Ole Einar Stavne

Implementation of Product Life cycle Management System in an Enterprise

Master's thesis in Master in Sustainable Manufacturing
Supervisor: Niels Peter Østbø
June 2023

Master's thesis

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Norwegian University of Science and Technology
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Abstract

This master thesis is written in cooperation with a Norwegian Enterprise which has merged with a Global Enterprise. A decision to implement the Siemens Teamcenter Product Lifecycle Management (PLM) system at the Enterprise has been made. This will be a common system for the Global Enterprise and the Enterprise. Two research questions aim to be answered:

- Which considerations need to be taken to avoid that new Teamcenter PLM stakeholders do workarounds?
- Is it necessary to make changes to improve the workflow before implementing the new Teamcenter PLM in the Enterprise?

According to change communication theory it is recommended to include the employees into the process when a new information technology (IT) system is to be introduced in an enterprise. However, it is important to be aware that there is a relation between how people act and what they know. In lean theory and sociotechnical systems, the research emphasizes the work culture differences within the departments at the Enterprise as an important discovery for the implementation of new procedures.

An introduction to Teamcenter PLM has been given. How it should be structured and the best way to be implement it, has been an important part of the work. To prepare for an implementation of a new IT system, such as Teamcenter PLM, increase the importance of understanding how the Enterprise operates daily. This has been important for the further investigation. Interviews with stakeholders at different departments at the Enterprise, have been conducted. Interviews have indicated that there are communication problems between departments, which have led to delays in the development process of new products.

The results of this thesis recommend the Enterprise to be aware of work culture differences between the Enterprise’s various departments. This will be important when creating work procedures and job descriptions for Teamcenter PLM. An industrialization group that will act as a link between the Development department and the Production department should be established.

Sammendrag

Denne masteroppgaven er skrevet i samarbeid med en norsk bedrift som er slått sammen med en global bedrift. En avgjørelse om å implementere Siemens Teamcenter Product Lifecycle Management (PLM) system i bedriften er tatt. Hensikten er at begge selskapene skal benytte seg av dette systemet. To spørsmål forsøkes å bli besvart:

- Hvilke overveielser må tas i betrakting for å unngå at nye Teamcenter PLM interessenter avviker fra systemets prosedyrer?

- Er det nødvendig å gjøre endringer for å forbedre arbeidsflyten før Teamcenter PLM innføres i bedriften?

Endringsteori for kommunikasjon anbefaler å inkludere de ansatte inn i prosessene når et nytt informasjonsteknologi (IT) system introduseres inn i en bedrift. Men, det er også viktig å være klar over at det er en relasjon mellom folks handling og hva de vet. I lean teori og sosiotekniske systemer, vektlegger forskningen at arbeidskulturforskjeller innad i avdelingene i bedriften som en viktig oppdagelse for utarbeidelse av nye prosedyrer.

En introduksjon av Teamcenter PLM er gitt. Hvordan det bør struktureres, og hvordan det kan implementeres på best mulig måte, har vært viktig del av arbeidet. Å forberede implementeringen av et nytt system som Teamcenter PLM, øker viktigheten for å forstå hvordan bedriften opererer i sitt daglige virke. Dette har vært viktig for den videre undersøkelsen. Det har blitt gjennomført intervjuer med interessenter fra de ulike avdelingen i bedriften. Dette har gitt indikasjoner på at det er kommunikasjonsproblemer mellom avdelingene, som har ført til forsinkelser i utviklingsprosessene av nye produkter.

Resultatene i denne avhandlingen, anbefaler bedriften å være klar over arbeidskulturforskjellene mellom bedriftens ulike avdelinger. Dette vil være viktig ved utarbeidelse av arbeidsprosedyrer og jobbeskrivelser for Teamcenter PLM. En industrialiseringsgruppe som skal fungere som et bindeledd mellom utviklingsavdelingen og produksjonsavdelingen bør etableres.

Preface

Working with the master thesis has been challenging but it has given me the opportunity to use my experience and knowledge from both my NTNU studies and several years as an employee at a Norwegian Enterprise. As an employee at the Enterprise I have been working in various departments: Production, Customer Support and Development department. This has given me a good knowledge about the Enterprise and its processes. The work on this thesis is based on my years working at the Enterprise, and will therefore be hard to recreate by someone without this experience. I hope the outcome of this master thesis will give some basic ideas on how to work with in the ongoing project to implement Teamcenter PLM at the Enterprise, which has been the main reason for the work.

I want to thank my supervisor, Niels Peter Østbø, who have been a valuable sparring partner for dicussions and advise carrying out the master thesis. I want to thank all employees at the Enterprise for sharing their knowledge and for all their support during my work with the master thesis. Ecpecially Vice President of Research & Development Erlend, for giving me the opportunity to write about the implementation process. Project Manager, Inger Lill, for support and help to understand the processes. Lastly, I want to thank my wonderful wife Ruth Helen and my family who have been extremely patient throughout my years of studying.

Trondheim, 31 may 2023

Ole Einar Stavne

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List of Abbreviations (or Symbols)

ADM	Architecture Development Method
BOM	Bill of Material
BOP	Bill of Processes
CAD	Computer Aided Design
EA	Enterprise Architecture
EBOM	Engineering Bill of Material
ERP	Enterprise Resource Planning
FAT	Factory Acceptance Test
FBOM	Forecast Bill of Material
GCS	Global Customer Support
HW	Hardware
IPR	Intellectual Property Rights
IT	Information Technology
MBOM	Manufacturing Bill of Material
MES	Manufacturing Execution System
MOM	Minutes of Meeting
PBOM	Physical Bill of Material
PCB	Print Cardboard
PDCA	Plan, Do, Check, Act
PLM	Product Lifecycle Management
SBOM	Service Bill of Material
STS	Socio Technical Systems
SW	Software
SWOT	Strength, Weakness, Opportunity, and Threats
TC	Teamcenter
TOGAF	The Open Group Architecture Framework

1 Introduction

New Information Technology (IT) systems have become standard in the manufacturing industry. These systems are meant to help employees become more efficient and storing data from the production process. New IT systems affect how products are being manufactured, but also how people work [1]. A successful IT systems integration is when procedures are followed. Then the system will be given enough information, so people can get the correct information out of the system.

The automation pyramid classifies different IT layers of industrial manufacturing, where the top two layers contain Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES) and/or Product Lifecycle Management (PLM) [2, 3]. ERP systems are used for the organization to automate core business processes and maintain an optimal performance. MES are mainly used in companies which manufacture large parts, sub-assemblies or have projects over a longer period. The MES helps the manufacturer to track and document the transformation from start to finish by increasing machine utilization and reducing lead time [4]. PLM systems manage all the information about the product e.g., which parts the product is made of, drawings of the parts, software versions.

This Master Thesis is conducted in cooperation with a Norwegian Enterprise, which, until recently was a limited liability company, but was merged with a Global Enterprise from 1 January 2023. The merger has led to the decision of implementing the same PLM system as the rest of the Global Enterprise and there are also parallel investigations about the best way to integrate a new ERP system to a common system. The Enterprise, which has not had a PLM system before, now has a golden opportunity to investigate the best way to structure their PLM system. A group consisting of two engineers from the Development department have been appointed to investigate the best way to implement a PLM system in the Enterprise. The investigations and results in this Master Thesis, will be the foundation of further work implementing the new PLM system at the Enterprise.

The implementation of new IT systems can make employees reluctant to start using the IT system. It will therefore be important to reflect on how the implementation of Teamcenter PLM will affect people’s behavior. When new IT systems such as PLM is decided to be implemented by an enterprise, such technology is treated as a matter of interest only in certain organizational circumstances [5]. Implementing PLM will affect all areas of the organization. A logical structure and a good user application is important to avoid parties involved to do workarounds [6].

1.1 Problem

The chosen PLM system is Teamcenter, which is delivered by Siemens. The system structure is built upon experience that the Global Enterprise has acquired over several years. There are several Global Enterprise standards which the Enterprise must take into consideration when implementing Teamcenter. The investigation started in November 2022, and the implementation date is set to April 2024. The idea is that both the PLM system and a new ERP system are going to go live at the same time.

Implementing a PLM system in the Enterprise will lead to new ways of working for the employees. The need for training and correct use of the system will be mandatory for a successful implementation of Teamcenter PLM. A reorganization of the Enterprise could be necessary to make sure that all mandatory product documentation is completed before the product is released. At the same time, it will be important to take into consideration the human behavior paradigm e.g., communication between people, and cooperation between human and machine.

1.2 Research Questions

This Master Thesis will try to answer the following research questions:

1. Which considerations need to be taken to avoid that new Teamcenter PLM stakeholders do workarounds?

2. Is it necessary to make changes to improve the workflow before implementing the new Teamcenter PLM in the Enterprise?

2 Theory

2.1 Change communication in complex projects

Introducing new Information Technologies (IT) into an enterprise could be received in different ways based on who you ask. IT technology is treated as a matter of interest only in certain organizational circumstances [5]. It is therefore important that managers involved in the implementation of new IT tools communicate with the end user. Since such an approach helps to inform the stakeholders of any ongoing projects which will affect how they work [7].

2.1.1 Sociotechnical Systems

Sociotechnical Systems Design (STS) was intended to enhance how human behavior affect the operation of technology. Increasing knowledge and capabilities of the end user help dealing with technical uncertainties [8]. According to Kyriakidis [9], "*challenges for characterizing human performance and embodiment becomes an important and crucial concern. The interplay of physical, physiological, and psychological is a crucial determinant of various approaches of behavior in systems' design*". Figure 1 shows that there is a relation between a person's acting related to what he or she knows. Human performance is conjoined with knowing and acting.

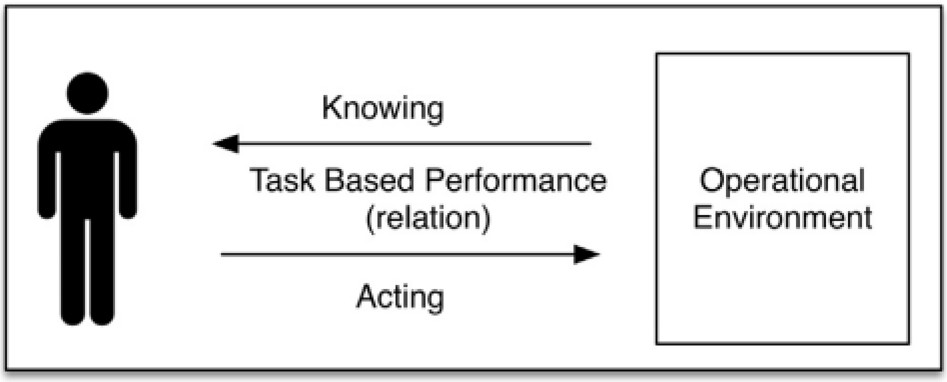

Figure 1, Reciprocity between human behavior and environment [9]

An experiment carried out for the implementation and use of a monitoring and control system on a lathe machine at Kongsberg Automotive AS, shows that the experiment was considered as a failure. Later studies have shown that problems were caused by insufficient training and communication between operators at different shifts. Type I errors such as false alarms halted the system. In this experiment there were no consequences relating to the quality of the product itself. But these types of errors can lead to "creative" operators, doing workarounds to fool the system [10].

2.1.2 Sociomateriality

When new technology, such as an IT system, is introduced into an organization, it is important that the system can be updated when new and better technologies appear. Such systems are designed to allow the user customizing for ongoing challenges. Local adaptions of the technology and their use is necessary to keep them relevant to situated work practices [11]. One of the downsides of having the ability customizing the system, is the danger of exploring alternative ways of working. Which can even be encouraged by the manager but may lead to creative solutions or workarounds which conflict with the main purpose of the system [6, 10, 11].

2.2 Lean Management

Lean management is a concept for process optimization throughout the value chain. The philosophy has its roots from Japan and is based on the Toyota production system established in the 1950s [12]. The idea of Toyota production system is that anything that does not add value to a product or from a customers' view is waste [12-14]. Waste can be such as, unnecessary output, input or processing but also man-hours, expenses or other activities that do not add value [14].

2.2.1 Kaizen

One of the lean management tools is Kaizen. It is a strategy where employees work together proactively to achieve regular, incremental improvements in the production process [14]. A common structure of Kaizen is based on four different stages of PDCA: PLAN, DO, CHECK, and ACT which is an iterative cyclic process (Figure 2). PDCA cycle is a method to coordinate a continuous improvement project [15]. PDCA is originated from Walter Shewhart back in 1939 but popularized by Edward Deming in the 1950s, known as the Deming Wheel [15].

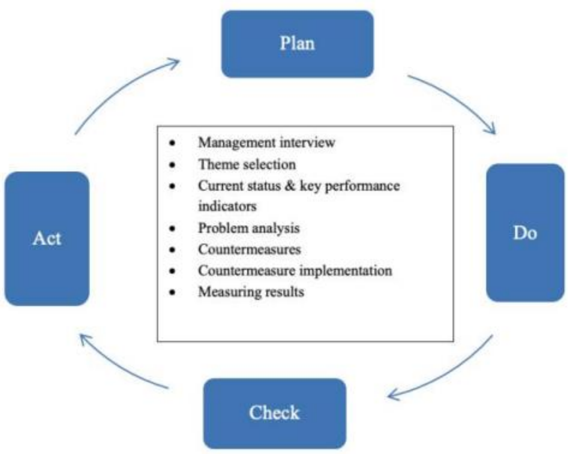

Figure 2, PDCA cycle [16]

2.2.2 Human Resources in Lean Management

Management must enable a human culture, so problems that occurs are understood and being addressed by employees to implement corrective measures. The necessity of implementing a strategy and leadership culture, which centers the employees in the organization is important to help the employee adapt to change [17].

2.2.3 Organizational Learning

Powell and Coughlan [18] mention three learning-related factors which are important for organizational learning:

- Well-developed core competencies that serve as launch points for new products and services.
- An attitude that supports continuous improvement in the business's added value.
- The ability to fundamentally renew and revitalize.

