Tampere University

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BENEFITS OF STANDARD LIBRARIES IN PRODUCT DESIGN AND PROCESS

Applied to the automotive industry

Master's Thesis
Faculty of Engineering and Natural Sciences
Examiner: Mikko Vanhatalo
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ABSTRACT

Joona Koski: Benefits of standard libraries in product design and process
Master's Thesis
Tampere University
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This master's thesis focuses on examining the utilization of the Teamcenter Classification library in an automotive industry company. The library aims to facilitate the reuse of parts and standardize the use of components in the design and product development processes. The objective of the thesis is not only to create the library but also to establish operational models for using the library and managing it.

The work addresses how standard and general components should be utilized and classified, as well as how general components are utilized in the industry. Regarding classification, the creation of a suitable library hierarchy and setting parameters for components to be classified are discussed. The thesis explores the challenges related to the use and construction of the Classification library, especially in the context of the target company.

As a result of the thesis, a library is created for the use of the company's tool design department, along with guidelines for using the library. The thesis also proposes a process for managing classification in the future.

Key words: Standard library, standard component, standard part, general component, general part, reuse

TIIVISTELMÄ

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Tämä diplomityö keskittyy tarkastelemaan Teamcenter Classification kirjaston hyödyntämistä autoteollisuuden yrityksessä. Kirjaston avulla pyritään helpottamaan osien uudelleenkäyttöä sekä yhtenäistämään komponenttien käyttöä suunnittelu- ja tuotekehitysprosesseissa. Työn tavoitteena on kirjaston luomisen lisäksi rakentaa toimintamallit kirjaston käyttöön sekä kirjaston hallinnointiin.

Työssä käsitellään se, miten standardi- ja yleiskomponentteja kannattaa hyödyntää sekä kirjastoida sekä se, miten yleiskomponentteja hyödynnetään teollisuudessa. Kirjastointiin liittyen käsitellään sopivan kirjastohierarkian luominen sekä parametrien asettaminen kirjastoitaville komponenteille. Työssä tarkastellaan Classification kirjaston käyttöön ja rakentamiseen liittyviä haasteita erityisesti kohdeyrityksen osalta.

Työn tuloksena luodaan kirjasto yrityksen työkalusuunnitteluosaston käyttöön sekä ohjeet kirjaston käyttämiseen. Työssä luodaan myös ehdotus prosessista kirjastoinnin hallintaan tulevaisuudessa.

Avainsanat: Standardikirjasto, standardikomponentti, standardiosa, yleiskomponentti, yleisosa, uudelleenkäyttö

PREFACE

This project has been highly interesting, and I have received valuable insights and perspectives. Thank you to everyone involved in the project and thanks also to those outside the project who helped me. Special thanks to the Valmet Automotive's employees Jani Mäkäläinen, Mariia Matyrko, Narendran Narasimhan, Sahil Shah and Tommi Tuominen. Big thanks also to Mikko Vanhatalo the director of that thesis for supporting.

Turku, 11th February 2024

Joona Koski

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LIST OF SYMBOLS AND ABBREVIATIONS

CSM	Component Supplier Management
ERP	Enterprise Resource Planning
EVS	Valmet Automotive business unit (Electric Vehicle Systems)
ICO	Classification object
ICT	Information and communication technology
ISO	International Organization for Standardization
KBE	Knowledge integration to design process (Knowledge Based Engineering)
KeyLOV	List of defined attributes in Teamcenter Classification library (Key List Of Values)
PDM	Product Data Management
PLM	Product Lifecycle Management
RKS	Valmet Automotive business unit (Roof & Kinematics Systems)
SFS	Finnish Standards Association, SFS Ry
VA	Valmet Automotive Oyj
VCM	Valmet Automotive business unit (Vehicle Contract Manufacturing)

1. INTRODUCTION

With the automotive industry's intense competition, it is important to continuously improve product development and design processes. Companies must consistently enhance design efficiency, reduce repetitive work, and improve product quality. This master's thesis deals with the design and product management of an automotive industry company, focusing on the use of Teamcenter's Classification library for the classification of standard and general components and the construction of the library.

