstly used only as a data bank for CAD product data, and the other functionalities were not as well utilized. However, as time went on, the utilization of the PLM grew, and functionalities such as supplier management through an enterprise resource planning system integration, and product change management started to gain traction. Historically during the lifecycle of the PLM in the case organization, there has been one manager – the PLM solution specialist – responsible for the development and use of the system, with some team leaders giving guidance to their individual teams. When the interviews were conducted, the current situation mirrored the case organizations historical use and development of the PLM: not all functionalities were used with the PLM, but the motivation to improve and advance the utilization of the system were visible for example through the newly started integration project.

As could be suspected, the amount the PLM system was used differed greatly from one team to another. Some interviewees noted that they used the PLM system daily, some said that they used it a few times per week, and some even mentioned how they had never used it. Notably, not taking into account the PLM solution specialist, the use of the system was highest in the mechanical engineering team, where multiple team members used the system daily. In the hardware engineering team, the use of the PLM system was also relatively high, and in the sourcing, compliance, and industrial design and development the use of the system was occasional. In the sustainability team the PLM system was not utilized at all.

The use cases for the PLM system were divided into three clear categories: those who do not use the PLM, those who use the PLM only for accessing product related data, and those who create, edit, and organize product data in addition to accessing it. The PLM solution specialist also detailed how there were roles for approving changes in the products, but in practice these roles were the same to the ones who created and edited the data. The biggest creators and modifiers for product data were the PLM solution

specialist, hardware engineering team and mechanical engineering team. The PLM specialist often helped with the trickier aspects of the PLM, while the hardware engineering team was in charge of the hardware components and data in the PLM system and the mechanical engineering team was in charge of mechanical components and product data respectively. Sourcing, compliance, industrial design, and production development teams only used the PLM system for accessing product data for various reasons. Most common way to utilize the PLM in these teams was to use the search bar to find a specific component or product structure and access the data that way. Surprisingly, many interviewees perceived navigation through the products and their structures "organically" to be complex, time consuming and too hard to find a specific aspect they were looking for. This method of only utilizing the search bar to find product structures and components heralded the first major issue in the use of the PLM: usability.

One common nominator in the interviews was the usability of the PLM system. While not all interviewees would outright say that they find the PLM hard-to-use, each who had used it for a prolonged time identified some way it was complex to use. Notably in those teams where product data was created and edited, the use of the system was deemed as a "necessary evil" in the sense that while using it *did* yield good results on product quality for example, the use of it was complicated and time-consuming and something that many people in many teams had a strong dislike for. As a result of the complicated nature of the PLM, one team held a semi-weekly workshop dedicated to learning and understand how to utilize the PLM in different situations. Still, many interviewees who had been a part of the organization for a long time did mention how the current situation of utilizing the PLM was miles better than the previous method of utilizing Excel and the company's ERP system to manage product structures. Nearly all interviewees also collectively saw that the utilization of the PLM improves overall product quality. Some answers on how the case organization's PLM improves product quality were that it provided a good and structured view on products and their components improving product development, it allowed functional product change processes, and functioned as a product library where all specifications and test documents for example were linked to corresponding items. Overall, the PLM was perceived as a complex, hard-to-master, and time-consuming system, that ultimately does give clear benefits to product development and beyond and can be seen as an asset to the organization's operations even though the usability is not the greatest. A collection of use cases and thoughts on the PLM can be seen in table 5.

Table 5: How different teams used the PLM system and their thoughts on it.

	Use of the PLM system in case organization		
	Do not use the PLM at all	**Only use the PLM for viewing product data**	**Use the PLM for data creation and editing.**
Team	Sustainability	Sourcing Substance Compliance Industrial Design Production Development	Hardware Engineering Product Lifecycle Management Mechanical Engineering
Amount of time used typically		Roughly one to four times per month	Varied from once per week to one or two hours per day
Thoughts on the system		*"Navigation can be hard"* *...* *"Search functions is your best friend"* *...* *"Usability is okay"* *...* *"Some specific product structures or components can be hard to find"*	*"System is not intuitive"* *...* *"Helps with product quality"* *...* *"Is time consuming to use"* *...* *"A bit too complex in some areas"*

Another important finding is, that while the *product lifecycle management system* that is used in the case company can be without a doubt classified as a fully-fledged PLM system, the way the system is utilized classifies more as the utilization of a *product data management system*. In practical terms this means that the end-of-life functionalities that are present in the system are not utilized, program/project management is not handled in the system, and the manufacturer and supplier data for some components is minimal and not often updated. The reasoning given was, that in some teams the use of the organization's ERP was more widespread, while the use for PLM was minimal and limited to display roles, so the responsibilities to update or add data did not specifically fall under anyone. Additionally, as for example the manufacturer and supplier data was not specifically requested to be used in the PLM, it was not deemed to be necessary to update said fields in some contexts.

4.1.2 Perceived product data and its utilization

Based on the interview, it seemed like there was a strong understanding of product data, technical product structures and standardized processes in the case company. Many participants had a strong understanding of what product data is, how it can be managed and governed, and what the different processes related to it are. All participants were also

very much aware of what a technical product structure is, and most knew how the designed and manufactured products are structured in the organization.

In the first interview the participants were asked how they perceived the product data quality from the different dimensions of accuracy, timeliness, completeness, consistency, believability, accessibility, and easiness to understand. Two different perspectives to the data quality could be formed from the answers. The first perspective was formed by the employees and teams who only viewed the product data and had no tasks to create, edit, or organize it. The employees in these teams saw that the data quality for the most part was accurate, complete, believable, accessible and easy to understand. The consistency was also seen to be very high, but the timeliness on the other hand was seen as mostly okay. The timeliness was said to be of high quality in newer products, but on the older products there were issues with outdated components for example. The other perspective came from the employees in teams who not only viewed the product data, but also had the tasks of creating, editing, and organizing it. In these teams the perceived data quality was seen to be lower across the board, as they were able to pinpoint clear examples of how the data was not accurate, timely, complete, or believable. Still, while the overall quality from these dimensions was seen as lower than as indicated from the other teams, it was not perceived to be of low quality *per se*. Rather, the data quality was seen as okay or adequate to the point that there were errors and uncomplete data sets, but these did not have enormous negative effects, at least not yet. Data consistency, accessibility and easiness to understand were seen as of relative high quality, likewise in the teams that only viewed the product data.

The most important finding regarding the product data came from trying to identify the data management and governance roles within the organization. The interviewees who had used the PLM system were asked if there were processes in place to measure and assess the product data quality and if there were roles assigned to different aspects of data creation, editing and keeping the quality of it in check. While not all interviewees were able to answer with confidence how the current situation was, the ones that did have a grasp on it, explained how there were no processes in place to govern the product data or cleanse it periodically. Data corrections were at the time done *ad hoc*, as whenever an error or incompleteness came up, it was either corrected immediately, or communicated to another person to be corrected at some point in time.

Based on the interview, it seemed like the responsibility of overseeing and maintaining data quality in the PLM was understood as an unofficial shared responsibility, but not specific to anyone and not enforced by protocol. Previously, there was a component engineer who had the task of maintaining product data quality among other duties, but that employee was not part of the workforce anymore. This had slowly resulted in data quality starting to decay, which at the time of conducting the interview had already affected sourcing and product development processes by having a component be listed as a preferred one in the PLM, where in actuality the component's manufacturer had stopped manufacturing it, which resulted in production and inventory issues. Additionally, the role of data owner – and other data governance roles such as data stewards – were not in use in the organization. The people who had the most understanding of the PLM had the tasks of creating and editing data corresponding to their team and the people who were not sufficiently proficient with the PLM did not create, edit, or organize the data at all. The approval process for new data creation was utilized, but the responsibilities of who would approve of which data were not specified, which in practice meant that the approval could come from anyone within the team. Most likely the person to approve was the employee with the most amount of PLM experience, which incidentally often were the principal employees in teams.

4.1.3 Use and understanding of substance compliance

Currently, before the implementation and introduction of the PLM integration, substance compliance management in the case organization is largely handled by the company's internal compliance manager, sourcing team and an external compliance solution provider. This external organization provides a substance compliance management system as well as handles the systematic testing and substance compliance data collection on the requested components. The internal compliance manager and sourcing team on the other hand oversee all the other steps relating to the substance compliance management process in the case organization.

Based on the interviews and observations made during the five-month period, a rough visualization of the substance compliance management process in the case organization can be visualized. The process starts when a product structure is created in the organization's PLM system. The technical product structure containing all components – i.e., the bill-of-materials – is then exported from the PLM system into Excel form that can be more easily modified. This newly exported BOM is manually processed to be in the

correct format for the next steps. This includes marking components to be either in scope for the compliance check or out of scope as well as adding supplier and manufacturer information if these are not already found on the original BOM export. The outcome of this manually processed BOM is a so-called *compliance BOM*. The compliance BOM is then sent forward to the compliance solution provider for substance compliance data collection, where the solution provider gathers compliance data on the requested components from various suppliers and databases. If the solution provider is not able to gather compliance data on any requested component – because of erroneous supplier contact information, wrong point of contact in the supplier organization, or supplier not providing information to third parties for example – the case organization itself must try to resolve the issue, often by contacting the supplier directly. If the case organization is not able to resolve the issue and gather compliance data, the supplier and/or component must be switched to another one and the process started again from the first step. But if the issue is resolved, and the substance compliance data is gathered successfully – or there were no issues to begin with in the compliance data collection phase – the complete report is sent back to the case organization by the solution provider. If the product is compliant, the compliance report is then either used to perform government agency regulatory submittals and certifications and the process can be seen as completed for the time being. But on the other hand, if the product is noncompliant, actions such as modifying the product structure or its components, conducting further tests or adding warning labels must be taken before continuing. A rough visualization of the entire process can be seen in figure 14.

For substance compliance the case organization and the solution provider both utilize full-material-declarations – FMDs – so that the process for validating most if not all substance compliance regulations on products can be done in one go. In the case organization gathering FMD data has become an unofficial requirement for products, as data on an individual regulation is often not enough. As noted by the compliance manager in the case organization, the most important regulations currently for the company's products are the RoHS and REACH regulations as well as California Proposition 65. Still, the organization of course aims to be compliant with all the regulations which are in scope in the countries where the company's products are sold.