Powell and Coughlan [18] visualize a Learning-to-Learn Sand Cone Model, as shown in Figure 3. The base represents the understanding of lean principles. Then, followed by collective learning initiative to learn about lean best practices. Learning outcome (L), programmed knowledge (P), participants reflect and adding questions (Q). Organizing insight (O) and inter-organizational insight (IO), arriving at a successful network action learning outcome, where L = P + Q + O + IO

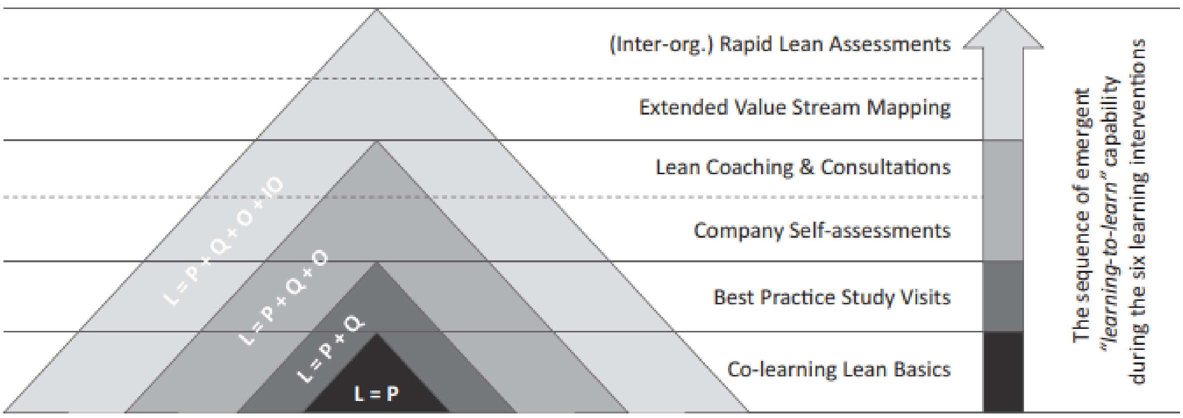

Figure 3, Learning-to-learn sand cone model [18]

2.3 Lean Methodology and Human Resources

The findings from a theoretical point of view have shown that research focusing on human resources is implemented in the lean methodology. It has been stated that *"changes in the organizational culture is the biggest challenges that companies face"* [19]. The same paper also pointing out that it is important to be aware of the cultural differences between Japan, where the lean methodology has its roots from, and western countries. A report identifying common obstacles related to lean implementation [20], states that 36 percent is backsliding to old ways of working. Also, 25 percent do not know how to do the implementation. When introducing lean methodology into an enterprise, it is important that the whole organization take part in the implementation. Training the personnel and following the same strategy is important to have a successful implementation [21], such as Teamcenter PLM.

2.3.1 Knowledge Boundaries in Product Development

Paul R. Carlile [22] are introducing terms as syntactic, semantic, and pragmatic approaches which describes current ways of thinking about knowledge and boundaries within product development.

- A **syntactic approach** is based on the existence of a shared and sufficient syntax at a given boundary. This approach is integrated through processing information and/or transferring knowledge across a boundary.
- A **semantic approach** recognizes that differences exist or emerge over time. This can lead to different interpretations of a word or an event.
- A **pragmatic approach** recognizes that differences in knowledge are not always adequately specified as differences in degree or interpretation.

A syntactical approach, where the information and knowledge are processed across departments. Semantic approach, where each department is to be seen as a process, and there will be differences in the way they think. The pragmatic approach, where individuals represent, learn, negotiate, and alter current knowledge across departments. Recognizing that knowledge has to be transformed to create new knowledge [22].

2.4 Product Lifecycle Management (PLM)

Product Lifecycle Management (PLM) is a system for managing product-related technical data for the complete life cycle of a product. It is a secure storage device for storing product design information, such as Computer Aided Design (CAD) models, drawings, Bill of Material (BOM) and other metadata of the product. A PLM system supports the process of managing the entire lifecycle of a product from the developing phase, through design and manufacturing, to service maintenance and disposal [23, 24].

PLM has become a business necessity for companies to meet challenges such as customization, traceability, shorter product development and delivery time. The PLM system’s fundamentals are to integrate and store all data about a product including revisions and workflow processes. The objective of PLM is to increase product revenues, reduce product-related costs, maximize the value of the product portfolio, and maximize the value of current and future products for both customers and shareholders [25-27].

A PLM system should make the product information consistent, traceable and “long-term archiving”. Meaning to be able to retrieve information about a specific time in the products lifetime [25, 27].

2.4.1 Product Data

Product data could be referred to as information related to a product, and could be divided into three main groups:

1. Definition data of the product
2. Life cycle data of the product
3. Metadata that describes the product and life cycle data

The data of a product determines the physical and functional properties of a product. Form, fit, and function describe the properties of a product from the viewpoint of a certain party (e.g., customer or producer) and connects the data to the interpretation of the party in question. The information could be characterized as being a complete product definition [28].

Life cycle data of a product is always connected to the product, and which stage of the product process. It defines the level of support and development/maintenance of the product [29].

Metadata is “data about the data” and is used to describe digital data. By describing the contents and context, the usefulness of the data is greatly increased as it identifies and organizes the resources. For each metadata the following variables should be used:

Description – Explanation of the metadata. Why – Description of why the data is applicable and how to use it. Where used (process) – Description of which processes that uses the data. Where used (tools) – Description of which tools that use the data [29].

2.4.2 The PLM History

Product Data Management (PDM) appeared during the 1980s to control and manage product information created by various information tools such as the Computer Aided Design (CAD) systems which were developed at the time. The need for an easy method for searching and securing data during the product design process was the start of the development of PDM. The main goal of the early version of the PDM was to provide users with the required data, to continuously update product data and control how the data was created and modified [24, 30].

The PDM system gradually developed, adding functionality such as change management, document management and workflow- and process management, promising streamlined product processes in an enterprise.

2.4.3 Benefits of PLM

A PLM system enables companies to reduce product-related costs and to grow revenues by improving innovation, reducing time-to-market for new products, and providing support for existing products. PLM helps bringing new products to the market faster, by having control over the whole lifecycle of a product. PLM gives transparency of what is happening over the product lifecycle. It helps the product owners to have control over the product status, and with easy access to the right information, they can make better decisions [26].

2.4.4 Siemens Teamcenter

Teamcenter is a PLM software developed by Siemens that connects people and processes across locations, with a digital thread for innovation. Teamcenter PLM controls product data and processes, including 3D-design, electronics, embedded software, documentation, and Bill of Materials (BOM). It is flexible to adapt changes and manage all product development stages [31].

2.4.5 Siemens Teamcenter Active Workspace

Active Workspace lets you view and create data in your enterprise's PLM system (Figure 4). It ensures that only the relevant data and tasks which are needed, are seen. Commands which are to be executed are active while others are grayed out or not shown. Active Workspace includes a powerful search that allows you to locate the data needed quickly. It also supports workflows for carrying out work assignments and manage product changes. Active Workspace runs in a browser on traditional mouse-driven computers, Windows devices, Android OS tablets, and smart phones. Active Workspace has a user interface with layout and icons which help distinguish content from commands. Bringing together data from multiple objects into a single view reduces the back-and-forth needed between function windows to understand the information [32].

Figure 4, Siemens Teamcenter Active Workspace [33].

2.4.6 Siemens Teamcenter Workflow

A workflow is a series of required tasks, such as approvals and reviews. After creating an item, document or similar, the chosen object is the target of the workflow. All tasks in a workflow are sent automatically to the responsible participant's inbox. This is executed when releasing a product, to ensure that another participant has made sure that the object is correct. It also requires the Product Owner to approve the task before a release. Figure 5 shows an example of a workflow in Teamcenter [34].

Figure 5, Workflow in Teamcenter [34].

2.5 The Enterprise's Teamcenter PLM

The Enterprises Teamcenter PLM is built upon a hierarchy structure, where the Global Enterprise is at the top node, with the different divisions beneath. The core product structures; Global Enterprise's main systems, are system release based on subject to revision control by software release. This implies that each time a new version of the product is to be released, a new version of the structure shall be made in form of a new tree node. The structures are to a certain degree required to follow a predetermined setup for categorizing Hardware (HW), Software (SW) and documents. The intent is that the product structures are as similar and easily recognizable as possible [35].

General rules for the product structure:

- To give an easy overview of all products in active use.
- Shall consist of all Global Enterprise core products.
- Shall only contain recommended and approved products for use in basic deliveries.
- Shall be based on system releases.
- Not to be used as an engineering- or configuration tool. If the number of products within a tree-node exceeds some pre-defined number, a new (sub)category in the form of a tree-node should be made to maintain an easy overview of the products.
- Each product shall have only one item number in TC, to avoid multiple product registrations.
- If applicable, a tree-node made by one Global Enterprise department may be used by another, provided ownership is maintained by the original tree-node owner.

2.5.1 The Enterprise's Teamcenter Structure

The product structure (portfolio) is divided into nine levels in the tree-node hierarchy. The purpose is to give an overview of all the company's core products for the respective system releases, recommended and approved by Product and Services in collaboration with Technology for use in deliveries.

The user of the structures should to some extent be familiar with the different core products, hence the importance of uniform structures. The general structure of the new Teamcenter hierarchy is shown in Figure 6. Although, it is up to each division to decide how detailed the node structure should be. Level 1 to 4 is standard, from top – down:

- **Company** is the name of the division
- **Product line** is array related and similar products and/or technology platform which are sold to customers.
- **Product group** is a group of products that share similar function(s), shape(s), and/or markets within a product line.
- **Product** is a self-contained element or combination of interacting self-contained elements purchased by a licensed customer, as it is or after customization, and that must be supported throughout its life cycle.

Other divisions use more levels, to describe components within the product, e.g., print cardboard (PCB), components on the PCB, software versions. It can be very detailed describing the smallest component within a product.

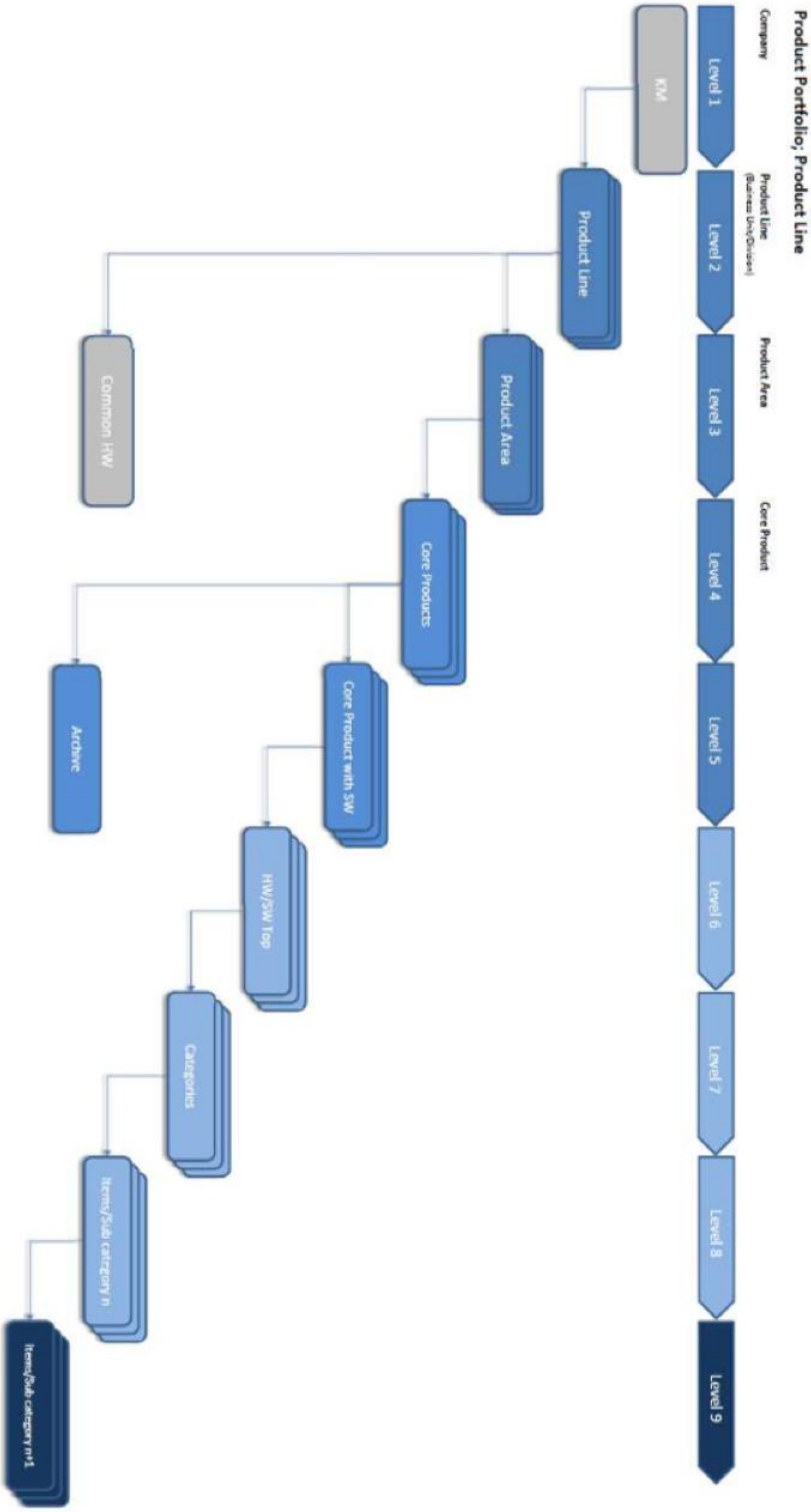

Figure 6, General hierarchy structure for The Global Enterprise's Teamcenter PLM [35]

2.5.2 The Enterprise's Teamcenter PLM Product hierarchy

To further define levels within the product, Table 1 defines item category definitions

Table 1, The Enterprise's Teamcenter PLM product hierarchy [36]

Terminology	Product hierarchy description
System	System describes an item within one or more functional areas where the performance is depended on configuration.
Unit	Unit is an individual item or group of items that is considered a structural or functional whole.
Kit	Kit is a sub-assembly of components and/or modules that adds functionality to a module or unit.
Module	Module is an item which is used to describe a collection of components that have gone through an operation of fitting, fixing, or adding more components.
Component	Component is an item which is completely defined and finish item with no connected items.
Material	Parts are typically manufactured from materials. Materials are organized in catalogues and have different characteristics.
Substance	A material consists of substances, one or more. Substances are found in nature or are manufactured.

2.5.3 Creating Items in the Enterprise's Teamcenter PLM

The tree-node structure within level four and below (Figure 6), is made by adding items which consists of information about the product. When creating an item in TC, the type of object you want to create needs to be chosen (Figure 7). There are five mandatory fields to be filled out when creating an item; ID (which is automatically generated by TC), Revision (first revision start at "A"), name (can have a maximum of 32 characters), Protection level and Security Group.

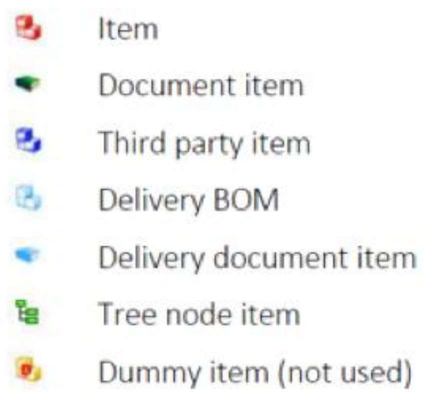

Figure 7, Item object types in the Enterprise's Teamcenter PLM [29]

The rest of information choices about the item are not mandatory, but the more information to be filled in, the better for searchability later. If the item is not released, it is possible to fill in other information about the item. When the item is released, a new revision needs to be made before being able to make changes.