Various systems facilitate engineers daily work, providing efficiency and reducing the possibility of errors. However, besides implementing these systems, it is essential to use them correctly in each company and identify which systems are suitable for each purpose. The adoption of systems requires the creation and implementation of new processes.

Standard libraries are an efficient way to utilize commonly used parts in design. The Teamcenter Classification library offers an effective tool for library construction and management. The efficiency of library usage depends significantly on how the library hierarchy is structured and how component parameters are defined. According to Sivaloganathan and Shahin (1999), the system should support the reuse of components, and, for example, in the case of standard components, it is essential to emphasize how a suitable component is identified and selected.

The thesis examines the utilization of Teamcenter's Classification library in a manufacturing automotive industry company. The goal is to construct a standard library that effectively serves designers, along with providing guidelines for library usage. The work's scope is restricted to the tool design division of the organization, considering designers technical requirements for the library and the library's capabilities to meet these demands.

The thesis not only provides practical guidelines for building an effective library but also explores the utilization of the Teamcenter Classification library in various other areas. The resulting library enables designers to reuse components and standardize their usage more efficiently. The library facilitates easy management of components that designers are primarily encouraged to use.

2. DESCRIPTION OF THE WORK

The planning of the topic of the work started from the customer's need to develop the use of their PDM system. The customer had a few perspectives on the subject from which we chose in collaboration the specific perspective that was related to building the tooling library. The work was carried out in close cooperation with experts from different fields of the client.

2.1 Presentation of the target company

Valmet Automotive Oyj is a publicly traded company founded in 1968, with its headquarters located in Uusikaupunki. Valmet Automotive is an automotive contract manufacturer, meaning they do not have their own brand of vehicles in production; instead, they manufacture cars on demand for various automakers. The company has produced over 1.8 million cars at the Uusikaupunki car factory. Valmet Automotive is one of the world's largest automotive contract manufacturers and a leading supplier in Europe of electric vehicle battery systems and kinematic solutions, such as electric charging ports and active air deflectors.

Currently, the Uusikaupunki factory manufactures Mercedes-Benz A-Class cars, and the production of the new Mercedes-Benz AMG GT Coupe has begun in late 2023. The Uusikaupunki factory also produces batteries for electric vehicles used in cars and machinery. In addition to Mercedes-Benz, Valmet Automotive has manufactured cars for companies such as Saab and Porsche.

Valmet Automotive is divided into three business units: RKS (Roof & Kinematics Systems), EVS (Electric Vehicle Systems), and VCM (Vehicle Contract Manufacturing). RKS develops and manufactures convertible roof and kinematics systems. EVS produces batteries for electric vehicles. VCM is specialized in automotive contract manufacturing, and it is the largest business unit.

2.2 Backgrounds for doing the work

The target company's business (VCM) is highly cyclical because of contract manufacturing, so it is important to respond quickly to market offers. Therefore efficient, and flexible design of new manufacturing lines is essential. By identifying and solving design-related challenges, the time and costs associated with design can be reduced.

The target company extensively uses external suppliers, such as line builders and designers. Managing subcontractors in projects involves a lot of management, which can be challenging. Hence, having an easily manageable component library, which external actors can also utilize but is easily manageable from the perspective of the target company, is important.

Currently, the target company is in a transition phase with its PDM system, where many aspects of information management are being developed. Transitioning to a new PDM system brings changes to the design process and requires much new development and learning. This work examines the transition phase from one perspective.

The implementation of the Classification Library aims to streamline the work of designers and reduce the costs associated with design. Teamcenter must be operational, and the necessary information must be available before its full implementation. The Classification Library is one of the features of Teamcenter whose building is promoted in this master's thesis.