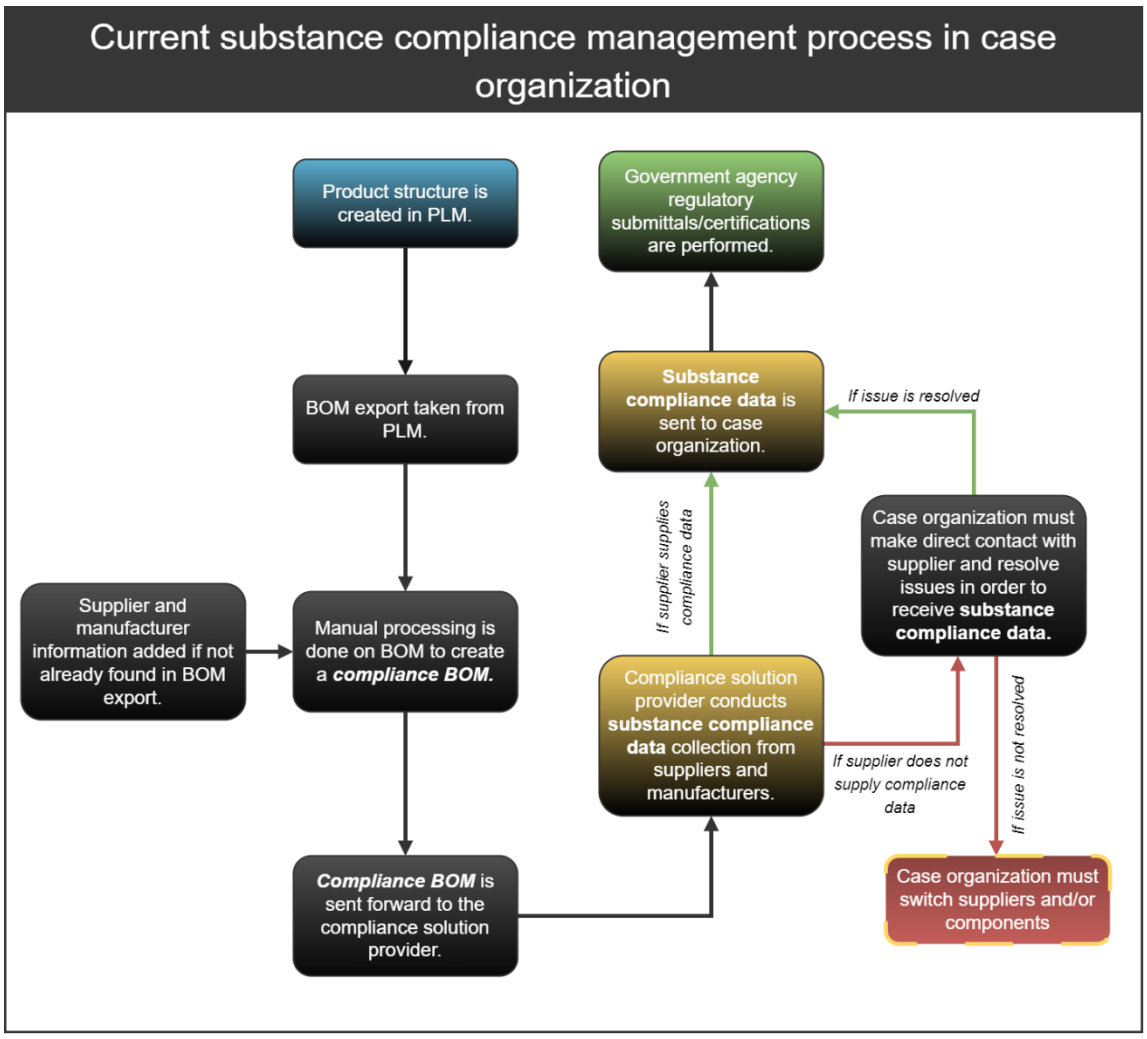

Figure 14: Current substance compliance management process in case organization

While the overall process and successfulness of the substance compliance management process in the case organization could be perceived as good, some issues were also identified in the interviews. Firstly, according to some interviewees, substance compliance is handled as a reactive method rather than proactive, as rather than trying to design products and components with the compliance perspective in mind, the thought of staying compliant to different regulations comes often more as an afterthought. In practice, the sourced components in product development are nearly always compliant – as the market for noncompliant components is close to nonexistent – but the requests and evidence for compliance lags behind in the product development process. Also, while various teams in product development often try to choose and pick components and materials that are RoHS and REACH compliant, there is no structured process on picking compliant components on these teams. According to the compliance manager, there should be strict requirements for picking compliant components likewise there are with some mechanical requirements. Additionally, there is no leadership team agreed upon

strategy or process map on how substance compliance is conducted, as it is more or less done how the compliance manager sees fit. Manufacturer or supplier data is gathered as an ad-hoc way via emails from other team members when issues are realized. According to the interviews, the compliance perspective is also not as well utilized in sourcing to the extent that it should be, as while there is a compliance requirement document that can be used with new suppliers, there is no strict protocol to adhere to using it. Still, the biggest issue in the process is the fact that substance compliance as a whole in is largely dependent on only one person: the compliance manager. No other employee has the level of skills or understanding of the process to easily transition to the role, and as such if the competence would abruptly not be available in the organization, the whole process would come to a halt. As for the utilization of the substance compliance management system, virtually the only user of the system is the compliance manager and as such there really is not any transparency concerning the use of the system currently either.

The understanding of substance compliance was roughly the same across all teams. The end goal of compliance was clear to all: to comply with product regulations or standards so that the product can be introduced to the markets. From the regulations that the case company complies, RoHS and REACH were identified the most, as nearly all participants were knowledgeable of these and saw them as an important part of substance compliance. Most of the participants in the first interview were also able to name California Proposition 65. Still, while the most important substance compliance regulations to the organization were known, the methods to practice substance compliance were not on the same level; the gold standard for substance compliance management – the full material declaration – was known to less than half of the participants. In addition, when asked how the process was handled in practice, the answers ranged wildly from not knowing at all to giving very specific answers on what to do in each specific instance. The overall process was more well-known than the practical methods to conduct it, as around half of the participants were able to give a crude description of what needs to be done to stay compliant in the big picture, but fewer were able tell for example that the case company employes a compliance solution provider and that there is a substance compliance management system in use currently. It also became apparent, that the case organization currently does not have an agreed compliance strategy or roadmap for substance compliance. Because of this, most of the participants in the interview saw substance compliance as a separate part from the “normal” product development, and as such saw the responsibility to aid in the process of substance compliance to be outside of their job

description. Ironically, the importance of substance compliance was seen as extremely high; only one participant thought that substance compliance is not highly important as a business function. All the other participants noted that compliance is crucial for the case company, and that it must be done and done well. Most also even noted that compliance becomes more important as time goes on and more regulations are introduced. But, even if the importance of compliance was well understood, the common view was that currently the resources are spread so thin that if the responsibilities of substance compliance were to be divided among other teams, new capabilities should be introduced, as existing employees do not have the time, knowhow, or interest in taking more responsibility in substance compliance.

4.2 Integration project analysis

4.2.1 Project goals, roles, and planning

According to the second interview – for which the questions are available in the appendix 2 – all the interviewed stakeholders in the project shared the same goal: to develop a PLM-integrated substance compliance management interface. The significance of the project from the case company's business perspective was also well understood by all parties, as with the integration the substance compliance management process should become more visible to other employees within the organization and possibly allow a better distribution of responsibility. The motivations for the project on the other hand of course varied depending on the organization. The case company wanted to improve the compliance process and had a very strict "improve the product development process" perspective, the compliance counselor as well as the PLM developer both had the interest of boosting their already existing service and software sales with the help of the integration. The PLM developer distributes and sells the PLM software and related services, and the integrated substance compliance module is a good additional selling point. Similarly, as the compliance counselor distributes the compliance provider's software and sells consulting and services related to it, the integration with a well-known PLM was also a welcome addition. So, in essence both external stakeholders share the motivation of selling their own individual software and services and use the integration as a boosting effort for the sales.

The organizational roles in the project were clear. The PLM developer oversaw the development and maintenance of the PLM software while the compliance counselor aided

in substance compliance related issues, provided the substance compliance management software, and worked as a consultative role in the project. The case company had the role of working as a pilot organization for the integration as a customer to both other two organizations and gave real-life data and use cases for the project. But while these organizational roles were clear to all stakeholders, the individual roles in the project were not as clear. While some could identify that the product manager in the PLM developer organization most probably was the project manager equivalent for the project, the role was not decided or agreed upon. The other roles for the project were somewhat unclear, as they were not named, but the responsibilities for each participants respective role in the project were understood relative well. Still, it was clear that at least in the beginning of the project a clear leader for the project was not defined.

Structurally, the project was not as organized as some participants had hoped. As the project was conducted as a small-scale project to be done in parallel to other tasks, some participants noted that there was no agreed upon project plan. This resulted in an ambiguous schedule and milestones, as most of the participants were unable to give a precise idea what the schedule of the project currently was. The delays on the already unclear schedule made evaluating the project timeline even more difficult. From all the interviewees in the second interview, the PLM developer had the clearest idea of what the timeline and practical steps of the project were, which should not come as a surprise as they are in charge of developing the technical implementation of the integration. A visualization of the practical steps and current timeline based on the various answers can be seen in figure 15.

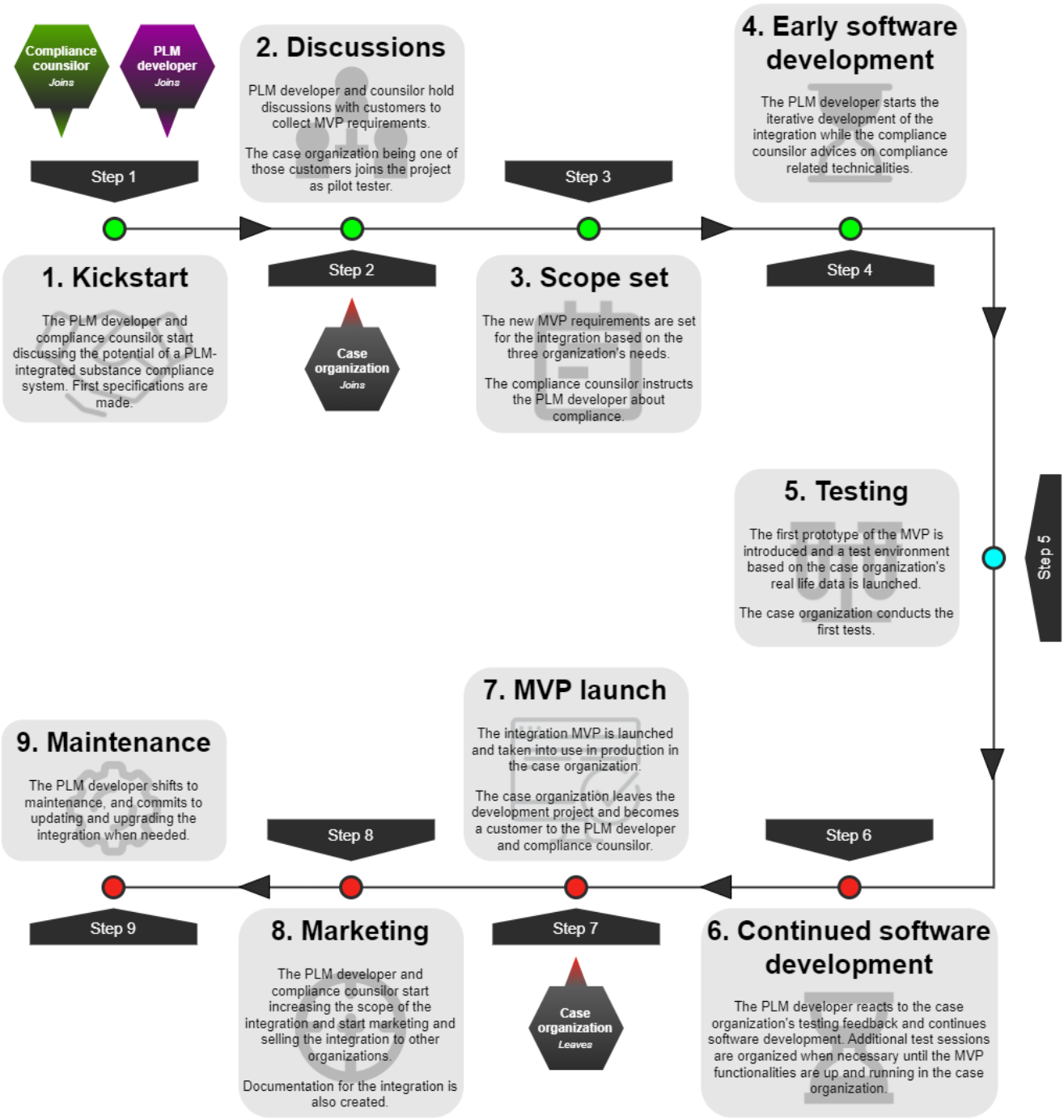

Figure 15: Integration project practical steps timeline for the three major organizations

4.2.2 Project challenges

Like in any project, a number of challenges could be identified in the integration project. While numerous challenges were named, the three challenges of communication, delays, and setting up a test environment were the most prominent ones in the interview. Communication was seen as the biggest challenge, as not all of the stakeholders in the project had been aligned and properly informed at times. This view was shared by many, as there had been sizable intervals between communications previously, and it had

become apparent that not all pieces of information had flowed to all parties. As the project was a joint-operation between three – or even four if the compliance provider is taken into account – organizations the way that the information flowed could be seen as an issue at times, as sometimes discussions were held between only two parties, and the third was partially left out in the dark at least in same scale. A participant from the case company described that in the beginning of the project communication was sparce and minimal, but after the product manager from the PLM developer had taken the role of being the key communicator in the project, the communication had become more frequent and functional.

The second big challenge in the project was the multiple delays that had occurred in the time frame of the project. The reasons for these were various. Firstly, at the beginning of the project the PLM developer deemed developing a compliance integration to be challenging, as while they did have extensive experience in PLM, CAD, and various IT system development, developing a system with substance compliance in mind was a first-time experience. Because of this, the compliance counselor organization had to advice and provide instructing on what substance compliance is, and what are the important functions of it. So, in other words, the PLM developer organization had a knowledge-gap on substance compliance, which needed to be remedied before moving forward. Additionally, in both the case organization and the PLM developer organization there were resource allocation problems, as the project was done as a parallel project to other work tasks, meaning that not enough resources were allocated at times to the completion of this project.