2.5.4 The Enterprise's Teamcenter PLM Lifecycle Status

The lifecycle attributes shall describe status information related to specifying the main support status, expected lifetime, product release status, and the maturity of the item. In Teamcenter PLM the main attributes are listed in Table 2 [36].

Table 2, Lifecycle Status in the Enterprise's Teamcenter PLM [36]

Item attribute	Item attribute description
Lifecycle status	Status describing the Enterprise's capability to support the item. Valid statuses: • Development (i.e., Feasibility, Specification & Plan and Realization) • Utilization • Standard Maintenance • Limited Maintenance • Obsolete
Utilization Date	The planned date for the status is active
Standard Maintenance Date	The planned date for the status is active
Limited Maintenance Date	The planned date for the status is active
Obsolete Date	The planned date for the status is active

- **Development** is set if the item is still a project, feasibility study or prototype
- **Date utilization** is the day when the item enters the utilization lifecycle phase. From this date the item is free to use for all activities, sales, delivery, maintenance, and spare parts.
- **Date Standard Maintenance** is the day when the item enters the maintenance lifecycle phase. From this date the item has limited availability and shall only be used for Maintenance and Spare parts (not new deliveries).
- **Date Limited Maintenance** is the day when the item enters the limited maintenance lifecycle phase. From this date the item is not to be used in new deliveries and normal maintenance. Updates/upgrades are not processed, and service knowledge may be limited.
- **Date Obsolete** is the day when the item enters the obsolete lifecycle phase. From this date the item is not to be used in new deliveries, maintenance, and limited maintenance. Requisitions are not processed, and service knowledge is not available.

2.5.5 Document types/Categories in The Enterprise's Teamcenter PLM

According to the Global Enterprise's procedure [37], all product related documents shall be linked to the relevant product structure. Detailed descriptions of what to use, and why, shall be covered in relevant work instructions. Categories of documentation to be linked to an item in Teamcenter PLM are such as:

- Drawings
- Procedures
- Fact sheets and data sheets
- Product specifications
- Test procedures and logged results
- Manuals
- Certificates (case-by-case and type approvals)
- Declaration/Certificates of conformity

In addition to the item attributes described above, the main attributes to be added are document name, author, and language.

2.5.6 Integration with other Applications in the Enterprise's Teamcenter PLM

The Teamcenter PLM integration is one of several parallel tasks to be implemented 2nd quarter of 2024. A new ERP system is to be integrated with TC in addition to design systems such as 3D- and 2D CAD integration tools (Figure 8). The new ERP system will be released at the same time as Teamcenter PLM.

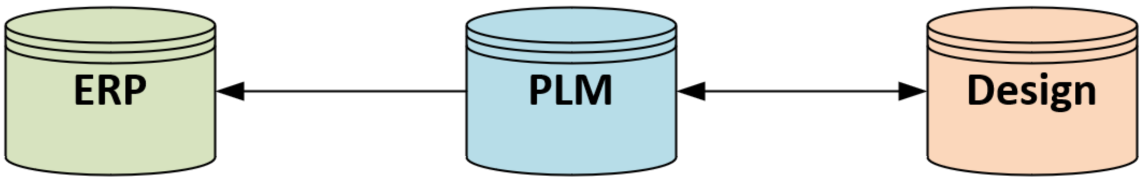

Figure 8, The Enterprise's integration portfolio

2.6 Bill of Materials (BOM)

Bill of Material (BOM) is an inventory describing which parts a product consists of. The BOM describes which raw materials, parts, assemblies, and sub-assemblies are needed to build the product. It is a complete list of how to produce the product. A typical BOM has a hierarchal structure, with the finished product at the top, then assemblies and parts below. The purpose of the BOM is to provide all the information that goes into building a final product. Figure 9 shows an example of a BOM, which is typically stored as a document in Teamcenter. The first red marking shows the BOM and describes the different parts an ice scrape is built from. The marking in the bottom is the document identification number under which the drawing is saved in Teamcenter.

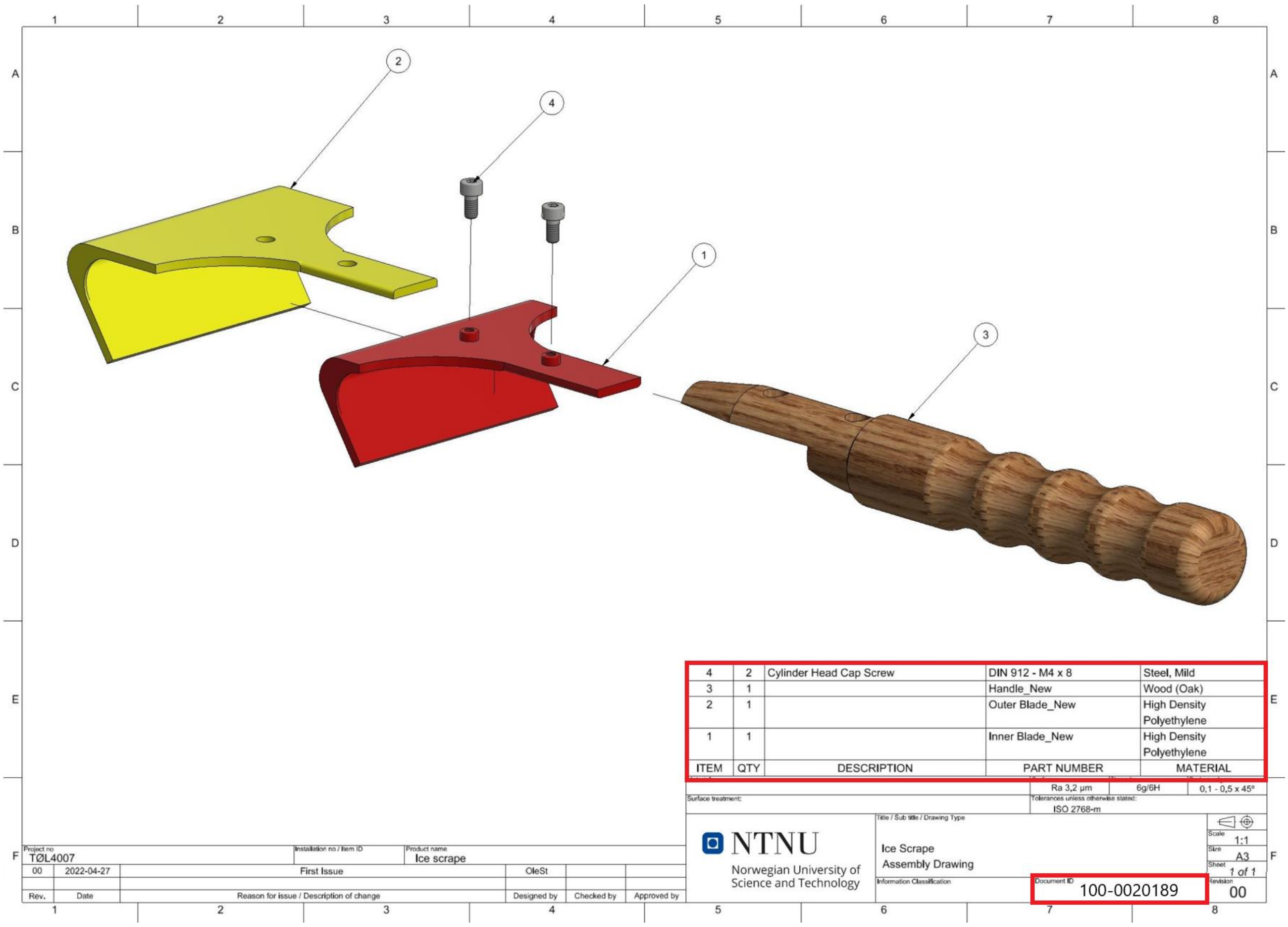

Figure 9, Example of a BOM [38]

Figure 10 is an example of how a typical BOM structure could be in Teamcenter PLM. The marked document item is where the drawing in Figure 9 is stored. All added parts stored in Teamcenter PLM have a unique identification number linked to them.

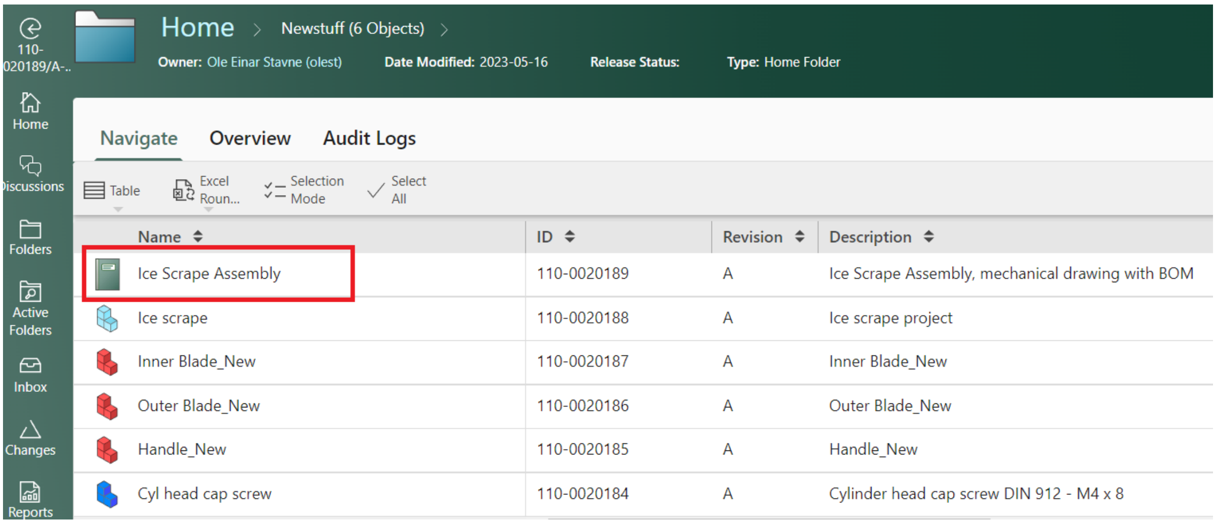

Figure 10, Example of a BOM structure in Teamcenter

The following sub sections describe how the BOM View defines the types of BOM from a process perspective depending on the process. Procedures [36, 37] defines the valid BOM views to be used.

2.6.1 Forecast BOM (FBOM)

Forecast BOM (FBOM) is an incomplete product structure for forecasting purposes and/or documenting the main structure of a sold product. Semi-products and components with long lead time shall be included to ensure that these are available when required. A typically FBOM is up to 90% of a complete configuration [37].

2.6.2 Engineering BOM (EBOM)

Engineering BOM (EBOM) is a product structure which represents “form, fit and function” from a functional and design perspective. It can be divided into three groups, the 150%, 100% or the 80% EBOM. The 150% EBOM is a configurable product structure consisting of several optional items to be configured to meet e.g., the customers’ needs or a specific requirement. 100% EBOM is a configured product structure, which represents a fully configured product from a functional and design perspective. An 80% EBOM is a partly configured product structure and consists of the main solution items. The 80% EBOM is to be further configured to fit the purpose and design of a deliverable product variant [36, 37].

2.6.3 Manufacturing BOM (MBOM)

Manufacturing BOM (MBOM) consists of all materials, assemblies and components required for manufacturing a final assembly of a specific product. It consists of purchased parts and own manufactured parts. Child components of purchased parts are not included. The connection between the MBOM and the Bill of Processes (BOP) is important as a part of revision control and traceability of process steps attached to the planned processes to be performed in its production. MBOM is the base structure to be used to link manufactured assets, e.g., serialization to an asset management system [36, 37].

2.6.4 Service BOM (SBOM)

Service BOM (SBOM) is a product structure to represent “form, fit and function” of a product from a service and maintenance perspective. I.e., documents needed for supporting an operative product – including all possible spare parts to be used in a Maintenance Plan and related to Service Events [37].

2.6.5 Physical BOM (PBOM)

Physical BOM (PBOM) represents the structure of used materials, assemblies, and components of the manufactured physical asset (with associated tracking dimensions). It describes how the actual product was built, e.g., parts, sub-assemblies, serial numbers. The PBOM is enriched and updated during the lifecycle of the asset [37].

Figure 11 explains where in the Enterprise’s hierarchy the different BOMs are used. This figure is a simplified model compared to a complete architecture model. The PBOM is not included in this figure.