The target company already has pre-built catalogs for specific components, which are initially intended for use, for example, with sensors and clamps. These catalogs are often in PDF format and are not systematically available in any information system. This makes it challenging to find and reuse the right components. In such a system, the necessary 3D models are also not readily available, so the models are either obtained from the supplier's website or copied from a project folder where another user has uploaded a model. In this work, the library to be built for Tooling Design is particularly needed for systematic information handling. The library makes it significantly easier to find and use components.

2.3 Structure and objectives of the Master’s thesis

The work consists of a theoretical part that covers the use of standard components and literature related to the construction of standard libraries. In the practical part, a new section for components used in car manufacturing jigs is built into the target company's PDM system. The goal of the thesis is to construct an efficiently functioning library for standard and general components in the target company's system. In addition to building the library, the project includes creating instructions for library usage and management. The thesis describes how the standard library is constructed in the target company's system.

Background research has been conducted on the use of standard and general components, the construction of reuse libraries, PDM, and PLM systems. In the practical part,

a Classification library for components used in the design of jigs is built into the target company's PDM system. At the end of the thesis, the benefits that the library brings to the design process are discussed.

The aim of the work is to identify the components to be cataloged, construct a standard library that serves the design process, and create guidelines for using the library so that its development can be easily continued. The second main objective of the work is to analyze the target company's design process and identify the benefits of the use of the library. The workflow of this thesis has been described in *figure 1*.