The final often-times mentioned challenge in the project was the issue of setting up a test environment. As the project was done more as an ad-hoc way, rather than conducted through a structured project plan, the topic of setting up a test environment was not properly discussed. Then, when the time came to start setting up the environment, no groundwork had been done for it, as the participants in the case company had thought that the third-party compliance provider would have a ready-to-use test environment for the occasion. But, as it turned out, the organization only had a test environment with randomized data, which could not be utilized with real-life data as the personnel in the case company had hoped. Because of this a new test environment had to be built, which of course further affected the delay on the project. This then cascaded into other problems, such as facing data privacy issues due to using real-life product data, and not having the

latest version of the PLM system in use in the case company, even though the integration was specified to be used with the newest version.

Other challenges were also identified in the interview, such as the possibility that if not enough customers are found for the new integration, the allocated budget and resources for the future development and maintenance of the integration could be minimized, resulting in a less functioning integration. Additionally, while not mentioned in the challenges part in the interviews, the unstructured way of doing things in the project could also be classified as a challenge, as there were no metrics to evaluate the completion of the project, and the schedule of it was also unclear.

4.2.3 Internal change management

In addition to evaluating how the integration project has been conducted so far, a reasonable number of questions were asked regarding the internal change management plans and ideas in the case company in the second interview seen on appendix 2. The findings from these questions can be separated into two categories: (1) how the vision of change is perceived and articulated to others in the case company and (2) how the change is planned to be implemented and sustained.

The vision of change could be perceived as vague, at least according to the interviews. While the goal of the project is clear – to implement a PLM-integrated compliance interface and start using it – the clear vision on how things should change is missing. The hope is, that through the integration the process of substance compliance in the organization becomes more visible to other employees and teams, but the practical ways of reaching that point with the use of the integration have not been thought of. The compliance manager in the organization had the clearest vision on how the integration could help and what it might accomplish, and it was noted that the same vision might not have been visualized well enough to other internal stakeholders. An example of this is the technical specifications for the minimum viable product (MVP for short), which for the most part only the compliance manager was sure of what they were internally. Additionally, it became apparent that some internal stakeholders might not currently or in the future see the value of the project, as the original reasons for starting the integration were not visible to others. In practice this means that currently some stakeholders see that the substance compliance process is working and is being handled sufficiently well, and increasing the resources used for it do not yield enough benefits. In other words, these

stakeholders might not regard the risks related to the process as relevant enough to warrant huge improvements. Currently the visibility to the issues concerning the substance compliance process is limited, as the process is largely contained to the use of a singular system which is actively operated only by the compliance manager.

The second major finding related to the internal change management was how the change was planned to be implemented and sustained. Or to be more specific, how it was not planned. At the time of conducting the interviews, no specific plans were set in place. This also meant that there were no continuous review processes for the project, nor were there agreed-upon metrics for conducting reviewing. When internal stakeholders were asked how they intended to spread the use of the integration internally, a unanimous "we currently do not a have plan on how to do so" was given by all three internal interviewees. As pointed out by one participant, the scope of the integration and its introduction – and as a direct consequence the scope of the master's thesis – was originally wrongfully seen as smaller than it turned out to be, and as such the plans for internal change management had not been developed. Additionally, the people who might be affected by the change were not properly identified, even though some teams like the mechanical engineering, hardware engineering, and sourcing were seen as the most likely candidates for the new integration. In the same vein the employees in those teams were not informed of the upcoming integration, nor were they a part of the testing. It was also noted that it is very possible that there might be change resistance to the use of the integration, or more specifically to the new potential division of responsibility for the substance compliance management. Still, while the upcoming change was not structurally planned or the effects of it visualized, a capability model – the capability triangle – was seen as something that should be used if the integration was to be taken full advantage of according to one of the participants. A visualization of this model can be seen in figure 16.

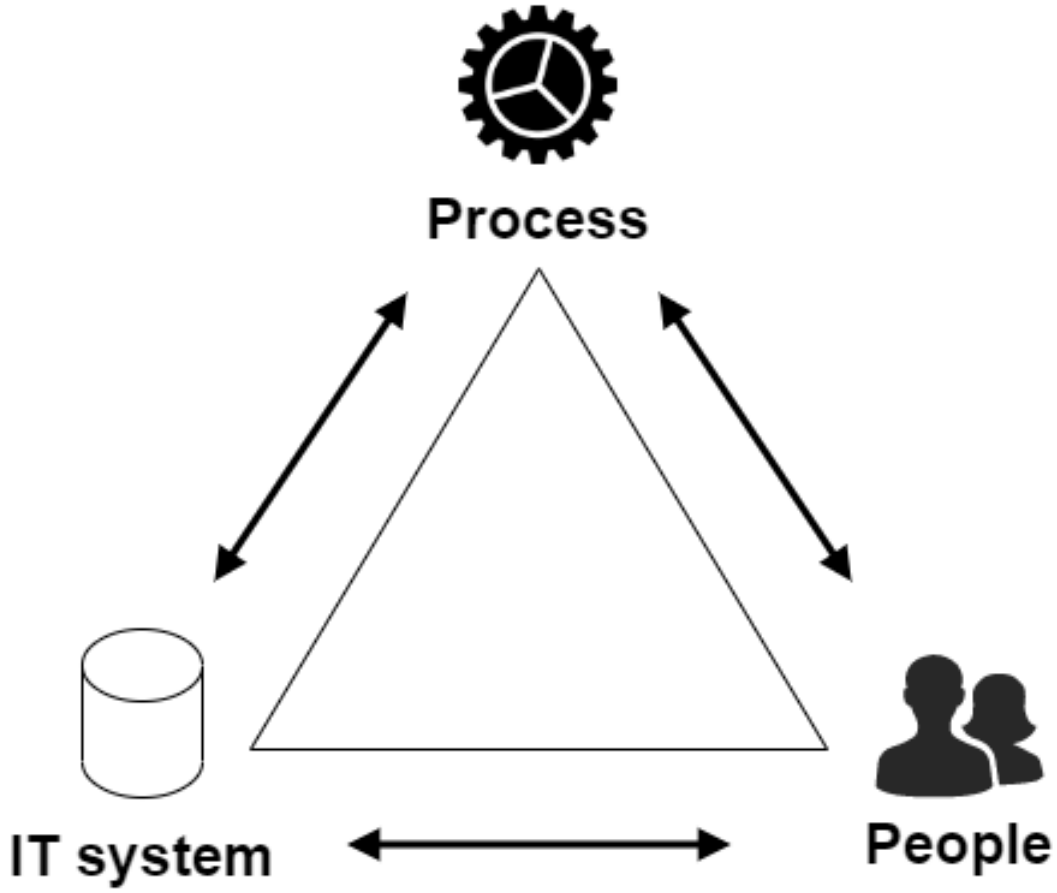

Figure 16: Capability triangle to be used for the successful implementation of the integration, described by one of the participants in the interviews

As described by one of the internal interviewees, the capability triangle could be very well used for the implementation and sustaining of the change efforts brought by the integration. In order to take full advantage of it, firstly the IT system should be in good condition. In practical terms this meant good technical implementation of the integration and improvements in the product data that was to be used in the project going forward. The second aspect of the triangle was the process, which means having figured out the roles and responsibilities of each stakeholder and having clear operating models. The third aspect was the people concerning in the project. In practicality this means having training and training materials ready, having the support that is needed for the people, and having documentation among other things. So, while no particular plans on how to conduct the change and sustain its benefits in the short- and long term were thought of, the needed capabilities in the way of the capability triangle were thought of and visualized.

4.3 Technical implementation of the integrated interface

In the technical implementation evaluation, it became clear that the first prototype of the PLM-integrated substance compliance interface offered major new functions that can be divided into two sections. The first being the changes to the product structure view, where each component can be seen in a clear and structured way. According to the previous interviews, functions in this technical product structure view are used the most and it is the most familiar to the majority of the users. The upgrades to this view were the ability to see the compliance status of each component and to mark specific components, assemblies or entire bill-of-materials to be checked for regulatory compliance. The second new set of functionalities can be seen in the compliance check view, where the compliance status of previously selected components can be requested from the substance compliance solution provider.

4.3.1 Changes to the product structure view

The first major function of the integrated substance compliance comes via upgrades to the familiar technical product structure view of the product lifecycle management system. Traditionally, in this view the entire technical product structure can be seen down to individual component level, and the different component variables from each manufacturer – i.e., manufacturer parts – are visible with notations such as *preferred*, *active*, or *end-of-life*. Now, with the integrated substance compliance, users are able to mark specific components, assemblies or even entire BOMs to be requested for their compliance status. The selections to be marked for each component are:

- YES – *Compliance data is requested, and there are no subcomponents underneath this item.*
- NO – *Compliance data is not requested, and there are no subcomponents underneath this item.*
- YES (TREATED AS ITEM) – *Compliance data is requested, and there are subcomponents underneath this item for which compliance data is not requested.*
- SUBASSEMBLY – *Compliance data is not requested but there are subcomponents underneath this item for which compliance data is requested.*

After the components have been marked and the compliance data request has been completed through the second *compliance check view* the compliance status of each

component is visible in the product structure view. In the first MVP prototype, the regulatory statuses of EU RoHS and REACH are visible with one of four possible notations. *Passed*, which means that the component has passed the regulatory check and is fully compliant with said regulations. *Passed with exemption,* which means that the component has passed the regulatory check, but under an exemption. These exemptions can vary, but usually they mean that the component contains an amount of some material or substance that is currently only allowed in some specific cases but is going to be re-evaluated by the regulator and might become non-compliant in the future. *Failed* means that the component has failed the regulatory check and contains too much of some material of substance that is on the list of forbidden substances. And finally, if the field is blank, it means that the compliance status of the component has either not been requested, or it has not been received yet from the compliance solution provider. Currently in the first prototype only the statuses of EU RoHS and REACH were visible, but it should be noted that the FMD status has already been discussed to be added in the next iteration of the integrated substance compliance interface. According to the case company's compliance manager, the current way of marking compliance requests and viewing finished compliance statuses in the technical product structure view feels intuitive and good.

4.3.2 Compliance check view

The other major functions brought by the integrated substance compliance can be found under a completely new view within the PLM: the *compliance check view*. In this page, all of the components and assemblies that were set to either YES or YES (TREATED AS ITEM) status in the check compliance field can be seen as a complete list. The user can see each marked component and manufacturer part with relevant info such as status summary, name, component number, context, and so on. Still, the most relevant functionality in this view is the option to request compliance data on the selected parts from the compliance solution provider directly from the PLM. While previously employees had to manually prepare a compliance BOM based on the BOM export from the PLM and then send an email to the solution provider which was a time-consuming endeavor, now the process can be slimmed down to marking the components to be requested for compliance data and then sent through the use of a single button which automatically formats each component into the correct format and sends an email to the solution provider for analysis. A visualization of substance compliance management process with and without the integration can be seen in figure 17.

After the analysis, the statuses of the requested components are automatically updated in the PLM and are visible to all who have access to the product structure view. In the first MVP the components and manufacturer parts in the compliance check view are stored in an arbitrary list, and as according to the compliance manager can be perceived to be problematic once a large number of components are requested for compliance data. As the case company has an extensive catalogue of products and multiple product variants, the list of all the requested components can easily become exhaustive and navigating the page can become difficult. As such, it was noted that in the following versions of the interface, the view would be configurable for example to show certain products with their technical structure.