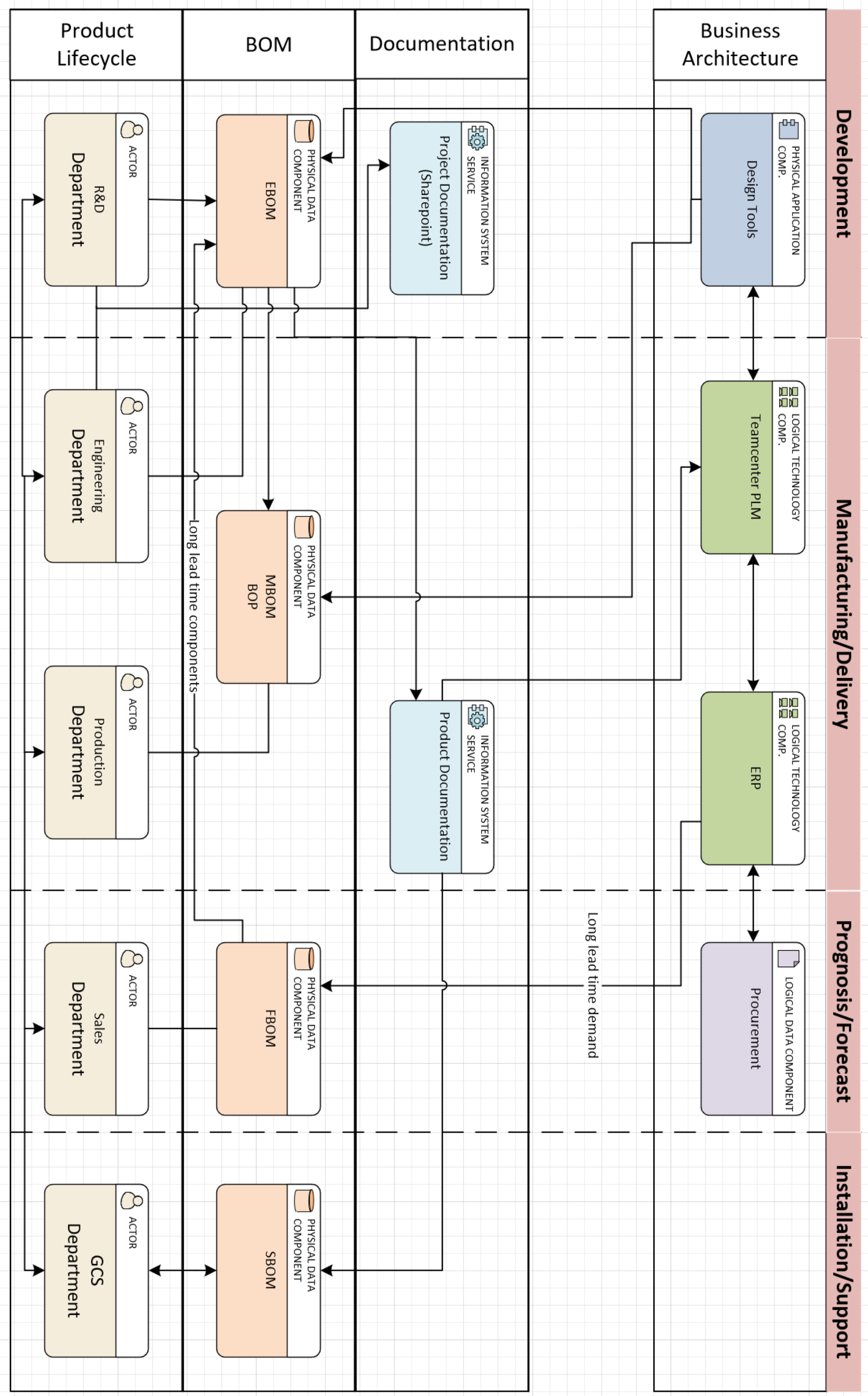

Figure 11, Example of where different BOM is utilized in the Enterprise

2.7 Enterprise Architecture (EA)

The purpose of Enterprise Architecture (EA) is to describe the structure and behavior of a business. The term enterprise can be defined as describing an organizational unit or collection of organizations sharing a set of common goals [39]. While the term Architecture refers to fundamental concepts or properties of a system in its environment, embodied in its elements, relationships, and in the principles of its design and evolution [40]. The definition of an EA is a coherent whole principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information system, and infrastructure [40, 41].

EA is a helpful tool to map the essentials in a business, allowing full flexibility and adaptivity.

2.7.1 Architecture Principles

Principles are general rules and guidelines, that inform and support how the organization should achieve its goals. Architecture principles is related to architecture work, and reflects a level of consensus across the enterprise, embodying the existing enterprise principles [42]. Architecture principles is a way to capture the basics and fundamental importance to an enterprise. They are general rules that inform and support the way an organization sets about fulfilling its mission [43].

2.7.2 Systems Architecture

Systems architecture focuses on components that make up the system, how they are linked together, and integrated with each other to accomplish the system's functionality. A system architecture focuses on the whole system e.g., data and infrastructure domains. It is important for an architect to illustrate how various systems interact at different architecture levels. A thorough understanding of the enterprise, the business capabilities, and its processes is necessary to illustrate how components interact with each other [44].

2.8 The Open Group Architecture Framework (TOGAF)

The Open Group Architecture Framework (TOGAF) has been recognized as a major reference in the field of enterprise architecture [45]. The TOGAF standard is a proven Enterprise Architecture methodology and framework to improve business efficiency. It is an Enterprise Architecture standard which ensuring consistent standards, methods, and communication among Enterprise Architecture professionals [46].

The TOGAF method primarily propose an architecture structure, and not that much on the actual transformation approach. To successfully carry out a transformation operation, it is important to be clear about the results to be obtained. TOGAF distinguishes a series of elements to structure the formalization [45, 47]:

- Strategic objectives, or **goals**, which describe general orientations.
- Operational objectives, or **objectives**, which formalize these goals in terms of measurable results at a given date.
- **Drivers**, which often motivate decisions regarding architectural change, such as changes in conjecture or the need to adapt to technical evolutions. These are the "why", which justify and orientate goals.
- **Requirements**, which specify exactly what will be implemented to reach these goals.
- **Constraints**, which are external elements that influence the system, sometimes restraining its capacities.

2.8.1 The Open Group

The Open Group is a global consortium that enables the achievement of business objectives through technology standards. The Open Group use several standards, including the TOGAF® Standard. License options include corporate and academic licenses for non-commercial use, as well as commercial licenses for using standards for commercial purposes [48].

2.8.2 Gap Analysis

Gap analysis is a technique used in TOGAF Architecture Development Model (ADM) to validate the development of an architecture. The main purpose is to highlight the differences between the Baseline Architecture and the target Architecture, which is items that has not been defined or not defined [45, 49].

2.8.3 TOGAF Architecture Development Method (ADM)

The TOGAF ADM describes a method for developing and managing the lifecycle of an Enterprise Architecture, and forms the core of the TOGAF standard [42]. The ADM is an iterative process, where the TOGAF® 9.2 standard [42] describes that a decision must be taken care for each phase to:

- To define the breadth of coverage of the enterprise
- To define the level of detail
- Determine the extent period aimed at, including the number and extent of any intermediate time periods
- The architectural assets should be included, such as:
  - Assets created in previous iterations of the ADM cycle within the enterprise
  - Assets available elsewhere in the industry (other frameworks, systems models, etc.)
- Decisions should be based on practical assessment of resource and competence availability

As a generic method, the ADM is intended to be used by enterprises in a wide variety of different geographies and applied in different vertical sectors.

The TOGAF ADM includes 8 phases for implementing an enterprise architecture in addition to a preliminary phase. Phases within the ADM are described as follows in the TOGAF® Standard [42, 50]:

- The **Preliminary Phase** describes the preparation and initiation activities required to create an Architecture Capability including customization of the TOGAF framework and definition of Architecture Principles.
- **Phase A: Architecture Vision** describes the initial phase of an architecture development.
  It includes information about defining the scope of the architecture development initiative, identifying stakeholders, create Architecture Vision, and obtaining approval to proceed with the architecture development.
- **Phase B: Business Architecture** describes the development of Information Systems Architecture to support the agreed Architecture Vision
- **Phase C: Information Systems Architectures** describes the development of the Technology Architecture to support the agreed Architecture Vision
- **Phase D: Technology Architecture** describes the development of the Technology Architecture to support the agreed Architecture Vision.
- **Phase E: Opportunities & Solutions** conducts initial implementation planning and the identification of delivery vehicles for the architecture defined in the previous phases.
- **Phase F: Migration Planning** addresses how to move from the Baseline to the Target Architectures by finalizing a detailed Implementation and Migration Plan.
- **Phase G: Implementation Governance** provides an architectural overview of the implementation.
- **Phase H: Architecture Change Management** establishes procedures for managing change to the new architecture.
- **Requirements Management** examines the process of managing architecture requirements throughout the ADM.

3 Research Method

3.1 Process and Assumptions

Implementing Teamcenter PLM will affect people in the whole organization, which will lead to the need for them to change how they work. The practical work on the Master Thesis has mostly been focusing on mapping of the Enterprise's processes, and there has not been enough time to investigate how individuals and groups solve daily challenges. Therefore, a theoretical approximation has been reviewed to point out tools and possible danger to be aware of form a human behavior point of view (chapter 2.1 - 2.3).

System architecture models are usually built over a long period of time, and it could take years to see the benefits from changes. With limited time on this master thesis, the processes to be evaluated is the preliminary phase of the TOGAF ADM system architecture model. All evaluations and experiments conducted in this master thesis has been executed by following methods:

- Interviews with stakeholders at the Enterprise.
- Interviews with Teamcenter PLM experts at another division within the global enterprise.
- Weekly meetings in the Teamcenter PLM project group.
- Value stream mapping based on the Enterprise interviews.

3.2 Teamcenter PLM Project Group

A project group consisting of two people in the Development department was established in November 2022, and a third person as the project owner, working among other things with the new ERP system. The main purpose of the group is to investigate how the Enterprise can implement Teamcenter PLM for managing its products. The group's members had not any knowledge about Teamcenter PLM before the establishment and therefore had to get access to the software and read its documentation.

The group was having meetings and conversations either via Microsoft Teams or physically daily. Exchanging information and relevant documents regarding Siemens Teamcenter PLM.

3.3 Teamcenter PLM Platforms

To understand the building blocks in Teamcenter PLM, required extended access rights in the software not only having a viewer role but be able editing documents and building BOMs. Not being an expert using Teamcenter PLM, led to the requirement getting access also to the Teamcenter PLM test. It is a platform built the same way as the Teamcenter PLM product, except that punching wrong will not have any consequences. Teamcenter PLM test has been used actively throughout the preliminary phase, for testing functions and to know which attributes is necessary for adding items and documents.

3.4 Teamcenter PLM Stakeholders

Interviews with the Enterprise's stakeholders were conducted, to map how each department carries out its tasks. It has been important to map these, to fully understand how the entire organization is organized and cooperates between departments. Also, to map which tools that needs to be in place for the Teamcenter PLM migration to be as smooth as possible. Table 3 shows dates, persons interviewed and subject of the conversations.

Table 3, Interviews conducted with Teamcenter PLM Stakeholders

Date	Persons Interviewed	Conversation Themes
06.12.2022	The Enterprise's Sales and Engineering department, with TC experience	Information about Sales packages imported in TC
16.12.2022	TC Expert at the Global Enterprise	Information about TC, documentation, questions, and answers
09.01.2023	Production Department	Information about which tools used today, who does what.
16.01.2023	Quality Manager	Questions and Answers about procedures, internal documents, and standards. Introduction to ARIS
17.01.2023	Production Manager	Information about ongoing projects connected with TC implementation in The Global Enterprise, and The Enterprise's Production department
20.01.2023	Product Manager A & B	Where project- and product information is stored. How this is done, communication procedures between R&D and Production department related to releases or changes,
24.01.2023	TC Expert from The Global Enterprise	TC Q & A
03.02.2023	Inhouse Sale	Organization of Sales Packages in TC. What needs to be in place first.
08.02.2023	Visiting The Global Enterprise, interviewing TC Expert	TC, concrete examples of how to work with TC. Q&A
09.02.2023	Visiting The Global Enterprise interviewing TC Expert, Industrialization Manager, and Quality Manager	Industrialization, value chain, purchasing, processes, and documentation at The Global Enterprise
03.03.2023	Project leader	Mapping of how to conduct a project at The Enterprise
06.03.2023	Engineering Department	Engineering's job description, involvement in development projects
13.03.2023	Production Department	Time consumption when purchasing goods for production
17.03.2023	Product Manager C	Which role and responsibility a Product Manager has. Storage of documents, and bottlenecks
21.03.2023	Engineering Department	Involvement in projects, challenges, solutions for challenges

3.5 SWOT-Analysis

Strength, Weakness, Opportunity, and Threats analysis (SWOT) was carried out based on the Teamcenter project groups knowledge of the organization. A SWOT-analysis is helpful to assess the organization's position before deciding on any new strategy [51]. The SWOT-analysis was conducted to get an overview over the organization's performance. It has been helpful to make models and suggestions for possible re-organizing of the Enterprise.

3.6 TOGAF Preliminary Phase

TOGAF is a generic methodological framework, and to facilitate the TOGAF ADM (Figure 12), the Preliminary Phase involves doing necessary work defining and initiate the framework and architectural principles to be used [52]. The preliminary phase is about defining "where, what, why, who, and how" the architecture is going to be applied regarding the Enterprise. Main aspects from the TOGAF® standard [42] are listed below:

- Defining the enterprise
- Identifying key drivers and elements in the organizational context
- Defining the requirements for architecture work
- Defining Architecture Principles that will lay the foundation for any architectural work
- Defining the framework to be used
- Defining the relationships between management frameworks
- Evaluating the Enterprise Architecture maturity

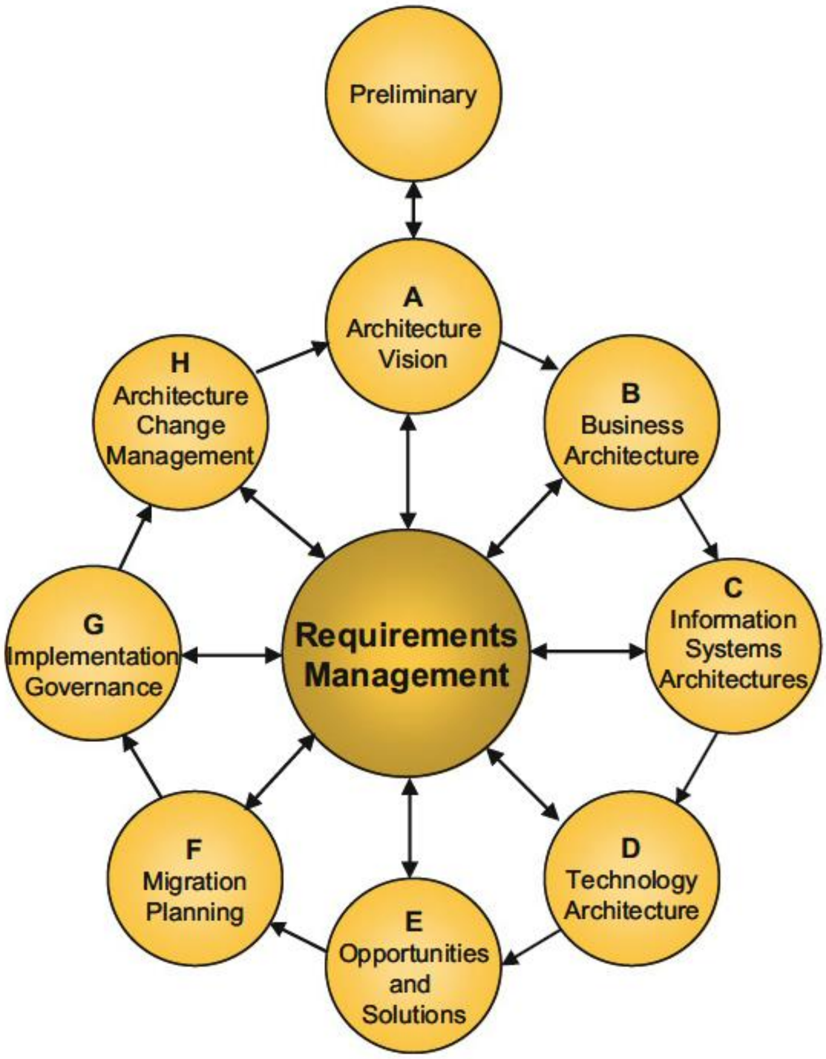

Figure 12, TOGAF ADM cycle [42]

3.7 The Development Department

As seen in Figure 13, the Vice President of Research and Development is responsible for eight developers and Product Managers, where six of them again has Project Engineers and Project Managers under them again. The Development department is the largest division at the Enterprise with a total of 64 employees in total. The Intellectual Property Rights (IPR) Manager assures that developed products get patented and licensed of intellectual properties. The Information Developer is responsible to make manuals for each product, and assure correct language and grammar is used. The Product Managers have responsibility of all their products through its whole life cycle. From an idea, developing, implementation into the production, maintenance, and disposal or end-of-life. Some of the responsibilities is delegated to Project Managers e.g., preparing BOMs, project leading.