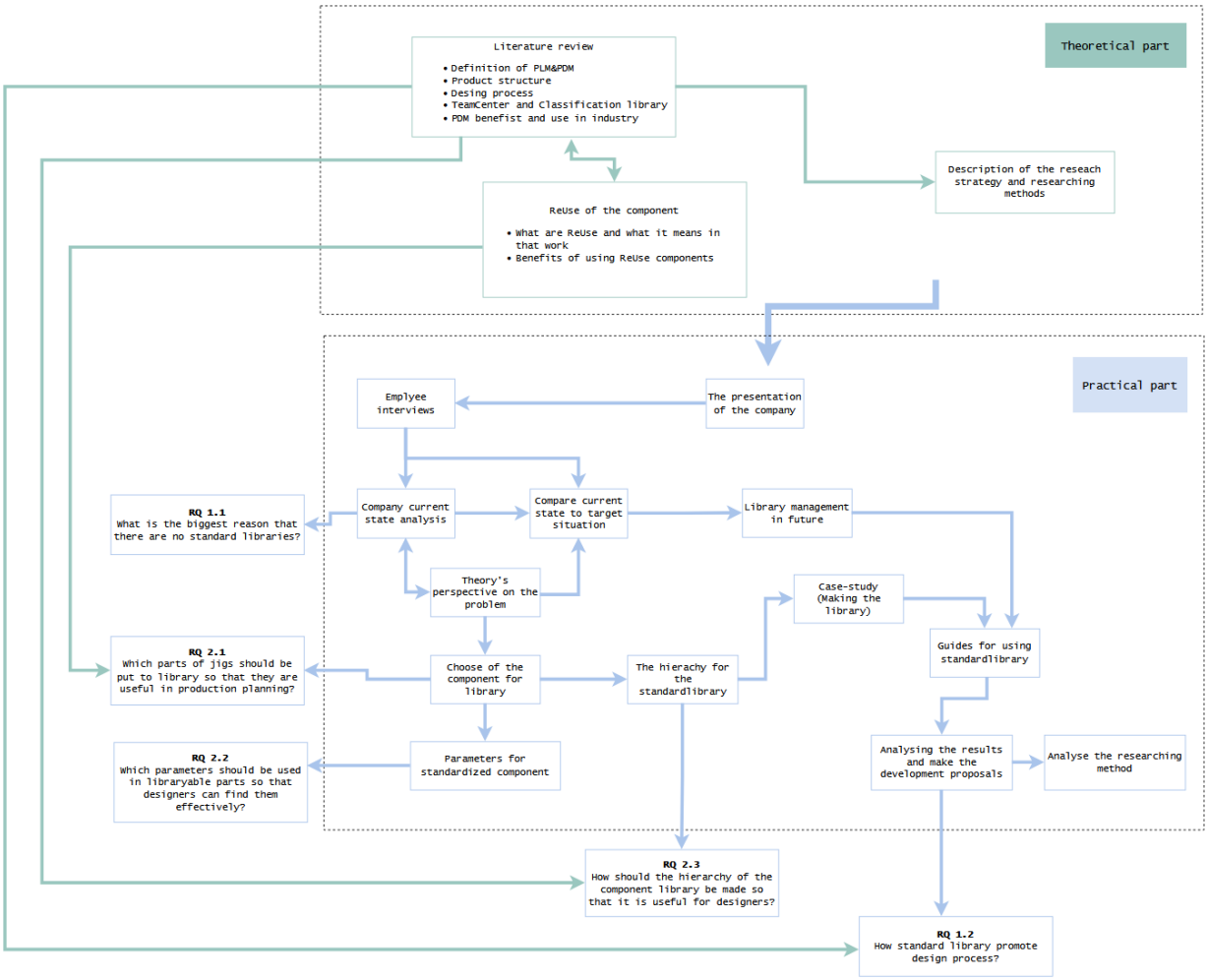


Figure 1. Description of the thesis workflow

The goal of the work is to build a functional library for the Tooling Design area and provide instructions for using the library so that it can be utilized as efficiently as possible. The following research questions are also intended to be addressed by this work:

1.1. What is the biggest reason that there are no standard libraries?

1.2 How standard library promote design process?

2.1 Which parts of the Jigs should be put to library so that they are useful in production design?

2.2 Which parameter should be used libraryable parts so that designer can find them effectively?

2.3 How should the hierarchy of the component library be made so that it is useful for designers?

The purpose of the study questions is to examine the target company's existing classification situation, the benefits of the library in the design process, and how the library should be constructed regarding parameters, hierarchy, and the components to be classified. The thesis also shows the technical aspects of how the library is built within the Teamcenter Classification environment.

2.4 Subject limitation

The topic is narrowed down to the Body-in-White area in the target company's VCM business unit. "Body-in-White" is a term used in the automotive industry, referring to the stage where the car body is welded together but has not yet gone to the painting. The scope of the work is limited to the components of jigs designed in the Body-in-White department and their cataloging. In this context, a "jig" refers to a tool used to position car parts geometrically correctly before welding. Jigs are instrumental in welding various parts of the car together. The design of jigs mainly occurs in the Body-in-White department, and the library to be built in this work will primarily serve their needs. The design of jigs is referred to as the Tooling Design department, which is part of the Body-in-White area.

3. RESEARCH STRATEGY AND RESEARCH METHOD USED

This research is divided into two sections: the theoretical and practical parts. In the theoretical section, a literature review goes through existing knowledge on the topic, and the information gathered from the literature review is applied to the practical part. In the practical section, a functional outcome is developed based on the acquired information. This study employs action research as the research method and is primarily qualitative in nature.

Qualitative research aims to investigate phenomena and their impact on human behavior. Qualitative research is not as predetermined as quantitative research, so it improves the depth of research. However, comparing information can be more challenging if data collection methods are not standardized. Qualitative and quantitative research each have their strengths and weaknesses and are not mutually exclusive. In the same study, both qualitative and quantitative data can be collected. In qualitative research, information is primarily collected through three methods: in-depth and open interviews, observation of activities, and written documents. Interviews provide information about people's thoughts, opinions, and behavior patterns. Through observation, the actions of individuals can be examined more closely, providing more detailed information about human behavior. Different types of documents may contain information that is different from interviews and observations, and it may be more precisely defined. Qualitative research data is mostly collected in the field and involves significant human interaction. (Patton 2002)

3.1 Research frameworks

The theoretical framework refers to the perspective from which research data is interpreted. The same observations can be interpreted from many different viewpoints, and thus, very different results can be obtained. (Alasuutari 1999) In this study, the framework is about understanding the benefits that designers get from component cataloging and how cataloging contributes to the design process. The framework confines the research specifically in a way that is useful for designers. The work also addresses classifying and standardization more broadly, but all aspects are based on the goal of creating an efficiently functioning library specifically for designer’s usage.