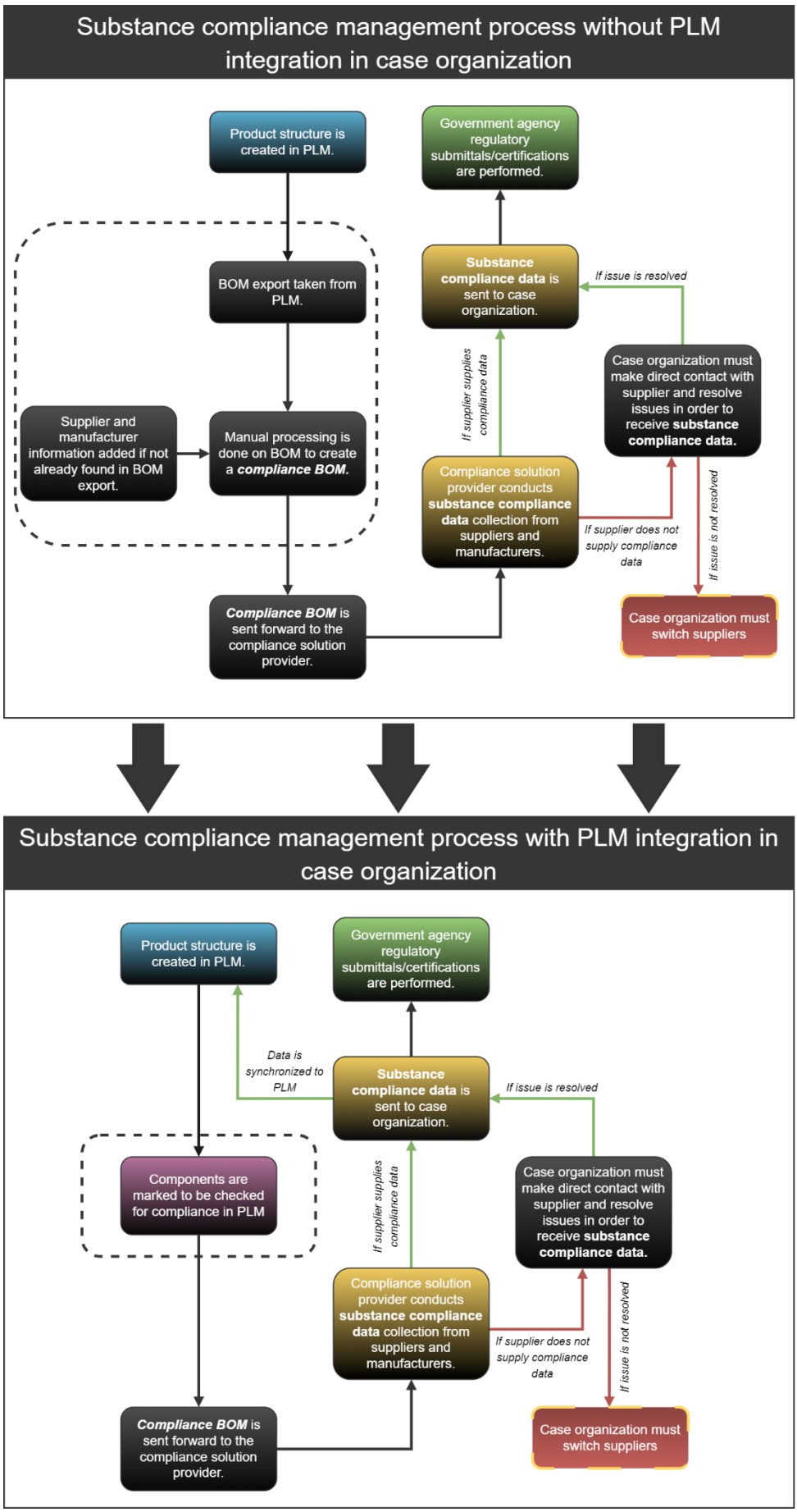

Figure 17: Substance compliance management process with and without the PLM integration in case organization

4.3.3 Synthesis of the current state analysis findings

The aim of the current state analysis was to create a view on the case organization's PLM system and substance compliance processes as well as to their understanding among the organization's teams. Additionally, the secondary aim was to uncover what was the current state of the PLM-integrated substance compliance management system project in the case organization, both in terms of general development and technical implementation. Furthermore, the goal was to be able to answer the third research question of:

RQ3: What is the current state of PLM, substance compliance, and the system integration in the case organization?

The findings from the current state analysis on the PLM and substance compliance processes can be divided into three categories of perceived use of the PLM, perceived product data and data governance, and perceived substance compliance. Firstly, it was noted that the current PLM system had not been in use for too long, and as such some of the systems functions were not yet utilized to their greatest capacity. The use of the PLM system in the case organization differed greatly from one team to another, since in some cases employees had never used it and in others the system was used nearly daily. As such, the use cases differed as well. Still, three categories of use-cases could be visualized: employees who did not use the PLM, employees who used the PLM only for viewing data, and employees who used the PLM to create and edit product data in addition to viewing. Ultimately, as noted by the employees who used the PLM system, the usability was perceived to be low, as the system was time consuming and hard-to-use. Still, the use of the system brought great benefits, and as aptly described by one interviewee, was deemed as a "necessary evil".

The perceived current state of data quality and data governance brought up two important findings. Firstly, there was the slightly split perspective to the data quality. The employees who only used the PLM for data viewing saw the data quality to be higher than those who used the system for data creation and editing. The employees who utilized the PLM system more saw the product data as sufficient and okay and had a shared perspective that even though there were errors and the quality was not perfect, there were no impactful negative effects, at least not yet. The second finding came from the perceived data governance. According to the interviewees, there currently were no protocols to uphold

data quality, and the responsibility to check and update potentially erroneous data was seen as an unofficial shared responsibility. In other words, while everybody shared the responsibility to uphold data quality, there was no specific employee responsible for data quality processes or data governance, and as a direct result the quality of the data had slowly started to decay.

The current substance compliance process in the case organization was seen as functional and successful, as currently the case organization employed an external compliance solution provider and an internal compliance manager to conduct substance compliance. Still, some issues were identified in the process, with the biggest being that currently the substance compliance process was largely dependent on one employee, the compliance manager. Additionally, the compliance perspective was not utilized to the extent that it should have been in the early phases of product development or supplier management, as there was not any leadership agreed upon strategy or process map on how substance compliance was to be conducted in the organization. The understanding of substance compliance among the various teams also shaped a somewhat clear picture. The goals of compliance were clear, and the most important regulations of RoHS and REACH were well understood. The importance of the process was also seen as extremely high. Still, the methods and practicalities for conducting substance compliance were not clear to the majority of the participants. Furthermore, as there was not any agreed upon roadmap or compliance strategy and the process was largely contained to the actions of one employee, most of the participants saw the process of substance compliance outside of their own job descriptions.

The secondary perspective on the state of the system integration also brought up multiple interesting findings on the state of the project as well as the technical implementation of the integration. On the project management side of the findings, all the organizations taking part in the project were well aligned in their goals and aims. It was also clear what the eventual outcome of the project would be, and the organizational roles for getting there were clear. Still, the individual roles for project participants were perceived to be less clear, as for example the role of project manager was not defined in the earlier phases of the project. Additionally, project planning was seen as minimal, as some participants noted that there was no clear project plan or schedule established. Still, based on various answers, a rough timeline for the practical steps of the project could be identified, and a visualization of this was introduced in figure 15. In addition to the unclear project plan

and schedule, the major challenges so far in the project were seen to be communication, delays and setting up a test environment for the first prototype. Internally, the view on what and how things change – i.e., the vision for change – after the implementation of the integration was not clear to the participants, and as such could be perceived to be vague. Plans for how to introduce the integration and how to make it part of the daily operations were not yet agreed upon. Most employees who potentially could use the integration after the introduction of it were not informed of it, nor were most of them part of the testing of the integrated system. Additionally, as the issue and reasoning for starting the integration was not visible to all, it is a possibility that the higher-ups do not see the imminent value in developing and improving the substance compliance process further.

Lastly, the technical implementation of the integration was analyzed, and two new major functionalities were identified in the new integrated PLM. The first of these came in the form of changes to the product structure view, where the compliance status of components could be seen, and components could be marked for compliance data gathering requests. The second functionality was the new compliance check view, which allowed users to inspect the marked components and then send compliance data requests to the compliance solution provider directly through the PLM. The combination of these two functionalities alone eliminates a time-consuming manual processing phase of product BOMs in the substance compliance process.

5 ENSURING SUCCESSFUL USE OF THE INTEGRATED SYSTEM

In this chapter the findings of the empirical study are mirrored to the theoretical framework built in the literature review and through those practical improvement suggestions are given to further improve the introduction of the PLM-integrated substance compliance interface as well as the overall process of managing the substance compliance process in the case company. These improvement suggestions are grounded in literature while also being practical and actionable. The improvement suggestions also follow structured processes described by surrounding literature, but as a result of the more theoretical approach used in this master's thesis, stay more on the general level as opposed to giving strict suggestions of "improving process X in team Y through the method Z".

5.1 Overview of the three-step improvement plan

Based on the findings from the empirical study, three separate issues came to light, that should be addressed in order to fully utilize the upcoming PLM-integrated substance compliance management interface. The first of these issues was, that currently at the case company there is no data quality management responsible, but rather the responsibilities of it are shared among all employees. That means that data quality management is not conducted structurally, and over time product data simply decays if nobody stumbles upon it and decides to correct it. The second issues based on the research findings was, that there were no plans in place to introduce and spread the use of the integration internally. The vast majority of the employees who currently use the PLM the most were not aware of the upcoming integration, and no plans were yet made to inform them. Plans on how to integrate the interface to the new ways of working were not made, and ideas on how to spread the use of it were not thought off. And finally, the third major issue as based on the findings was, that the current substance compliance management process rests mostly on the shoulders of one key employee: the compliance manager. The process also has very bad visibility to the other teams who were interviewed, as the ways it was managed were not that clear, and ultimately substance compliance management was seen as a separate entity or responsibility that was outside of other employees' job description.

Based on these three major issues, a three-step improvement plan to successfully introduce the integrated interface and improve current substance compliance management

process is introduced. The improvement plan answers each of the three major issues by mirroring the theoretical framework introduced in the literature review to the results from the current state analysis. In the plan, each issue is answered separately in consequent manner, as completing the first step is a prerequisite for the second step, which in turn is a prerequisite for the third. A visualization of the three-step plan can be seen in figure 18 below.

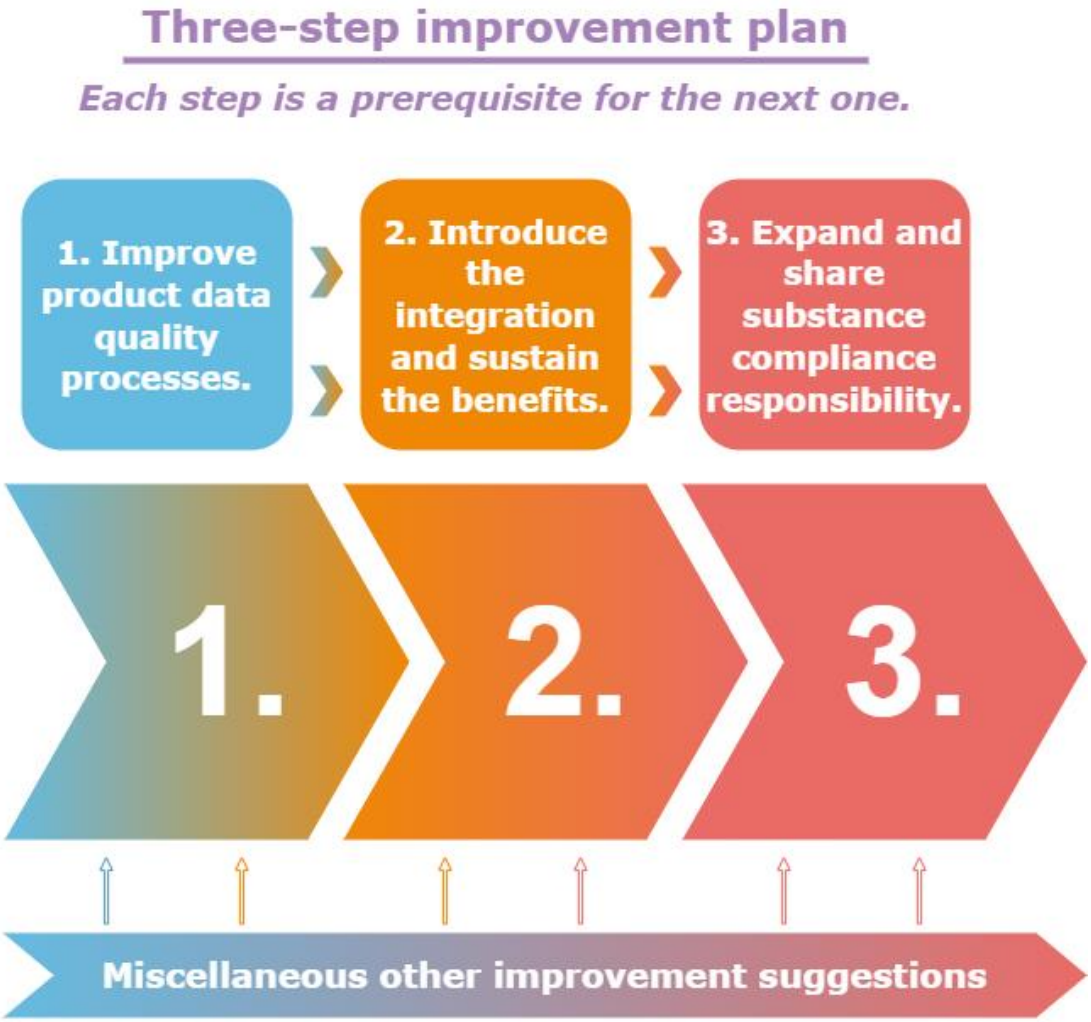

Figure 18: Three-step improvement plan on the case company's substance compliance management process