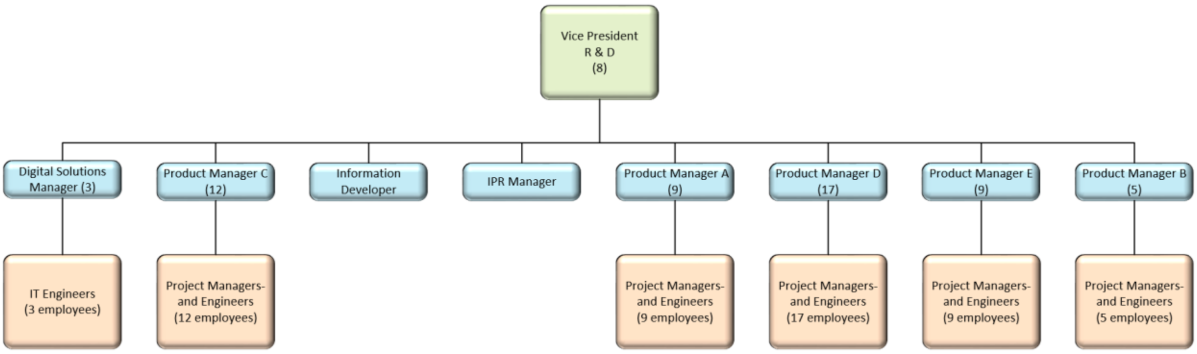

Figure 13, Organization Map Development Department

3.8 The Production Department

With a total of 31 employees the Production Department is the second largest department showed in Figure 14. Responsible for producing new products, systems, dispatching and logistics. The Production department are in addition to producing units also responsible doing purchasing. Each product area has one Production Engineer responsible for the product group, like the Product Managers showed in Figure 13.

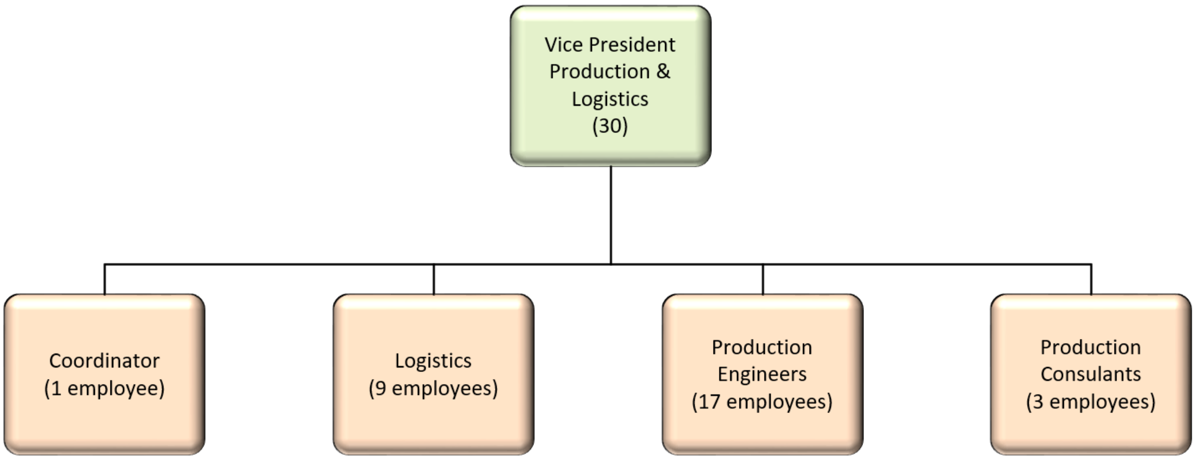

Figure 14, Organization Map Production Department

3.9 The Sales Department

The Sales department has nine Sales Managers, which is divided into inhouse- and Area Sales Managers which is responsible for different parts around the world. Also included in this department is one employee coordinating the training facilities (Figure 15). Inhouse sale is building sales packages based on demand and/or special deliveries sold by the Area Sales Managers. Sales packages has already been established in Teamcenter PLM, since many of the Enterprise’s products is being sold by the Global Enterprise which already using Teamcenter PLM with a link to their ERP system. All new developed products are currently being added in Teamcenter PLM as items and documentation for sale purposes. The Sales Department will most likely not have an active role in Teamcenter PLM when implemented, but mainly use it as a library.

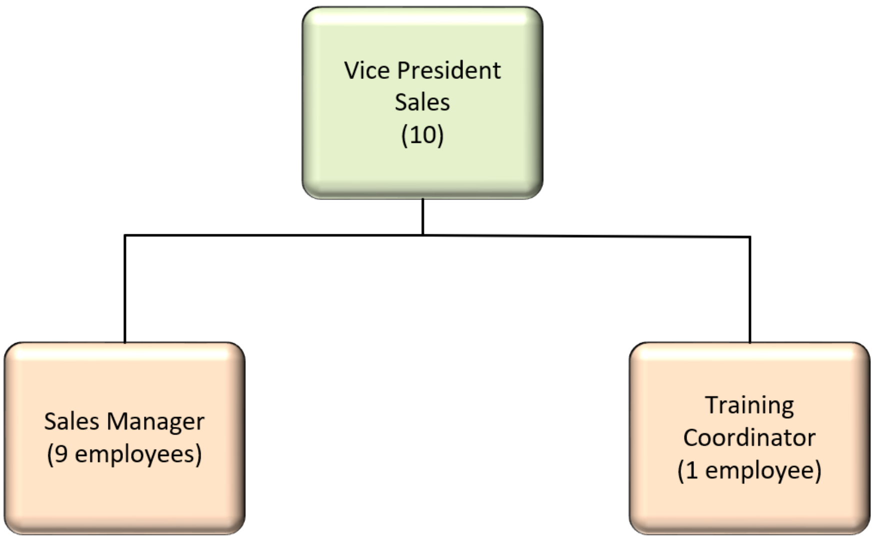

Figure 15, Organization Map Sales Department

3.9.1 The Customer Support Department

The Customer Support department is divided in three groups as shown in Figure 16. Customer Support (inhouse- and external service), Engineering, and Training Instructors. The Engineering group has a coordinator on the top which manage communication within the Engineering group, but also communicates with Production department, Product Managers and Project Managers at the Development department.

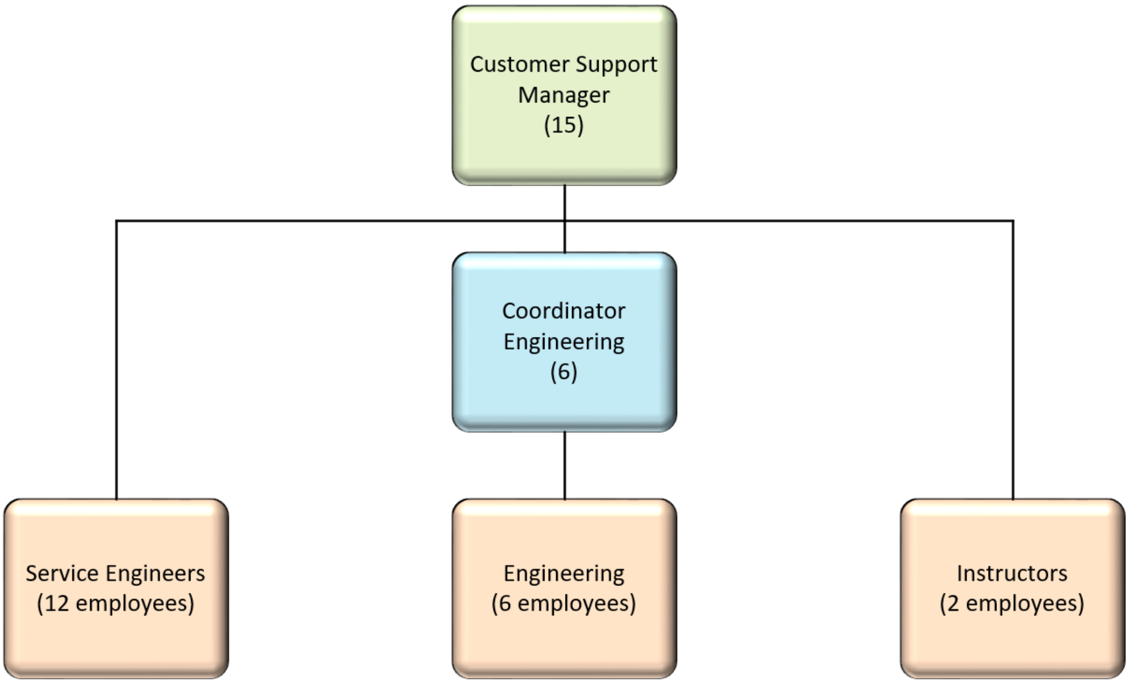

Figure 16, Organization Map Customer Support Department

3.9.2 Engineering Department Role

The Engineering department group has a total of 7 employees, their main tasks are to make solutions for special deliveries and draw wiring diagrams for systems, in addition to be working towards the Development department on the product development. Their main job against the Development department is to assure that junction boxes, cables, and common hardware necessary for the developed product to work is in place.

4 Results

4.1 Findings from Stakeholder Interviews

Important findings from interviews (section 3.4) which are relevant to be taken into consideration before implementing Teamcenter PLM at the Enterprise are:

- Documents and drawings belonging to products are located at different storage, which leads to difficulties getting an overview of all documents belonging to a product.
- Uncertainty about which documents and drawings to be included in a product release. An overview over defined documents is wanted.
- The Engineering department believes that they enter the product development process too late. Proposals made by Engineering to Project Managers meant for evaluation, are often perceived as finished.
- Missing a coordinator for common HW for all products. The coordinator should have an overview of the Enterprise portfolio and recommend reuse of existing parts for new development projects.
- Engineering department is unsure where drawings for common HW should be stored and how to name them. As the system is today, names and storage space are often linked to a project and/or a product.
- The Development department lacks feedback and information from the Production department about changes to a product e.g., when there are changes to a BOM.
- Production department spends a lot of time on planning and purchasing. The workload related to purchasing of goods will increase as there has been decided that every purchase is to be registered in the ERP system.

4.2 SWOT Analysis of the Enterprise

The SWOT analysis bullet points shown in Figure 17 are a result of the Teamcenter PLM project group’s knowledge about the Enterprise, and findings from interviews with its stakeholders. The strengths indicate effective development processes making profitable and innovative products. The weaknesses show that there are communication problems and lack of proper routines in the organization. These are problems which easily can be fixed by making procedures and check lists during the development phase. Lack of structure can lead to reduced traceability.

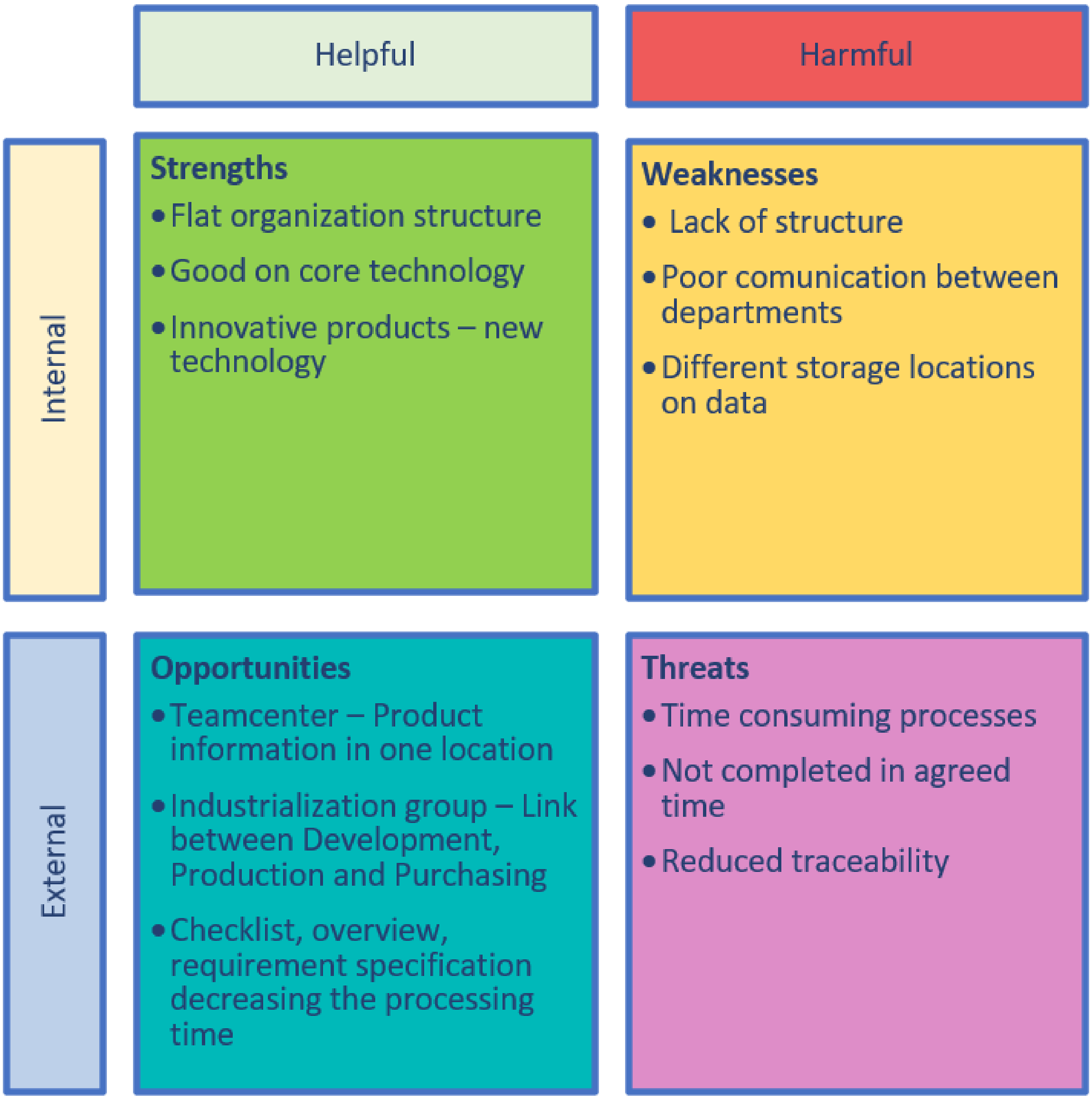

Figure 17, SWOT-Analysis of the Enterprise

4.3 Document Handling and Storage

When trying to find the best way of organizing product related documents in Teamcenter PLM, it was necessary to find out where these are located today. Firstly, if e.g., production CAD-drawings are stored in one location or several. Secondly, if the same documents are stored in multiple locations.

Figure 18 shows that there are used more storage locations than the Enterprise's guidance documents describe. Microsoft Teams has become one of these storage locations, especially after the COVID-19 pandemic. This is a consequence caused by most of the development engineers being at the home office. One of the more dangerous storage locations was revealed to be at storage locations of external consultants. Not having control of production drawings is a data protection offence, which in worst case could lead to loss or disclosure of company internal documents.

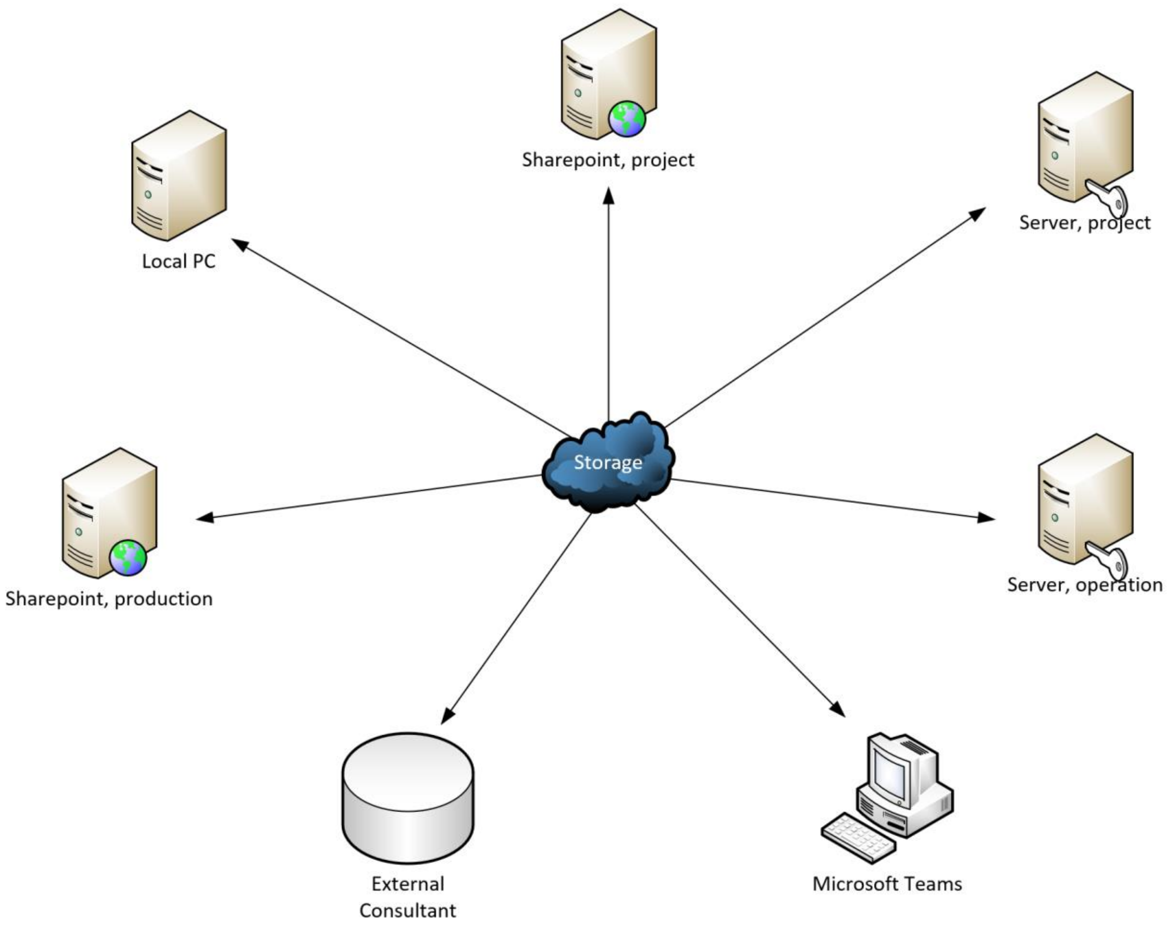

Figure 18, The company's data storing locations of project- and product related documents

4.4 Product Managers Role

There is a total of 6 Product Managers at the enterprise, where 5 has responsibility for the products through their whole life cycle. The last Product Manager is responsible for the IT department and cyber security. Being Product Manager is a very demanding job, and it varies how many products each Product Manager have in their portfolio. There is an uneven distribution between the number of products each product manager is responsible for. This is because the Product Managers are responsible for each of their product areas, shown in Table 4.

Table 4, Distribution of Products for Product Managers

Product Group	Product Manager	Number of Products
Group 1	A	7
Group 2	B	1
Group 3	C	13
Group 4	D	8
Group 5	E	6

Product Managers are responsible for the development of new products, updates, and maintenance until the product reaches end of life. They also have several employees under them, which means personnel responsibility. Figure 19 shows the different roles and responsibilities each Product Manager at the Enterprise has.

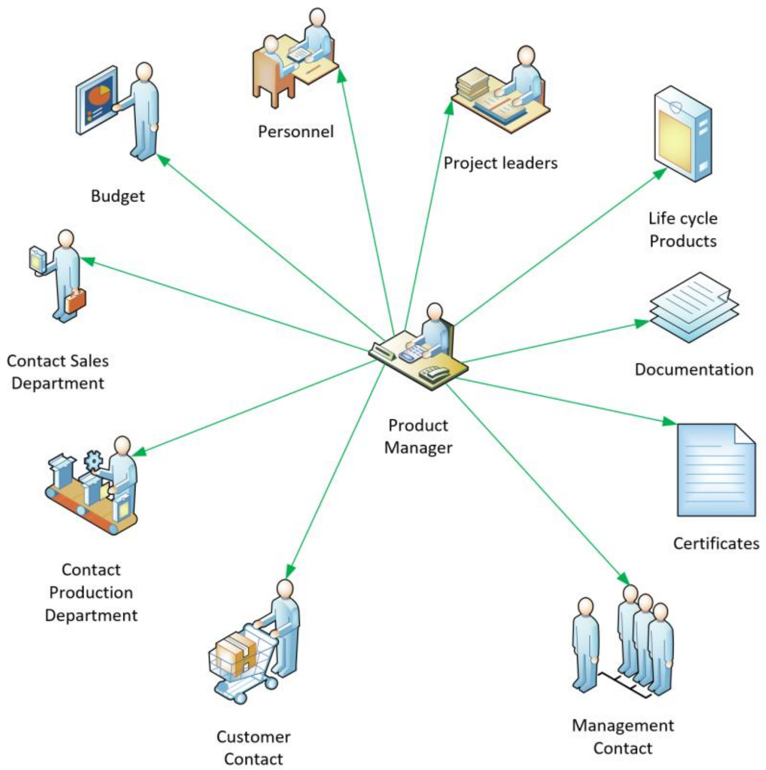

Figure 19, Product Managers Responsibilities

4.5 Production Responsible Engineers Role

The Production Responsible engineer purchases parts for their product. He/she also follows up subcontractors, makes prognosis and makes the BOM. Figure 20 shows how extensive and varied tasks the Production Responsible engineer performs. It has been estimated from interviews that approximately 20% of the job is purchasing. The remaining purchasing and sales follow-up are handled by the coordinator.

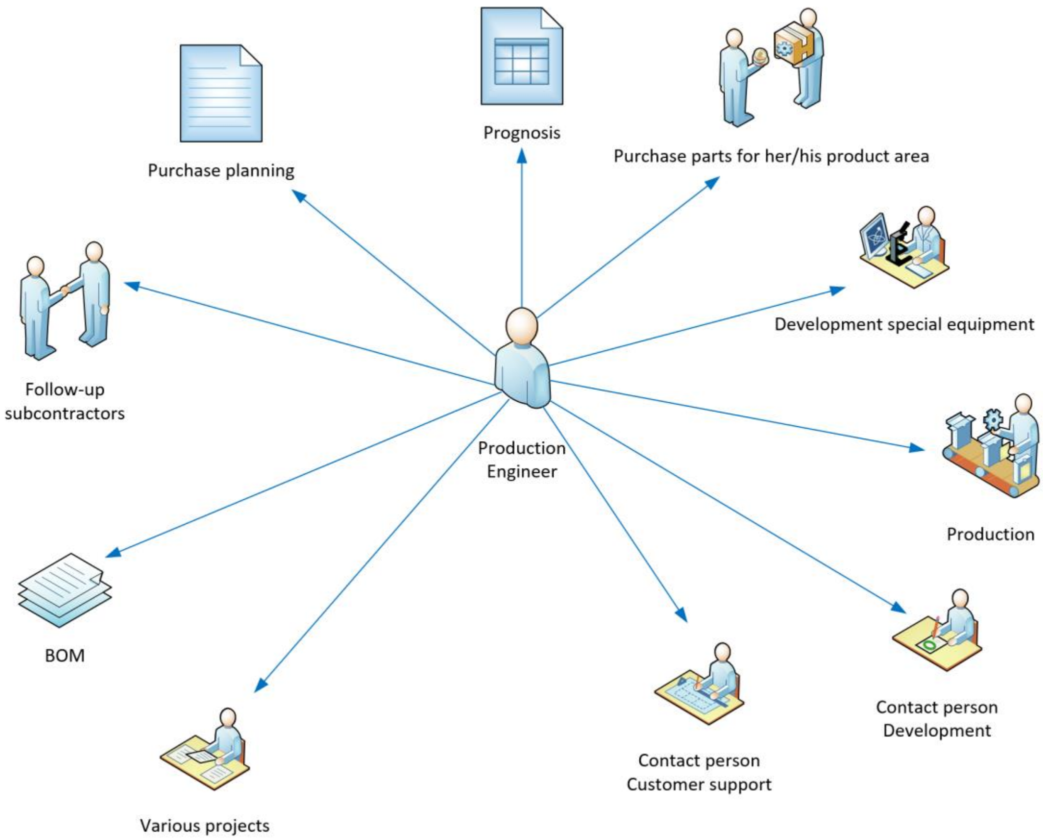

Figure 20, Tasks performed by Production Responsible engineer

4.5.1 Distribution of Roles in the Production Department

Figure 21 shows the distribution of roles in the Production department. Each row in the figure represents how much time each production responsible uses on purchasing parts for their products, and how many products they are responsible for. The different products are listed as P1, P2, P3…

There are currently two apprentices and one consultant at the Enterprise which will be there for a limited time. The figure show that Technician (Tech) 1, 2 and 4 overlaps between two or more product groups.

Production Responsible (PR) 4 marked in yellow have knowledge of two product groups. Some of the products have technicians who can work with multiple products, while others are more vulnerable. This map analysis shows that the Enterprise's Production department has some organizational weaknesses due to little overlap between the people working in the Production department.

It can cause problems if someone resigns or get ill, especially PR 2 and Tech 3, marked in red. Unforeseen events or problems in the P8 production could lead to PR 2 needing to step into the P8 production, which again will affect purchasing and other tasks described in Figure 20.

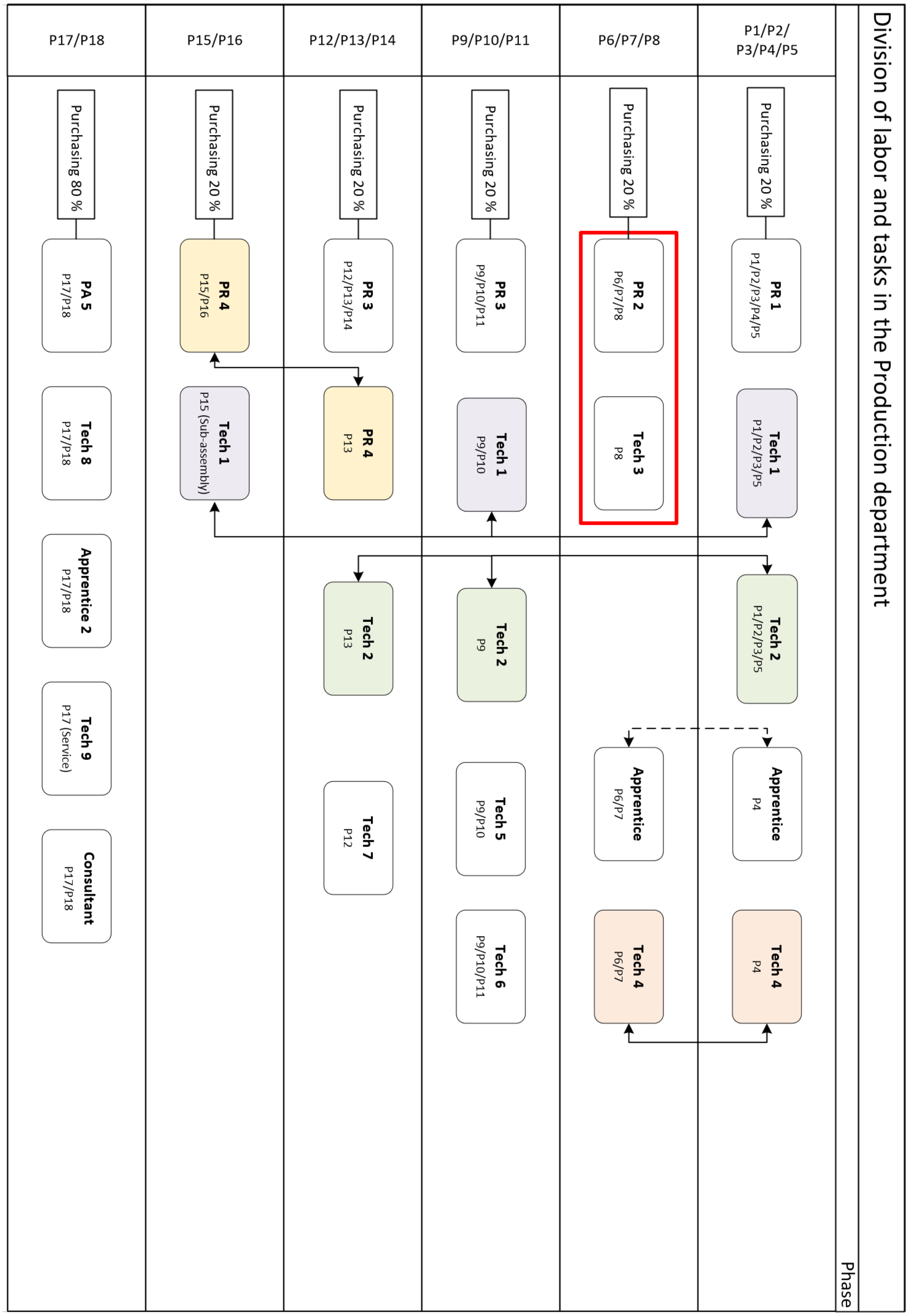

Figure 21, Division of labor and tasks in the Production Department

4.6 Sales Managers Role

The Sales Managers are responsible for selling products and systems in the company's portfolio. In addition to follow up existing and new customers, they also work closely with all the departments at the Enterprise. They are involved in development projects to ensure that the customers' needs are considered. They work with Logistics Support on system deliveries and provide documentation to customers or shipyards. Sales Managers cooperate closely with the Coordinator at the Production department to ensure that the production is according to the sales orders. Figure 22 presents the different tasks a sales Manager is responsible for.