The first step of improving product data quality starts the entire improvement plan by introducing ways to improve both the product data quality management, and data governance. Focus is put into quantitatively identifying the current product data quality, cleansing it, putting iterative monitoring and updating in place, and identifying and distributing data governance roles. The second step is to implement and introduce the integrated interface to the daily operations of the case company and sustain the benefits

caused by the change. This time focus is on continuing the technical implementation of the integration, while also planning for successful ways to introduce – i.e., inform, instruct and take into use – the interface to the different teams, and think of ways to make the new way of working sustainable while also spreading the use of it internally. The third step is to expand and redistribute the responsibility of substance compliance in the organization to avoid the risk of having the entire process be connected to one employee only. Focus is on making substance compliance more visible to the other teams and starting to conduct it more in a proactive manner, where different product development teams implement a "compliance perspective" to their daily operations. An integral phase in the third step is to also make an agreed upon compliance strategy, that is visible to other employees. Each of these three steps is a prerequisite for the next, and as such the three steps should be conducted in a consequent manner. To accompany the overall three-step improvement plan is the miscellaneous other improvement suggestions based on the findings of the current state analysis. These improvement suggestions are not as drastic as the three on the improvement plan, but are such that should be taken note, as they either help with the overall completion of the improvement plan, aid the substance compliance process, or further improve the use of the PLM system.

5.2 Step 1: Improve product data quality and governance

5.2.1 Overview and reasoning for the first step

The first step in the three-step improvement plan is to improve the product data quality and governance processes in the case company. Currently the product data quality can be seen as decent – i.e., not particularly good, but not bad either – when it comes to the data residing in the PLM system. The results are based on the answers of the first interview conducted in the current state analysis part mirrored to the most often used data quality dimensions presented by Wang and Strong (1996). The finding of having adequate product data quality itself is not alarming, as based on Orr (1998), organizations should not be aiming to have perfect data quality, but rather *good enough* product data quality. In the case company's situation, it could be argued that the product data quality currently is good enough, as it does not cause major setbacks or negative financial impacts.

But, while the current level of quality on product data might not be hugely alarming, the fact that there is no one in the case company fully dedicated to improving or maintaining the data quality could be seen as slightly alarming. The current situation in the case

company is sufficient and functional, but if nothing is done about the slowly decaying product data, negative effects such as the ones described by Moges et al. (2016), Haug et al. (2011), and Eppler and Helfert (2004) may inevitably come up. The company might end up making bad decisions that are based in bad quality data, running costs might increase as wrongful data cause errors in product development, employee performance could decrease as they have to be careful of trusting data, and customer satisfaction might lessen. Having poor data quality in the PLM system also affects other systems and various teams, including substance compliance. Even in substance compliance alone, bad data quality could result in breaking the RoHS, REACH and/or California Proposition 65 regulations, which could result in for example delays in entering markets, lawsuits and financial penalties.

Improving product data quality and its governance is also motivated by the PLM-integrated substance compliance interface, as having extensive and correct enough data in the PLM is necessary for the interface to function properly. This view is also heralded by both Miehe et al. (2015) as well as Bachmann (2010) who argue that high quality product data is crucial for substance compliance management, and by extension to the PLM-integrated substance compliance management interface as well. Currently, the product data quality could affect the integration, as for example according to the current state analysis findings the manufacturer and supplier data is not found in all components in the PLM system. As the interface is unable to conduct substance compliance management queries without the supplier and manufacturer data, having them is crucial. And, as the interface requires additions and a cleanse to the existing product data in the PLM system, it would make sense to start conducting improvements to the product data before widely introducing the PLM-integration of the substance compliance management software. If product data quality is not improved before the introduction of the interface, the successful use of it becomes more problematic. For this reason, this first step of improving data quality and governance is the first one in the grandeur plan, and a requisite to the following step of introducing the integrated interface. The first step is divided two activities of improving data quality management and improving data governance. While the activity of improving data quality management is presented first, the two activities should rather be conducted in parallel, as they are deeply connected and could be seen as mutually supportive.

5.2.2 Improving data quality management

In practical terms, the improvement of product data quality in the case organization should start with coming up with a data quality management process. In scientific literature many of such processes are introduced and described, but as noted by Ehrlinger and Wöß (2022) usually all the different processes share the same four core characteristics or phases. These four phases are the state reconstruction, data quality measurement or assessment, data cleansing or improvement, and the establishment of continuous data quality monitoring. While the findings in this master's thesis could be perceived as the first phase of state reconstruction, it should rather be used as a starting point and steppingstone to conduct a more widespread analysis on the current state of data quality management. The reasoning for this is the fact, that while the overall picture of product data quality management could be perceived to be clear based in the empirical results of this study, the results do not provide a widespread view of the contextual information on all organizational process and services, nor are the corresponding costs touched in it.

The second phase – data quality measurement – is the phase of improving the DQM in the case organization. As described by Batini et al. (2009), the phase can be divided further into five activities:

1. *Data analysis*
2. *Data quality requirements analysis*
3. *Identification of critical areas*
4. *Process modeling*
5. *Measurement of quality*

Since the second phase of data quality measurement is often described as the most problematic – as according to Sebastian-Coleman (2012) – the case organization should instill extreme care on the completion of this phase. The first activity, data analysis, relates heavily to the findings of the empirical study, and as such the findings should be used as a starting point in analyzing and building an understanding of product data, its related architecture, and the rules concerning its management. Likewise in the second activity – data quality requirements analysis – more thorough surveys should be conducted to get a more widespread view on the opinions of the data users. The goal of the second activity should be to further improve the understanding built by the empirical study, and to identify clear quality issues as well as set new quality targets. In the aid of

the second activity, the case company should analyze what is the optimum data quality, i.e., the theoretical highest data quality target that improves financial status by eliminating some risks related to poor data quality, while not going overboard with improvement costs resulting in a net loss in costs (Eppler & Helfert, 2004).

After completing the second activity related to data quality measurement, the case company should move on to the third step of identification of critical areas. While the main idea would be to focus on product data in the PLM, the most relevant databases would realistically be the product structures, the components related to them, and the related metadata. The data flows should also be identified, and the creation and current editing of product data – which according to the study findings currently happens the most in the hardware engineering and mechanical engineering teams – should most likely seen as a starting point to identifying the relevant data flows. The fourth activity – process modeling – should be started after the critical areas are identified (Batini et al., 2009). In practical terms, this means that in the case organization the processes for producing and updating data should be modeled and visualized to better understand the current situation. While the findings from the study indicate that there is currently no structured way of updating data in the PLM, but rather a more ad-hoc way of doing it, the processes for producing data should be modeled more in depth. After the process modeling, the fifth and final activity on data quality measurement can be conducted, which is the actual measurement of quality. This is arguably the most important step in the whole phase, as the data quality should further be measured by quantitative methods. The same data quality dimensions as described by Wang and Strong (1996) can and should be used as they are most important and practical dimensions that can be used for data quality measurement. The corresponding metrics for data quality measurement should be put in place so that the results can be perceived as objective and taken at face value. After the results from the data quality measurement are clear, the case organization can move on to the third phase of improving the data quality management: data cleansing.

Data cleansing refers to the activity of either automatically or manually cleansing, filling, and updating data so that it becomes that of better quality (Ehrlinger & Wöß, 2022). The methods to practically conduct data cleansing are numerous, and nearly always differ in terms of responsibilities, methods, and style, and as such are very case- and organization sensitive. As the empirical study in this master's thesis did not evaluate or analyze what kind of data cleansing method would be the most suitable for the case organization, the

specific ways of conducting data cleansing cannot be named here in this improvement recommendation. Nonetheless, the data cleansing should be conducted, as it is a necessary phase in the overall process of improving product data quality management, but also the prerequisite to introducing and fully taking advantage of the upcoming PLM-integrated substance compliance interface. From the perspective of the integrated interface, the most important areas to cleanse are the manufacturer and supplier data, which currently are somewhat outdated and, in some cases, omitted completely. Of course, missing component data and metadata should also be filled, and incorrect metadata corrected, as they are important for the integration to function successfully. After the data cleansing is conducted, the case organization can move on to conduct both the final phase of the data quality management improvement and introducing the integrated interface to the organization in parallel. This is due to the fact, that the prerequisite for introducing the interface comes from being able to utilize correct and currently occasionally missing data, but the establishment of continuous data quality monitoring – which is the final phase of the DQM improvement process – is not a prerequisite and can be completed in parallel with the introduction of the interface.

The final phase of improving the data quality management in the case company is the phase of establishing continuous data quality monitoring. From the perspective of long-term business value in the case company, this activity is one of the more important ones, as forgoing the step or doing it haphazardly can lead to a plethora of financial and operational setbacks as detailed by Moges et al. (2016), Haug et al. (2011), and Eppler and Helfert (2004). Conducting a one-time product data cleanse is not enough in the grand scale to improve the handling of data, as without structured and continuous data quality monitoring and updating, the product data quality will inevitably start to decay once more (Batini et al., 2009). Sure, the product data quality would be higher momentarily, but the more important issue and the reason that the product data quality decays would be left unanswered. As such, it is important that processes for establishing continuous data quality monitoring are put in place.

In practice the continuous data quality monitoring means that not only must the processes for monitoring the data be put in place, but also the processes for iteratively updating and cleansing the data according to the continuous monitoring put as well (Ehrlinger & Wöß, 2022). Again, as the methods for creating processes for continuous data quality monitoring vary depending on the organization and teams, there is no direct answer on

how to practically conduct the monitoring in the case company. Ehrlinger and Wöß (2022) present that in practice some organizations utilize data quality monitoring tools and software, which make the process of continuous monitoring easier and faster, but of course implementing them in the PLM environment could be problematic. As such, the creation of continuous DQ monitoring should start with having iterative monitoring for each product data sector – i.e., hardware components, mechanical components and sourcing data for example – that is conducted at certain intervals. The roles and responsibilities should also be commonly agreed to, as the chain of responsibility should be visible. And that is exactly where the topic of data governance comes up. As stated in the beginning of the three-step improvement plan, the data quality management improvement and data governance improvement could and should be completed in parallel, as understanding and effort in one topic reinforces the other.

5.2.3 Improving data governance

The other half of the first step in the three-step improvement plan is to define data governance in the case company. While data quality management refers to the activity of making and implementing decisions to improve data quality, data governance is focused on who makes the decisions and what the decision domains are (Khatri & Brown, 2010). As there currently are not any data governance roles appointed and the processes are still largely unidentified, developing both the data quality management processes as well as data governance models in the case company could be perceived as reasonable. An important distinction in designing the data governance models in the company is, that these only affect the data governance processes surrounding the use of the PLM and substance compliance management, as the perspective is in governing *product* data. A visualization of the potential roles for each data governance domain in the case company can be seen in table 6.