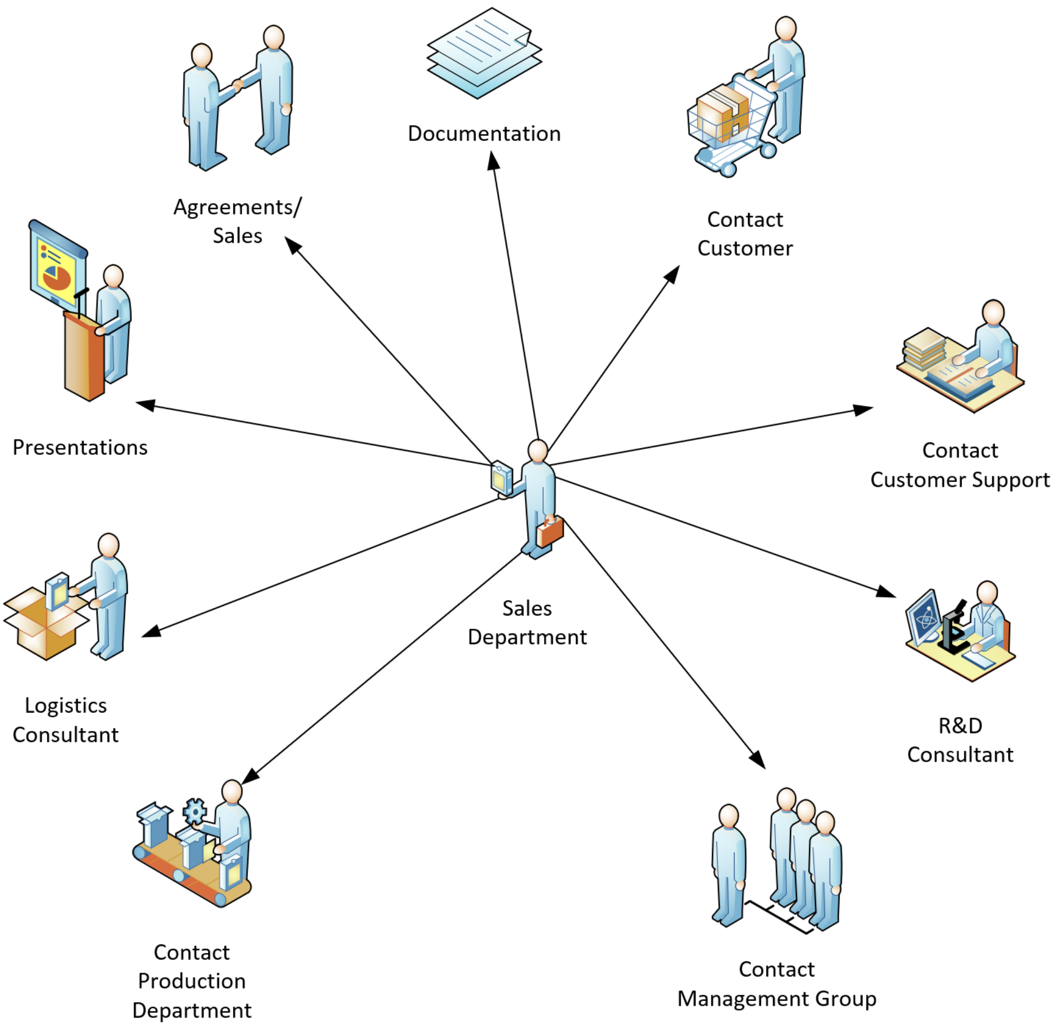

Figure 22, Tasks performed by Sales Manager

4.7 Engineering Department Role

Figure 23 illustrates the roles in the Engineering department. They are responsible for customer follow-up and support the Sales department regarding system solutions or technical expertise. Engineering is also responsible for drawing and maintaining technical documentation for the Enterprise's common hardware, e.g., cables, junction boxes, brackets. They cooperate closely with all departments mentioned in this chapter and have a technical support role towards both internal and external Global Enterprise engineers. They are responsible for testing and troubleshooting technical problems onshore- and offshore for Global Customer Support (GCS) and they assist Factory Acceptance Tests (FAT).

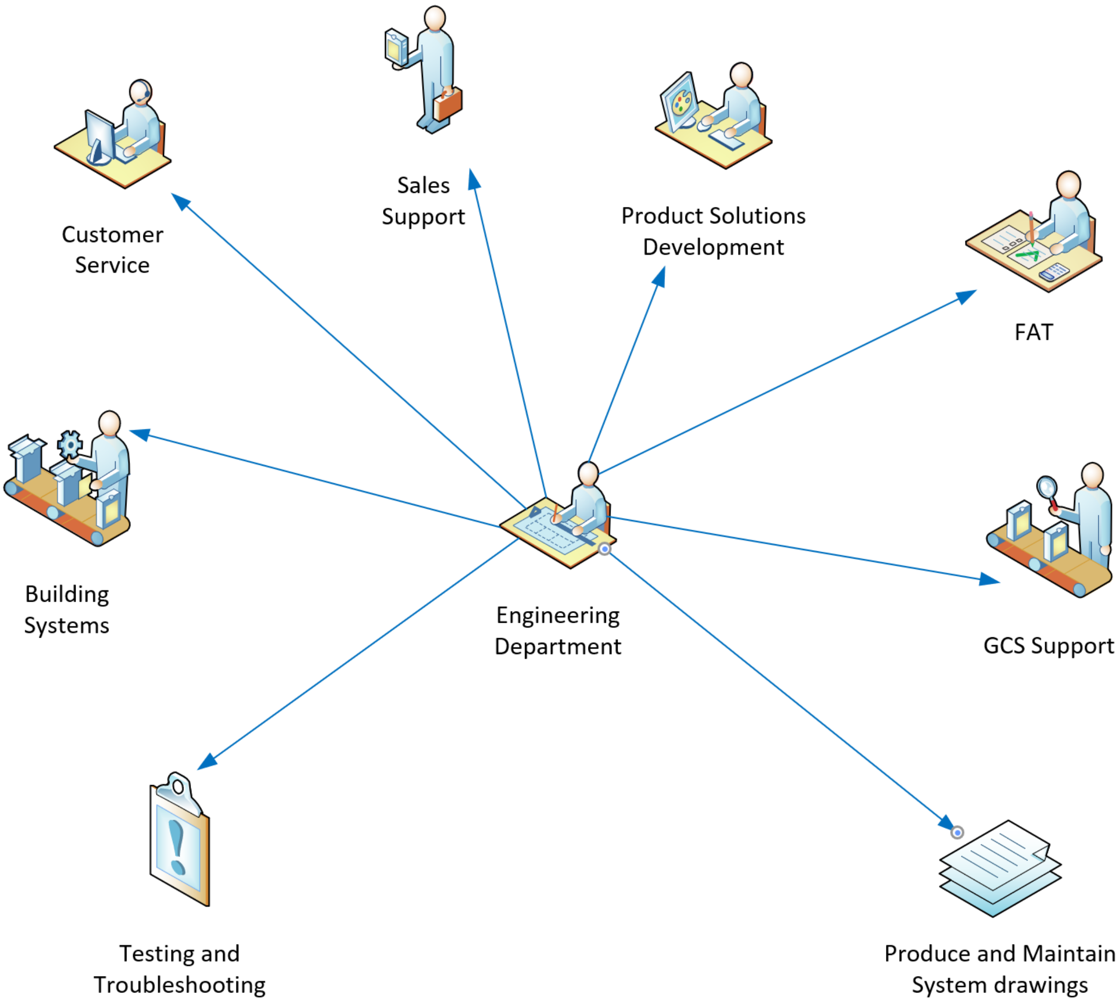

Figure 23, Engineering Department Role

4.7.1 Customer Support

The Engineering department is organized under the Customer Support department. Most of the employees hired in the Engineering department are formerly GCS personnel, with long experience from travelling worldwide installing and supporting customers products and system installations. That is why some of the Engineering department's tasks, especially regarding customer service and testing are being handled by GCS personnel.

4.8 Communication Between Departments

Interviews conducted with the Production-, Engineering-, and Development department reveal that there are some communication issues. Some of these problems are rooted in misunderstandings, while others revolve around oversights. Several interviews have been conducted with the Engineering and Development departments. Conflicting answers have been given to specific questions about tasks on collaboration between the two departments. While Project Managers from the Development department mean that the Engineering department has been informed and included through the course of development, Engineering believes the opposite.

4.9 Data Storage

It has been necessary to work out where supporting documents, drawings and development reports are being stored. This has a direct impact on how to structure Teamcenter PLM in the best way for the enterprise. And, for determining whether all documentation should be stored in Teamcenter PLM or if the documentation should be separated in other storing locations.

4.9.1 Documentation Flow at the Enterprise

As mentioned in section 4.4, the Product Managers are responsible for the entire lifecycle of a product. This means that all product documentation is sent from the Development department to other departments when needed. As shown in Figure 24, most documents and requests are one-way, e.g., from Development department to Production department or from Development department to Sales department. According to the figure, the only two-way communication is between Development- and Production department when there is a change request answer.

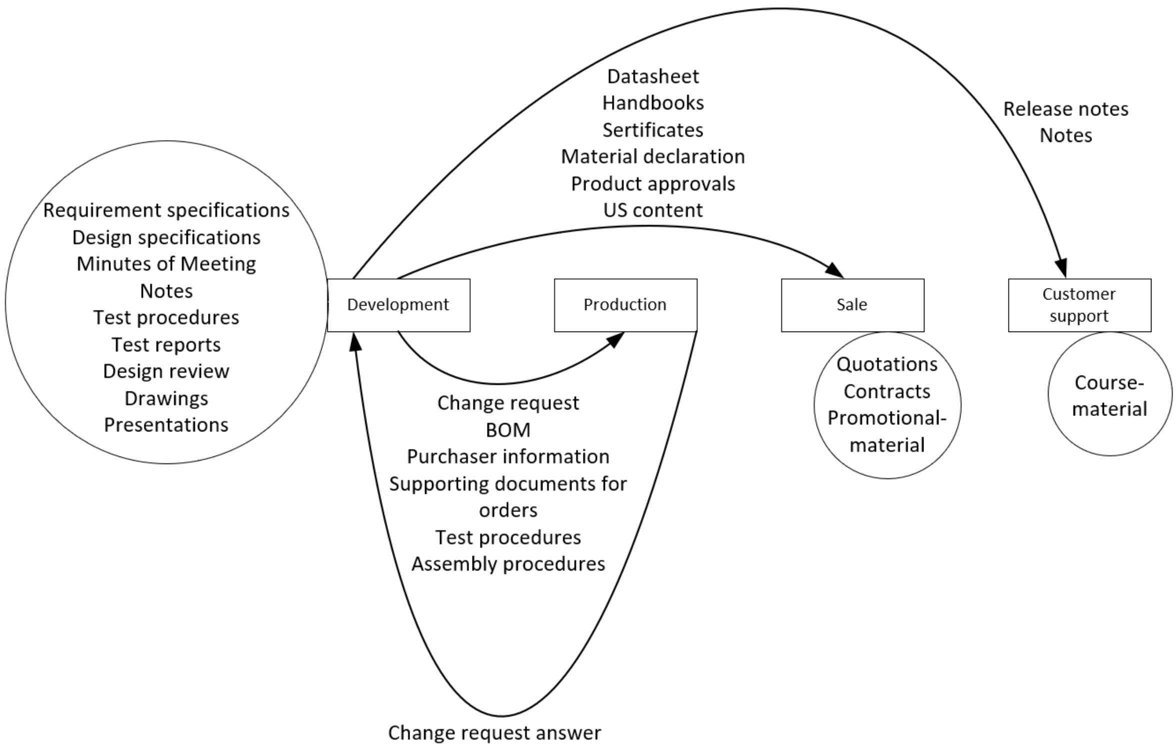

Figure 24, Documentation flow in the Enterprise

4.10 Product Development Project at the Enterprise

Based on the interviews conducted with each department at the Enterprise and how involved they are describing themselves in the development of a new product, a model has been made based on their answers. The model in Figure 25 explains how a typical development process is conducted from an idea to a product ready to be produced today.

The Sales department is usually the one presenting an idea, based on a need from a customer. The Development department is in this model divided into mechanics, electronics, and software. Development department is responsible for core technology. The Engineering department is responsible for the cables and boxology around the product, making it into a functional product. Documentation in this context is writing installation and operator manuals, data sheets, material declarations, and other mandatory documents necessary for releasing a product. Testing in this context is a collective term for product certification, necessary to operate the product in special environments. The Production department is responsible for building 0 -series and the finished product. Customer support often install the product and incorporates it into an existing system. This includes solving any unforeseen problems with the new product.

The model shows that there is a misalignment in resource allocation. While the Development department is involved throughout the whole development process, the Engineering department gets involved late in the process. The same applies to the documentation process and Customer Support. It is unfortunate for the overall perspective of the Product development not to involve all stakeholders early in the process. As a result, an unfinished product could be released into the market.

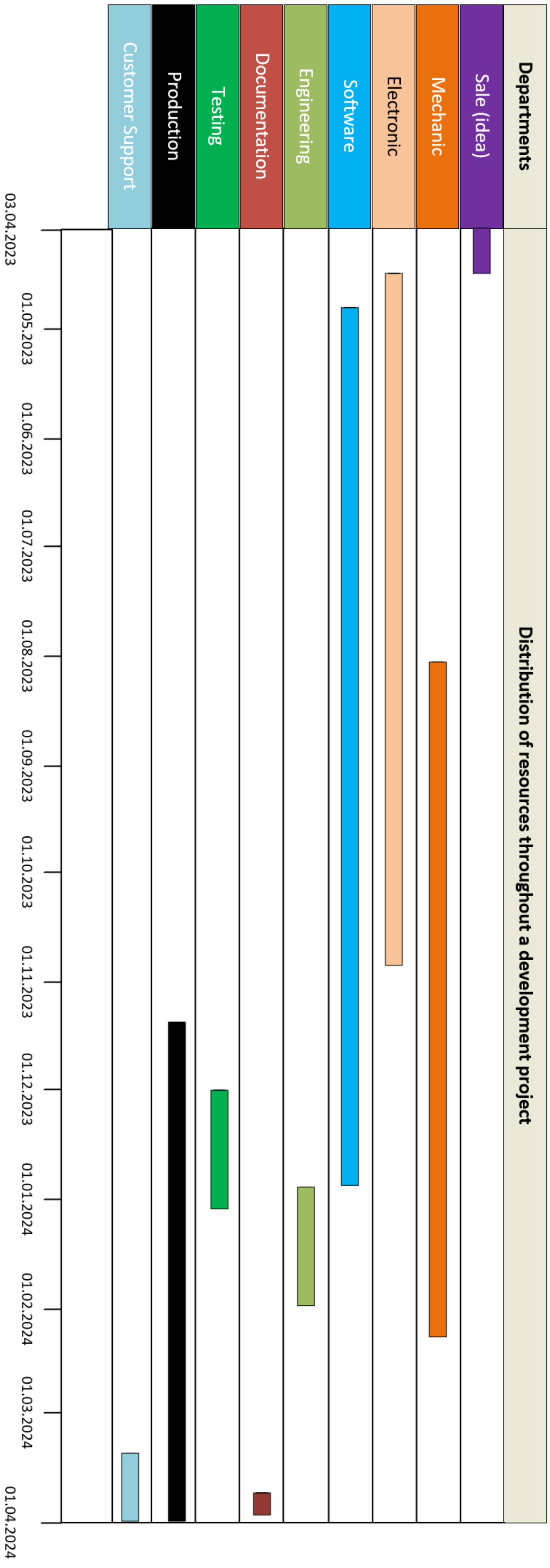

Figure 25, Distribution of resources throughout a development project

4.11 Industrialization of the Product Development Process

As a result of the interviews with the Enterprise’s stakeholders and modeling resources throughout the development of a product, the need for a better link between the Development department and other departments in the Enterprise is seen to be necessary. To involve all stakeholders earlier in the process will help to get a better flow throughout the development process and there will be less chance of missing out on necessary documentation and greater chance of finishing on time.

There has been raised questions about if the Product Manager has too many responsibilities. Is the Product Manager the most competent person to write the operation and installation manuals? Or should this be written by e.g., Customer Support or Engineering, who have hands-on experience with installations. Product Managers are also responsible that BOMs, documentation and test jigs necessary to produce the finishing product are in place before releasing the product. It will be more appropriate to delegate some of these tasks into other departments.

The link between the Development department and other departments is missing, causing development projects to exceed the time limits. The recommendation is therefore to implement an industrialization group which will ensure that developed products are designed in such a way that it is possible to produce in a cost-effective way, and within the time limits. An industrialization group should also make sure that necessary documentation, testing and tools for production is up to date and ready when the product is ready for release. Figure 26 explains which tasks the industrialization group should have when developing a product. It is also recommended to decrease the number of data storage places to two. Microsoft SharePoint for storing project related data, e.g., MoM, requirement specifications, test documents. Teamcenter PLM for product related data e.g., drawings, datasheets, revisions.

The need for a re-organization in the Enterprise is necessary to make the development processes being more efficient.

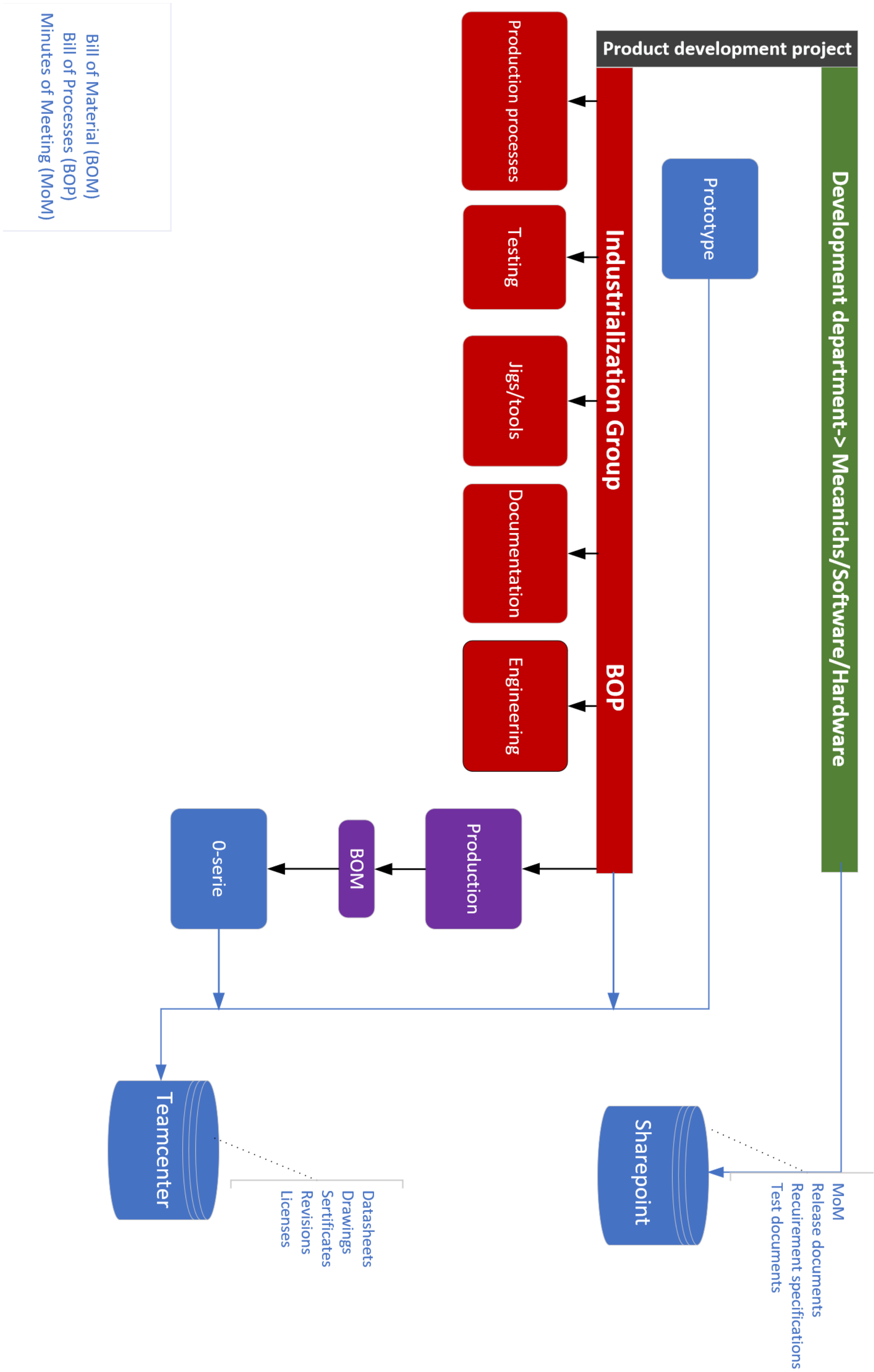

Figure 26, Creating an Industrialization Group at the Enterprise

5 Discussion

In the introduction, two research questions were presented. The first question if there was a need to take any considerations to avoid the Teamcenter PLM stakeholders doing workarounds after the implementation. The second question was to inquire if there any changes needed to be made to improve the workflow before the implementation of Teamcenter PLM.

The need to know how the Enterprise operates daily will be important before implementing a new system, such as Teamcenter PLM. Implementing new systems which affects a large part of the organization, will also affect how people work, and the need for them to change the way they work. To conduct a thorough pre-investigation before implementing the new system can help to adapt the final system integration. Being aware that there may be different working cultures from one department to another in the same enterprise is important to have in mind. As mentioned by Paul R. Carlile [22], syntactic, semantic, and pragmatic approach is a way to categorize how employees work across functional boundaries.

Interviews conducted with the Enterprise's stakeholders have revealed that communication across functional boundaries has not worked as desired. It seems that there are some departments which are better communicating across boundaries than others. Therefore, it could be assumed that there are different functional boundaries within the same Enterprise. Meaning that there are several working cultures within the Enterprise. However, Kyriakidis [9] claims that *"human performance emerges due to the interaction with the person and the immediate environment"*. This explains that to just categorize an enterprise into functional boundaries is imprecise. Each department is to be seen as an individual process or a culture within the Enterprise.

To answer the first question, it is important to have in mind that each department has different working cultures, and that the working environment has influence on the human performance. It will be important to be aware of the culture differences when Teamcenter PLM procedures and working descriptions are adapted to each department within the Enterprise.

The second research question inquired if changes needed to be implemented to improve the organizational workflow due to the implementation of Teamcenter PLM. Based on information gathered from stakeholder interviews, it can be stated that an industrialization group which links the Production, Engineering and Development department should be established. An industrialization group should ensure that all documents were in place and that testing were carried out during the development process, before the product is ready for release.

Interviews conducted with the Production department have shown that the department is vulnerable if someone gets ill or resign. Some of these issues could have been solved by more of the technicians learning other product areas. The investigation has also shown that the responsible persons at the departments interviewed in this study have many roles. There has been asked if the Product Managers have too much responsibility, as they make decisions through the whole life cycle of a product. However, no conclusion has been made on how the Enterprise should be better organized. Product and project documentation have different locations, which leads to uncertainty of where to store documents. It has been recommended to narrow down these locations into two locations. Product documentation should be stored in Teamcenter PLM, and project documentation in Microsoft SharePoint or similar server solution.

The TOGAF ADM architecture model and the preface phase have been used as a basis to map the Enterprise's organization. A decision whether to continue working with these architecture models need to be taken before moving to the next phase. It is still possible to change the architecture method, but it is important that the chosen method is the one to be followed through when moving towards phase A. This decision must be made with the enterprise architects who will continue to work with the next phases.

6 Conclusion

A theoretical review of which considerations need to be taken to avoid that Teamcenter PLM stakeholders do workarounds, has shown that there are work culture differences at the Enterprise's departments. The theory indicates that the working environment influences the human performance. Procedures and job instructions should therefore be created based on each department's needs.

This work has been to map the Enterprise's organizational structure to investigate if it is necessary to improve the workflow before implementing Teamcenter PLM. Interviews with the Enterprise's stakeholders have shown that there are communication issues between the Development, Engineering, and Production department which leads to delays when developing new products. An industrialization group which shall take care of documentation, testing and production processes in parallel with the development has been suggested as a solution to these problems.

6.1 Future Work

From the findings in this thesis, further investigation into the Enterprise's organization is recommended. It should be decided who should be included in an industrialization group, and what authority they should be given. Further investigation should be reviewed to qualify Kaizen or lean management as methods for making work procedures when implementing Teamcenter PLM. This study can act as a basis for further studies on how to implement new information technologies into an enterprise. It is recommended to see if more employees are needed in the Production department, to be less vulnerable to unexpected events.

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Appendix A: **Industrialization development process**

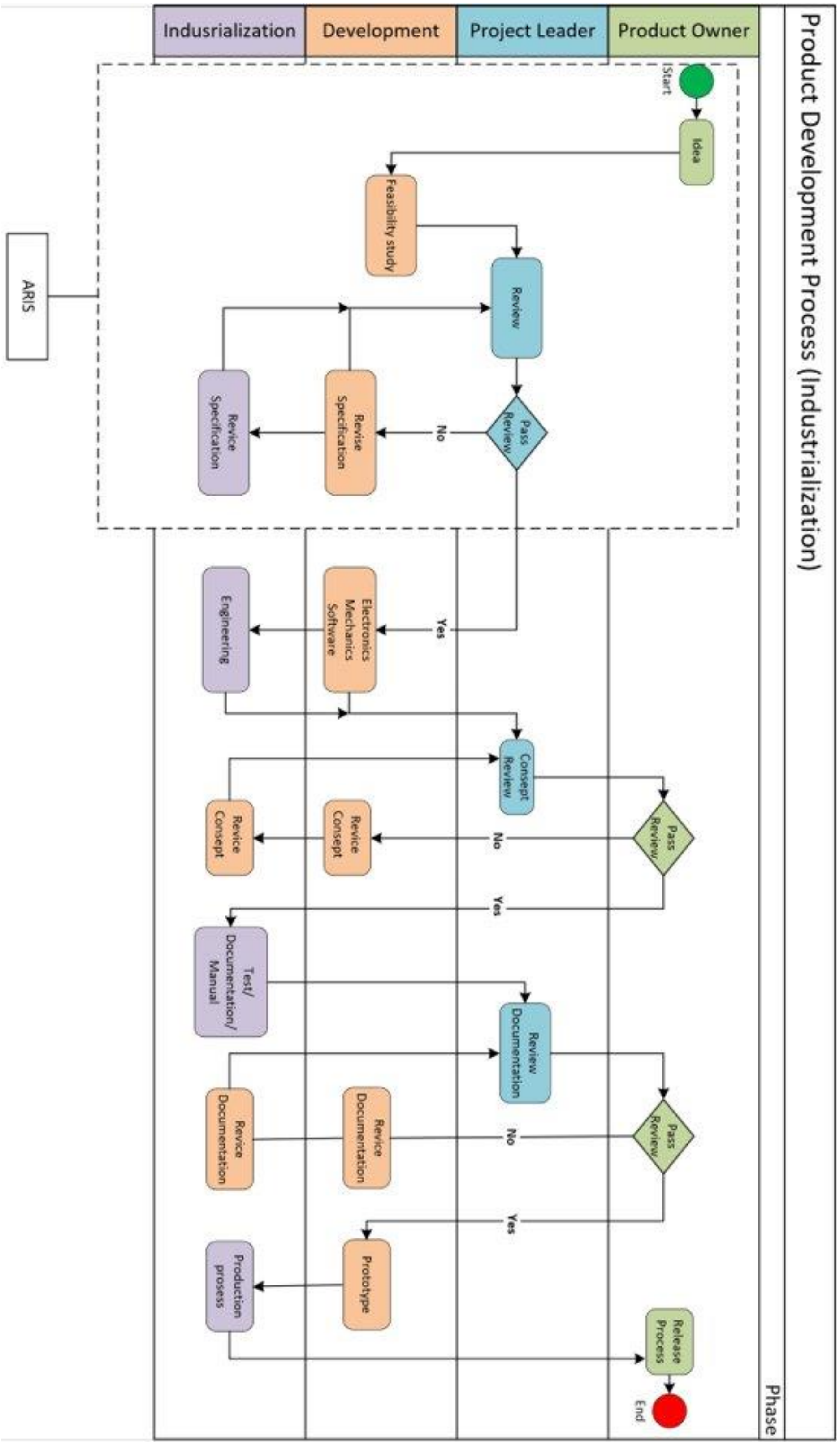

Figure 27, Example of an industrialization process, where ARIS is the Enterprise's business management system

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