Table 6: Potential roles for each data governance domain in the case company (based on the framework of Khatri and Brown, 2010)

Data Governance Domains	Domain Decisions	Potential Roles or Accountabilities
Data Principles *Clarifying the role of data as an asset*	• *What are the uses of data for the business?* • *What are the mechanisms for communicating business uses of data on an ongoing basis?* • *What are the desirable behaviours for employing data as assets?* • *How are opportunities for sharing and reuse of data identified?* • *How does the regulatory environment influence the business uses of data?*	*Divided between the **PLM specialist** and a higher ranking employee with business and strategic perspective*
Data Quality *Establishing the requirements of intended use of data*	• *What are the standards for data quality with respect to accuracy, timeliness, completeness, and credibility?* • *What is the program for establishing and communicating data quality?* • *How will data quality as well as the associated program be evaluated?*	*Hire a new competence of e.g. **data quality manager***
Metadata *Established the semantics or "content" of data so that it is interpretable by the users*	• *What is the the program for documenting the semantics of data?* • *How will data be consistently defined and modeled so that it is interpretable?* • *What is the plan to keep different types of metadata up-to-date?*	*Split between the different product development teams and **data quality manager***
Data Access *Specifying access requirements of data*	• *What is the business value of data?* • *How will risk assessment be conducted on an ongoing basis?* • *How will assessment results be integrated to the overall compliance monitoring efforts?* • *What are data access standards and procedures?* • *What is the program for periodic monitoring and audit for compliance?* • *How is security awareness and education disseminated?* • *What is the program for backup and recovery?*	***PLM specialist** (no changes)*
Data Lifecycle *Determining the definition, production, retention, and retirement of data*	• *How is data inventoried?* • *What is program for data definition, production, retention, and retirement for different types of data?* • *How do the compliance issues related to legistation affect data retention and archiving?*	*Split between the **PLM specialist** and **data quality manager***

When the five decision domains of Khatri and Brown (2010) are inspected in light of the case company's current data governance operations and procedures, clear improvement points can be identified. Starting from the first decision domain – data principles – it is unclear how much time and effort is spent on defining the principles surrounding the use and creation of data. As the first decision domain builds the foundation for the other domains, it can be perceived as important to go back and check what are the data principles in the case company and more importantly name the role of whoever is responsible for them. Previously the PLM specialist had the responsibility of defining the data principles for product data as they were in charge of the PLM and by extension the

use of product data but going forward the accountability should be split between the PLM specialist and an employee who has more perspective on the business processes, as the decision domain of data principles aims to clarify the role of data as a business asset. Abraham et al. (2019) also see the decisions related to defining the data assets as a strategic one, and as such it would be beneficial to have a more strategic view to the decision making process.

The second decision domain – data quality – can arguably be seen as the most important, as currently the responsibility of keeping up the quality of the data is not on the shoulders of any single individual but is rather a shared responsibility of all employees without clear guidelines or strict processes. As per the findings in the empirical study, the employees who have the most understanding in the use of the PLM do not currently have the resources to commit to the role of updating data quality. Similarly, the role of the PLM specialist is spread thin, and managing the data quality within the PLM should be distributed to another employee. Based on these aspects, it could be beneficial to introduce a new capability to the organization in the role of a data quality manager, data quality analyst or data owner. In essence this would fill the void left behind by the previous component engineer by ensuring that the product data quality would not decay and the processes for managing data quality would be designed and kept in check. In relation to the data decision domain framework by Khatri and Brown (2010) this new capability would answer to questions such as "*what are the standards for data quality with respect to accuracy, timeliness, completeness and credibility?", "what is the program for establishing and communicating data quality?"*, and "*how will data quality as well as the associated program be evaluated?*".

Metadata as the third data governance domain is currently partly managed by the appropriate product development teams by themselves. In practice this means that mechanical engineering team oversees mechanical component product metadata, hardware engineering oversees hardware components and so on. The test documents and other types of metadata are currently produced and linked to different components, but no structured processes are defined to keep the metadata up to date. By introducing a data quality manager or equivalent, the accountability for the third data governance domain could also be defined and managed partly by the product development teams and partly by the new data quality manager.

The fourth governance domain of data access is one that has historically been well implemented in the case company and has been one of the key tasks for the PLM specialist. According to the findings, there were no imminent issues related to data access, and as such it could be assumed that the current model of having the responsibility and accountability rest on the PLM specialist's shoulders is practical.

The final data governance domain of data lifecycle covers the definition, creation, and retirement of data (Khatri & Brown, 2010). While the creation and change processes for data are defined and the responsibility given to the PLM specialist, the EOL procedures, retirement, and retention of data are not determined. As a whole, the responsibility of the fifth data governance domain could be split between the PLM specialist and the data quality manager to ensure beneficial use of resources.

By utilizing the framework introduced by Khatri and Brown (2010) and naming the roles and accountability of each data governance domain, the data quality management also receives a boost as the processes and methods can be pinpointed to a particular role in the case organization. The overall aim of the first step was to create and design new product data quality management practices and link those to a responsible who would conduct the new processes. While the first step relied heavily to the framework described by Ehrlinger and Wöß (2022), and Khatri and Brown (2010), any other well-respected model for practicing data quality management and governance could be utilized instead. The important factor would be to instill new structured DQM practices and employ the responsibilities related to them inside the organization.

5.3 Step 2: Introduce the integration and sustain the benefits

5.3.1 Overview and reasoning for the second step

The second step in the three-step improvement plan is about using change management theories and practices to finalize the implementation of the PLM-integrated substance compliance interface and to sustain the benefits it offers in the long-term. Based on the findings in the current state analysis, no plans had been agreed upon to conduct the change resulted from creating the interface, and as such it could be beneficial to create a general plan or outline on how to introduce the interface and how to spread the use of it inside the organization. The first step in the grandeur improvement plan is a prerequisite to

continuing to this second step, as improving product data especially in the component- and supplier-level is essential in starting to fully utilize the interface once finished.

Creating and sticking to a plan in a small-scale project such as in this integration project could be seen as a waste of resources from some perspective, but it is also important to remember that according to Beer at al. (1990) and Hayes (2022) up to 60 percent of change programs either fail completely or fail to reach the set goals and outcomes. The danger of not reaching the set goals in the integration project does exist, since if the implementation of the interface is conducted poorly – by for example the usability being extremely not on par – the employees in the case company might reject using it altogether. Another very relevant potential risk is that the leadership team in the organization might not understand the value of the development project and might pull the plug on utilizing or further developing the integration, making it a wasted effort in the long-term. And the possibility that there could be some change resistance towards the use of the integration also cannot be crossed out, and as such having a plan to lower the potential resistance would increase the probability of successfully introducing the interface in the case company.

The structure of the second step in the improvement suggestion plan is twofold. Firstly, the implementation of the integration is mirrored to the theories of change management, and general improvements are given on communicating the change, managing the internal stakeholders, creating metrics to monitor the change project, and pointing leadership for the change based on Hayes (2022), Mento et al. (2002), Grundy (1998) and Gill (2003). Then, some ideas on how to make the change sustainable in the long run are given based on Buchanan et al. (2006). Additional focus is also put on the "spreadability" of change as described by Hayes (2022).

In contrast to the entire three-step improvement plan, it is important that the integrated interface is implemented and introduced successfully. The third and final step of the grandeur plan aims to expand and redistribute the responsibilities and management processes of substance compliance making the entire management process less prone to risks, but the step relies on the successful implementation and introduction of the interface. If the interface is not implemented or introduced well, the process does not gain visibility in other teams and the understanding of the compliance process will most likely stay ambiguous within the case company. But on the other hand, if only the technical

implementation and introduction of the interface is handled well without revisiting the substance compliance management processes, the potential gains provided by the integrated interface might largely be left unrealized.

5.3.2 Implementing the integration

As the technical implementation of the integrated interface is mostly in the hands of the third-party PLM developer and not the case company itself, the implementation from the case company's side focuses on testing, giving feedback on, and introducing the integration internally once finished. While there would be plenty of different ways to approach to implementation, from the perspective of implementing a small-scale interface integration of a not-well understood compliance management system, the biggest issues to tackle are to confront the potential change resistance as described by Lewin (1946) and communicate to and involve the relevant stakeholders to the implementation of the integration. Facing these issues go hand in hand, as involving relevant stakeholders to the testing and implementation of a new innovation often times lowers the gap to adopt the innovation to operations and lowers the resistance to change (Rogers et al., 2019).

Still, before moving to communicating about the integration, it could be beneficial to conduct a basic level of stakeholder analysis. As described by Grundy (1998) identifying and analyzing the relevant stakeholders is an important part in communicating and implementing change. What this means in practice in the case company's situation is, that the relevant stakeholders should be identified and their influence and attitude towards change should be analyzed. Of course, with the use of the integrated interface, the most relevant stakeholders would be those, who already use the PLM to a high degree, have some sort of connection to the process of substance compliance and have influence on others. After conducting stakeholder analysis to identify the relevant stakeholders and analyze their influence and attitude towards the integration, a corresponding approach to communication should be taken as described by Grundy (1998).

In the implementation of the integration, communication is one of the most important aspects. Of course, it serves the purpose of sharing the information about the integration, but more importantly it could have a large impact on how the integration is perceived and what the attitudes towards it are (Van Hau & Kuzic, 2010; Buchanan et al., 2005). Based on the findings of the current state analysis, a lot of employees see substance compliance as a responsibility that is outside of their own tasks. As such, giving them an interface

that helps with the substance compliance management process could be similarly seen as an external function that does not have connection to their operations. Furthermore, as the visibility on how the process is conducted currently and understanding on *why* the integration development was started in the first place is low, the importance of the integration and its functions can be perceived as nonexistent. Because of these factors, it is crucial that the relevant stakeholders are informed properly on the reason the integration is being developed and what is changing with it. Hopefully this is done sooner than later, as giving people time to react and adjust to the change has a positive impact on how the change is perceived (Mento et al., 2002).

Another important point in the implementation of the integration is the testing of the interface. Currently tests are conducted by the PLM specialist and compliance manager, but other major stakeholders inside the organization have so far been left out. To get better view on the functionalities through different perspectives, other employees from other teams should be involved to the testing. This would serve multiple points. Firstly, it would give a fresh pair of eyes on the current state of the integration. Often people who are a part of the development of a system, interface or equivalent become blind to the downsides of it after a certain time and involving people who do not have a preconceived notion helps to counteract the development blindness. Secondly, involving people in the development of the integration also lowers their resistance to the change caused by it (Rogers et al., 2019). And thirdly, the people from other teams might have different views on some functionalities and can offer good feedback on how they should be implemented from their perspectives.

Lastly, in order for the case company to successfully implement the integration internally and prepare for the introduction of it, the leadership for the project internally should be decided on. Gill (2003) highlights the importance of having clear leadership in change projects, and while this is a small-scale project, that importance should not be belittled. The one in charge of the change project should be able to align, enable, and support those who the change might affect, which in practice means taking responsibility on communicating the change, removing obstacles in the face of the implementation of the integration, and offering help and answers to those affected by the change (Hayes, 2022).

Externally, the integration project has moved on to the final development stage, and while it could have been beneficial to create a systematic project plan and schedule at the start

of the project, the importance of it has decreased as the project has moved on to the later phases. Similarly, the communication was perceived to be an issue earlier on in the project, but the problem has thereafter been fixed. Motivations and aspirations for the project are aligned, and the current momentum of the project should carry it to the finishing line.

5.3.3 Making the change sustainable

After the integration has been implemented and initially introduced, actions should be taken as to not let the benefits brought by the integration to decay. By utilizing the three factors affecting change sustainability by Buchanan et al. (2005), an approach to focusing on the substance and temporal dimensions of change can be developed. Firstly, the introduction of the integration should be made to seem beneficial and not trivial. Focusing on communicating the need of it is a good start – as detailed in the previous chapter – but to sustain the change in the long run, more actions should be taken. One way to make the integration seem more substantial to different employees would be to show what upside there is to them in the utilization of the interface. A clear example of this would be the more believable and accurate manufacturer and supplier data through the interface, which in the case of sourcing is a certain plus. The temporal dimensions – i.e., timing, sequencing, and pacing – also affect how the change is sustained and as such the introduction and deployment of the integration should be gradual. Too quick of an approach might induce confusion and not allow time to properly show the need for the integration, thus increasing the resistance to start properly utilizing it. Not going for a radical transformation strategy but rather a slower and incremental one would be a good approach, as it could be argued that the employees are suffering from change fatigue in the case company.

Additionally, from the ten practical issues affecting change by Buchanan et al. (2006), three can be seen currently important in the case company. The first issue of those who initiated the change move on to another organization realized, as the PLM specialist moved on before the integration could be finalized. As such, care should be put on retaining current people involved in the project and hiring a new PLM specialist with similar competencies and aims. Secondly, as the accountability and responsibility of the project internally is not clear, the responsibilities should be established, as having a line of accountability reduces the decay affecting change sustainability. Similarly, as the schedule for the implementation and deployment of the integration has not been agreed

upon, the project is at risk of getting sidelined by other, more pressing matters. As such, a distinct timetable of when each step is conducted would help in introducing the interface.

Finally, some focus should also be put on how to spread the use of the integration internally. Of course, informing people of the completion of the integration spreads it some, but to naturally spread the use and make the use of it the new norm, the five attributes affecting innovation spread introduced by Rogers et al. (2019) should be kept in mind. First, the relative advantage should be made visible to the people who start using the integration. Naturally, as the integration mostly helps with the substance compliance management process, the advantage to using it might not be as apparent. As such the importance to having the integration must be highlighted in the earlier steps via proper communication, so that the relative advantage becomes clear to other employees as well, not just the compliance manager. The compatibility of the integration – i.e., how well the innovation can be integrated to current ways of working – should also be highlighted, as the integrated interface offers a much clearer window to the side of substance compliance as opposed to the previous substance compliance management system. Contrary to the previous situation, employees who might affect the substance compliance process can now do it by using the same PLM system that they previously have used without having to learn to use a dedicated substance compliance management system. The third factor of innovation spread – as per Rogers et al. (2019) – is complexity, which in the case of the integration should not be an issue, as the interface itself is arguably easier to use than the more basic functionalities of the PLM. The only aspect that should be taken note of is, that the instructions on how to get the interface visible should be shown before utilizing the integration. Trialability – as the fourth factor – should have been already enforced in the implementation step by allowing employees who are going to use the integration in the future to test the interface before finalizing it. Similarly, the fifth factor of observability should also be completed by raising awareness of the integration, the reason behind developing it, and being able to witness how it functions firsthand.

5.4 Step 3: Expand and redistribute substance compliance responsibility

5.4.1 Overview and reasoning for the third step

The third and final step in the overall improvement plan is to expand and redistribute the responsibility related to substance compliance management. Before the introduction of

the integration, the responsibility of managing substance compliance has rested mostly on the shoulders of one key employee – the compliance manager – and while said person has done an excellent job of managing substance compliance at the company so far, it is undoubtedly a major risk that the entire process is largely reliant on one person. And not only that, as pointed out by the findings of the current state analysis, there currently is not any major documentation or strategic guide on how to carry out substance compliance. Nearly all of this information is tacit knowledge of the compliance manager, and as such liable for risks. In the potential situation where the compliance manager would have to leave their tasks abruptly for any unforeseen reasons, the entire process of substance compliance would come to a halt. And until the compliance manager would continue their job or a similar competence would be found, potential negative effects such as not being able to push new products to European markets due to not being able to get the CE mark could happen (George & Pecht, 2016). Similarly, even though a new product's components would fill the RoHS regulation's requirements, if there would be no proper California proposition 65 warnings on required parts, the case company would be liable to face lawsuits, fines and potentially pull the product from certain markets (Scruggs et al., 2015; Barsa, 1997). Additionally, as the current process of substance compliance is reactive rather than proactive, delays and costs caused by having to switch components late into the product development process due to uncompliant suppliers are a constant risk until the process becomes more proactive.

Because of these factors, the third step in the grandeur plan aims to first expand the substance compliance process so that it becomes a clearer part of the product design phase in other teams and then to redistribute the responsibility so that it no longer solely relies on one manager. This third step is in direct continuation from the second step, as it relies on implementing and introducing the PLM-integrated interface so that employees in other teams can sufficiently use it. Additionally, these employees must be knowledgeable of the current substance compliance process, and understand why the processes will be slightly altered, and as such it is imperative that the communication is handled well in the second step. This third step also has connections to the first one, as substance compliance as a process has connections to product data quality and the new competence of product data quality manager could be also utilized in redividing the responsibility of compliance. In short, the aim is to make substance compliance in the case company proactive rather than reactive by conducting compliance at an earlier stage in product design, involving more employees to the process, and minimizing the risk related to tacit knowledge

through redistribution of responsibilities and creating an internally available strategic roadmap to substance compliance.

5.4.2 Moving from reactive to proactive substance compliance

In order to improve the process of substance compliance management at the case company, the process of product data quality management must be put into place, and the PLM-integrated interface must have been introduced and the importance of redistributing the workload of substance compliance be made clear. In the overall three-step improvement plan these issues are addressed in the first and second step respectively. Once these are finished, the third step can be started by working with the relevant stakeholders to create a universally approved process map of substance compliance management. The generic substance compliance plan based on George and Pecht (2016), Goosey (2007) and Backman (2010) can be used as a starting point to develop the process map. The aim should be to create a strategic guide on how substance compliance is handled at the case company – or more specifically how it should be handled – that updates the current process. Most relevant aspects of the process map creation are how the integration affects the process, and how the methods to manage it can be made proactive rather than reactive.

The integration with the organization's PLM means, that employees no longer have to use the earlier substance compliance management system to see if certain components or materials are compliant with the RoHS or REACH regulation. This innately gives visibility for the process, but more than that, it allows for earlier compliance perspective, as people in the product development teams can see the current compliance state of components in the PLM already before the product structure is completely built. Additionally, thanks to the easy-to-use function of adding new components to the compliance search, people other than the compliance manager are also able to request compliance data, which in theory would allow for other employees to independently check the compliance of new components or materials. As such, the integration should be used as a tool to involve the relevant teams to the substance compliance process early in the product design phase. This approach is also heralded in surrounding literature, as Hornberger et al. (2014) explain how product compliance should be a part of the product development from the earliest stages as possible, as changes are the easiest to manage in these stages. Based on the research findings, employees in various teams already try to pick components or materials that are compliant in the eyes of substance compliance

management, but there is no strict protocol to do so. As such, the launch of the integration should be used as a reason to strike the earlier compliance perspective into protocol and start conducting substance compliance proactively.

The earlier substance compliance involvement should also be strengthened in the sourcing team, as based on the findings of the current state analysis the selection process for new suppliers does not take into account the substance compliance needs or requirements as often as it should. As requesting data from the entire supply chain is a relevant step in the substance compliance process, the strategic sourcing team should have close connections to conducting compliance (Goosey, 2007). According to the current state analysis findings an information package on substance compliance is available for new suppliers or manufacturers, but supposedly this package is not utilized fully, and as such there could be reason to reassess the substance compliance approach in the sourcing team.

To combat the risk associated with the tacit knowledge of the compliance manager, the responsibility of substance compliance at the case company should also be redistributed slightly. While it could be perceived to be good, that the main responsibility rests on the compliance manager, there should be at least one person who shares some of the competences and understanding of substance compliance. But, as the current state analysis results seem to indicate, the current resources for existing employees are already spread thin and not many would be able to take up further responsibility especially related to a field they do not have much understanding in. As such, the potential new competence mentioned in the first step of the three-step improvement plan – i.e., a product data quality manager or equivalent – could be also utilized in the redistribution of substance compliance responsibilities. The reasoning behind this is, that as thanks to the PLM-integration, the use of the PLM in the substance compliance management has risen, and as shown by Miehe et al. (2016) and Bachmann (2010) the field has direct connections to product data quality. And as such, maintaining high product data quality *even in the eyes of substance compliance* would perfectly fit the role. The aim would be, that while the main responsibility to conduct substance compliance still lies with the compliance manager, the product data quality manager would assist the process and help in issues related to the PLM and data quality, which in practice means aiding data creation, data gathering, and data monitoring. This shared responsibility in addition with the agreed

company strategy on conducting substance compliance would minimize the risk of tacit knowledge leaving the organization through an abrupt exit of the compliance manager.

5.5 Miscellaneous other improvement suggestions

To accompany the three-step improvement plan, a few minor other improvement recommendations can be put into practice. Based on the study results, three less important issues to tackle could be identified: the perceived bad usability of the PLM, the unstructured way of conducting small-scale development projects, and the nonexistent user rights for the integrated interface.

The first minor issue of perceived bad usability of the PLM came up frequently in the results. Bad usability in relation to PLMs and PDMs is not surprising though, as Liu and Xu (2001) explained how it is a common shortfall for utilizing these systems. While of course an annoyance and a cause for multiple delays, the perceived bad usability itself is not a huge cause for concern. But, as it does affect product development negatively and undoubtedly has an impact on the introduction of the substance compliance integration, it should be addressed. Based on the results, one of the things that had helped one team to get better in the utilization of the PLM was to conduct continuous semi-weekly workshops on the use of the PLM. This approach of using workshops could be expanded to other teams by conducting similar workshops, where each team would go over the necessary use cases relevant to their operations and would tackle usability issues by themselves. While it would be silly to presume that the issue of perceived bad usability would disappear by using workshops, the approach would not hurt either. And, combined with a more continuous use of the PLM rather than the sporadic use of current operations, could improve the usability as employees in other teams would get more comfortable with the system and its use.

The second minor issue worth addressing is the accessibility of the integrated interface. Currently the plan is, that any employee who has access to the PLM would also be able to access the compliance interface. And, while the functionality of seeing compliance data should not be hidden from anyone, there should be access rights in place for people who would be able to mark components for compliance checks and send items to be checked. The reason the accessibility is an issue is that if it is not restricted, anybody can make compliance check requests to the compliance solution provider. This could potentially

result in multiple duplicate requests and requests for compliance data that has already been provided. And since the process is not automated, but rather the compliance request sends an email to the compliance solution provider, there is the real potential that the compliance solution provider would be overwhelmed with unneeded compliance requests. As a counterattack, the PLM specialist should create new user-roles that have access to create and send compliance check requests, while others only have the view-option, as with the usual utilization of the PLM. Thankfully setting access rights should not be an issue, as it has been a core feature of any PDM or PLM system alongside the data vault functionality (Peltonen, 2000).

The final miscellaneous improvement suggestion concerns the unstructured approach to the integration project. As shown by the results of the study, the absence of an agreed project plan or schedule resulted in delays and other issues. But, as the project has already moved on to the later phases and no longer benefits majorly from having a schedule or plan for the end steps, creating a project plan and schedule would most likely be a wasted effort. Still, even though the current integration project does not require a structured approach anymore, the effects of not having one should be kept in mind for future development projects, even if these projects would be small in scale. Additionally, identifying the potential issues related to multi-organizational development projects should be prioritized, as these can create new unforeseen problems.

6 CONCLUSION

6.1 Key results

The aim of this master's thesis was to analyze the development and implementation of an integrated substance compliance management interface in a product lifecycle management system in the case organization and to give actionable recommendations on how to introduce the integration and how to best make use of it. The following four research questions were put in place to study the topic of integrating a substance compliance management system with a PLM system, and introducing the innovation to an organization such as the case company:

RQ1: What connections does substance compliance have with product lifecycle management?
RQ2: How can a PLM integration project be implemented, and the changes sustained?
RQ3: What is the current state of PLM, substance compliance, and the system integration in the case organization?
RQ4: How can the case organization ensure successful use of a PLM-integrated substance compliance system?

The first two research questions were answered in the literature review. In short, substance compliance is the act of complying with environmental standards and regulations related to product materials and substances. It is heavily influenced by the regulations it adheres to, and in the electronics industry – and specifically in Europe – the biggest regulations are the RoHS regulation (*directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment*), REACH regulation (*Registration, Evaluation, Authorization, and Restriction of Chemicals*), California Proposition 65, and POP regulation (*Stockholm Convention on persistent organic pollutants*). Additionally, full material declarations – FMDs – have been started to be utilized as an efficient tool to conduct substance compliance more thoroughly in the electronics industry and is often seen as the gold standard for substance compliance processes. Substance compliance has connections to product lifecycle management, as it needs large amounts of product information and data to be conducted successfully. In practice this means that substance compliance management is either directly connected to a PLM or an ERP so that it can access product data, or it relies on data exports from

either enterprise system to function, as it requires comprehensive supplier and manufacturer data. Additionally, as only timely, comprehensive, and accurate product data can be utilized in substance compliance, it innately has connections to data quality management and data governance. Understanding of product lifecycles and technical product structures is also vital in conducting substance compliance management.

For the second question, important aspects to consider in implementing and introducing a PLM-integration are both the technical implementation of the integration as well as the organizational perspective of introducing and spreading the use of the integration. In the technical implementation care should be put into identifying the current, hoped-for, and full maturity of the PLM, which refers to the level that the PLM is utilized for. Focus should also be put on data quality management and governance, as high-quality data is crucial for system integration to ensure that erroneous data does not infect other systems. The most notable issues related to the use of the PLM system – i.e., bad usability, comprehension of product data, lack of a product data owner or responsible among others – should also be addressed in the integration, as current issues affecting one system can and will affect the other after the integration as well. On the organizational perspective, important factors to take into consideration when implementing a PLM-integration project are communication in all its forms, stakeholder management, monitoring and reviewing change progress, and leading and managing of people issues. Additionally, in order to sustain the benefits of the integration in the long run, actions should be taken to increase the spread of the innovation by highlighting its relative advantage, compatibility to current operations, minimal complexity, trialability, and observability.

The third research question addressed the current state of the PLM system, substance compliance and the system integration project in the case organization. The PLM system was well utilized – even though not fully – and it was seen as beneficial to product development, but also time consuming and hard-to-use. Product data quality was perceived to be from decent to good, but more importantly there was no clear responsible for maintaining data quality and data governance roles were not named. Substance compliance process was seen as functional and successful, but also had the risk of being dependent on mostly one employee and their tacit knowledge. There was also not any leadership agreed upon strategy or roadmap for substance compliance. Lastly, the analysis on the current state of the integration project revealed that the project had reached the testing phase successfully and was moving forward, even though some issues on

delays, communication and unclear plans did hinder its progress a little. More importantly, it became evident that the case organization did not have an actionable plan on how to introduce the integration to the daily operations.

As for the final research question, the way that the case organization can fully implement and successfully introduce the integrated substance compliance interface relies on addressing the three most critical issues related to the current substance compliance management process and the integration development project. The three issues were the lack of product data quality management processes and data governance responsible, the lack of any plans on how to introduce and spread the use of the integration, and the risk of being largely dependent on only one employee in the substance compliance process.

To answer critical issues and ensure successful short- and long-term use of the integration, a three-step improvement plan for future operations was introduced. This three-step improvement plan consisted of three separate and sequential steps that should be taken, so that the issues are addressed, and the use of the benefits brought by the integration are maximized. The first step relied on improving the data quality management process by utilizing a four-phased process model for establishing data quality management procedures. The phases of state reconstruction, data quality measurement, data cleansing, and the establishing of continuous data quality monitoring ensure that the needed processes and methods are in place for anyone to conduct data quality management. To accompany those processes, the responsible for said processes had to also be appointed via the data governance framework, which in practice meant acquiring a new competence of data quality manager or equivalent to share the data quality management decision making responsibility with the PLM specialist.

The second step in three-step improvement plan described suggestions on what to take into consideration with the introduction of the integration and how to sustain the benefits offered by it. Most important aspect was the point of communication, as other teams and employees needed to be informed about the integration and more importantly, they needed to be informed on the reasons why the integration was being implemented. Most people were unaware of how substance compliance was handled and did not know why an integration or even any changes to the processes had to be made, and as such explaining the intricacies might affect the way the change is being perceived. Encouraging other employees from other teams to test the integration was also an important aspect of the

second step, as involving people from other teams not only gives more specific feedback on the functions nearer to those teams, but it also doubles as a factor mitigating the change resistance by involving the necessary stakeholders to the development. Appointing a change responsible that is in charge of conducting the change was also named as one of the factors in the second step of the improvement plan, as having a face for others to ask questions and guidance improves the overall change process. Additionally, the point of change sustainability and spreadability was brought up, as focusing on factors such as early involvement, the temporal dimensions of sustainability, and the five attributes that affect innovation spread – relative advantage, compatibility, complexity, trialability, and observability – make the change into something that can be sustained even in the long run.

The third step in the improvement plan focused on expanding and redistributing the substance compliance responsibility. The first phase to do so was to develop an internally available strategic substance compliance process map, which would help combat the risk of tacit knowledge and improve the knowledge on substance compliance across the organization. Then the process for conducting substance compliance can be made proactive by focusing on the compliance perspective on various teams already in the product design phase, which the integration allows. The main responsibility for substance compliance management was also to be split between the compliance manager and another competence. As there was a clear connection between product data quality and substance compliance, having the new competence of data quality manager be the second responsible for substance compliance would be practicable.

In short, the case organization can ensure successful short- and long-term use of the integration by implementing the aforementioned three-step improvement plan which focuses addressing the three major issues related to the implementation and introduction of the integrated substance compliance interface.

6.2 Limitations

One of the biggest limitations of this study is the aspect that only qualitative data gathering methods was used. No research results were found through numerical methods, making it hard to evaluate if the results actually indicate certain findings or if the interviewed participants simply perceive things to be as such. A clear example of this is

how the product data quality was perceived to be of decent quality, but without quantitative testing, the state of the case organization's data quality cannot be determined more clearly. Even though the aim was to construct a qualitative picture of the company's current operations, having additional quantitative findings would reinstate the validity of the other qualitative findings. Additionally, while a large number of interviews helps construct a less biased view on a topic or process, it must be understood that the answers given in the interviews of this master's thesis depict a subjective view and understanding of the issues rather than the objective truth. As such, some process descriptions can be prone to misunderstandings or errors, simply because multiple interviewees had a false belief or understanding.

Another limitation of the study was the aspect that some findings on the first interview were based on only the perspective of one employee on one team. This could result in a biased perspective to the interviewed issues, as it is possible that a single employee does not share the same understanding or perspective towards an issue as the rest of the team. Furthermore, the interviewed participants were selected based on availability and estimated knowledge on the topics of substance compliance and PLM, and as such the test results could vary in comparison to interviewing other participants in the team instead.

For the technical analysis of the integration, the study results were uncovered using a participatory observation session, and the functionalities of the integration were being shown by the compliance manager of the case organization, who – while part of the development of the interface – was without a doubt less experienced in demoing the integration than for example the product manager at the PLM developer organization. As such, the findings could be slightly skewed, and for example a small functionality or two could have been left not introduced.

Finally, the interview structure and questions were based on earlier research, but the frame was created for the specific use of this master's thesis, making it hard to compare to surrounding literature. The interviewing methods also affected the results, as the interviewee in the study aimed to uncover larger aspects by conducting several follow up questions when the answers and schedules so allowed.

6.3 Future research

This master's thesis uncovered multiple potential topics for future research. Firstly, as the field of substance compliance is still largely unstudied, more thorough studies on how substance compliance is perceived among different kind of organizations could be an interesting continuation point for this study. Alternatively, as this study has introduced one way of managing substance compliance through the use of a PLM, additional studies could be conducted on other types of integrations with enterprise systems, most notably how a digitalized ERP system would be integrated with a substance compliance management system. Furthermore, as this study only analyzed the first MVP of an integrated substance compliance interface, analyzing quantitatively the effectiveness of a finished integration in contrast to using *just* a typical substance compliance management system would be interesting.

Additionally, studying further the operations of data quality management in the case organization would be a natural continuing point, as proving the decreased state of data quality with quantitative methods would be beneficial. Going further into studying the link between product data quality and substance compliance would additionally provide an interesting springboard into improving substance compliance processes in large electronics manufacturer organizations.

Lastly, studying how change management can affect specific system integration projects would undoubtedly lead to more successful introductions of innovations, as focusing on the humane aspects of implementing and introducing integrations has a connection on the successfulness of system introductions based on this study. There is also a research gap on how to utilize change management practices on small-scale integration development projects, and filling that would have at least in the case of this study provided a firmer footing for conducting research.

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Appendix 1. Current state PLM and compliance analysis interview questions

1. *What is your job title in this organization?*
2. *How long have you been working here?*
3. *Do you use the PLM system?*
    a. *If yes:*
        i. *How much do you use it in a typical work week?*
        ii. *How do you use the PLM?*
        iii. *Do you think the PLM makes your job easier? How so?*
        iv. *Is the PLM easy to use? If not, why?*
        v. *Do you think the PLM saves time? Why/why not?*
        vi. *Do you think the PLM improves product quality? Why/why not?*
        vii. *Do you think the PLM reduces the tied-up capital? (Explain if necessary) Why/why not?*
        viii. *Do you know what a technical product structure is? Can you see it in the PLM?*
        ix. *Do you see the product data in the PLM as…?*
            1. *Accurate?*
            2. *Timely?*
            3. *Complete?*
            4. *Consistent?*
            5. *Believable?*
            6. *Accessible?*
            7. *Easy to understand?*
        x. *Do you or anyone in your team measure or assess if the product data is accurate/timely/complete/consistent etc.? If yes, do you have an iterative system in place to measure/monitor the product data?*
        xi. *Do you cleanse (complete unfinished data, fix errors, correct metadata, etc.) data? If so, how often and do you have an iterative system in place to cleanse it?*
        xii. *Are there different roles in your team for using/editing/organizing/etc. product data?*
        xiii. *Are there data owners in your team? (Explain if necessary)*
    b. *If no:*
        i. *Have you used it previously? Why/why not?*
        ii. *Do people in your team use the PLM? If yes, why do they use it and you do not?*
        iii. *Where do you access product related data? Why there?*
        iv. *What could make you start using the PLM system?*
4. *Do you know what substance/material compliance is? (Explain if necessary)*
    a. *Do you know how substance compliance is carried out? I.e., are you aware of how a substance compliance plan looks like?*
5. *Are you aware of which product regulations/standards this organization complies with?*
6. *How important do you see substance compliance as a function in the organization?*
7. *Are you aware of what an environmental compliance management system is? Have you used the one that is being used in this organization?*
8. *Do you take part in the substance compliance process?*
    a. *If no, does anyone in your team take part in it?*
    b. *If yes, how?*
9. *How does substance compliance affect your job?*
10. *Would you be willing to take more of an active part in substance/material compliance? Why/why not?*

Appendix 2. Integration project analysis interview questions

1. ***Both**: From which organization are you from? Could you bring a little background on what this organization does?*
2. ***Both**: What is your job title?*
3. ***Both**: In your words and from your perspective, what is the aim of this integration project? What is your organizations motivation for this project?*
4. ***Both**: What kind of significance and goals does this project have from the case organization's business perspective?*
5. ***Both**: What is your role in this project?*
6. ***Both**: Is there a development/implementation plan for the project and is the schedule clear?*
7. ***Both**: Could you describe the steps that have been taken so far in this project?*
8. ***Both**: What are the next steps in this project from your perspective?*
9. ***Both:** Are there milestones set for the project? Are the reached milestones celebrated and if so, how?*
10. ***Both**: What challenges have you faced during this project?*
11. ***Both**: What challenges do you see in this project going forward?*
12. ***Both**: How would you describe the communication between stakeholders in this project? I.e., has it been clear, have there been issues, etc.?*
13. ***Internal:** What are/were you hoping to change with this integration project?*
    a. *How have these goals for change been considered in the implementation of this project?*
14. ***Internal:** In the beginning of the project, was a plan for the project/change efforts created?*
    a. ***If yes:***
        i. *Has the plan been revised since? If yes, when, and why?*
        ii. *Are there periodic reviews in place to check if the change is still valid?*
    b. ***If no:***
        i. *Was a plan devised during the project?*
15. ***Internal:** Is the ongoing project monitored and reviewed? If so, by what metrics?*
16. ***Internal:** Has a clear vision for the change been presented or discussed?*
17. ***Internal:** Are clear project and line management responsibilities set for you and other members in the project? How? (I.e., how do you see the accountability in this project?)*
    a. *Can you identify a leader – or manager – for this project?*
18. ***Internal:** Is there someone in your organization that removes obstacles relating to the change efforts and creates conditions to implement the change?*
19. ***Internal:** Is there someone in your organization that supports those affected by the change? (i.e., recognizes and responds to concerns)*
20. ***Internal**: Are other people who could potentially take part in substance compliance/PLM use knowledgeable of the change that is brought by the integration?*
    a. *If yes:*
        i. *Can you estimate how the change brought by the integration is currently perceived?*
        ii. *How advantageous is the new integration perceived as? How about the gains brought by it?*
        iii. *How complex is the use of the upcoming integration perceived as?*
        iv. *Have people been able to test the integration before committing to the changes?*
    b. *If no:*
        i. *Do you have plans to inform the other parties? If yes, what kind and when?*
        ii. *Is the original issue that resulted in the beginning of this project still visible to people in your organization? How so?*

21. ***Internal:*** *Have different stakeholders who might affect the change been identified in your organization?*
    a. *If yes:*
        i. *Have these stakeholders been analyzed regarding their influence on the change?*
        ii. *Are there plans on how to increase/decrease the change efforts/resistance on these stakeholders?*
    b. *If no:*
        i. *Are there plans on conducting stakeholder analysis regarding the change efforts? Why/why not?*
22. ***Internal****: Do you have plans/ideas on how to spread the use of the integration to other parts of the organization? If yes, what kind of plans/ideas?*
23. ***Internal****: Are there plans for how to make the integration use part of the daily working after it is introduced? If so, could you describe these plans?*