3.2 Action research

One often-cited research technique is action research and it is particularly suitable for examining technology from a human perspective (Baskerville & Wood-Harper 2000). Action research combines practice and theory, providing a means to obtain valuable research results (Keel 2001, cited in Baskerville and Wood-Harper, 2000).

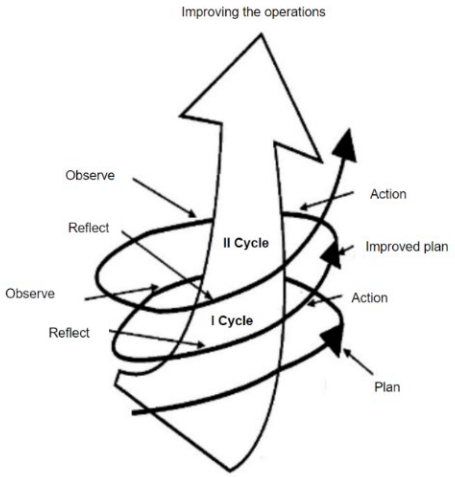


Figure 2. Action research spiral (Adapted from Heikkinen 2001, cited in the source Heikkinen et al. 2007)

A spiral-shaped process is how action research is frequently characterized *(see figure 2.),* aiming to improve performance and outcomes in following cycles. According to Susman & Evered (1978), action research can be divided into five phases of action:

1. Making diagnoses
2. Action planning
3. Action taking
4. Evaluating
5. Specifying learning

The problem must be defined in the first stage, and it is crucial at this stage to identify the issue related to the research topic. The initial phase includes a current-state analysis to precisely define the problem. The analysis of the situation utilizes the expertise of the target organization, and the researcher also incorporates research knowledge in defining

the problem. These pieces of information contribute to forming a comprehensive understanding of the problem to be addressed (Tiainen et al., 2015). According to Susman and Evered (1978), problem definition entails discovering and identifying problems along with their underlying causes. At this stage, the researcher and the target organization collaboratively establish a working hypothesis, which will be utilized in later phases of the cycle.

In the second phase of the cycle, the action plan is designed to address how the previously defined problem will be solved. The action plan often consists of several small developmental steps, and at this point, the decision is made regarding the initial developmental step to be taken. Scientific literature is used as a guide in planning these actions (Tiainen et al., 2015). According to Susman and Evered (1978), determining the steps to take get to the intended improved condition is part of the planning phase of the cycle.

In the third phase of the cycle, the planned actions are implemented. This is often made out in collaboration with experts within the organization and external specialists (Tiainen et al., 2015). According to Susman and Evered (1978), the implementation phase involves carrying out the actions as planned.

In the fourth phase of the cycle, there is evaluation. Evaluation involves defining evaluation criteria and self-assessment. It is common for evaluation criteria to be established when planning the actions in the research. When planning activities, it is beneficial to know how results will be evaluated and based on what criteria, to determine whether the desired results have been achieved (Tiainen et al., 2015). According to Susman and Evered (1978), the evaluation phase assesses the quality and efficiency of the work and various evaluation methods can be utilized.

The last phase is the identification of learning. In this phase, the organization has transitioned into a state after the implemented cycles. It also describes the type of new information the research has brought to the scientific discourse. At this stage, researchers have the opportunity to test scientific knowledge in practical situations and discover new problem areas, concepts, and models from a scientific perspective (Tiainen et al., 2015). According to Susman and Evered (1978), in the specifying learning phase, one examines what has been learned during the cycle. The relationship between scientific and practical components should be considered in the learning process.

3.3 Research methods and implementation of work

The target company originally had some idea of the problem for which they needed solutions. The company had noted difficulties with the use and categorization of standard components during the design phase. The specific research problem was defined collaboratively with the target company, the university, and the researcher. From several different options, a more precisely defined research problem was compiled. The research decided to investigate the cataloging of standard parts and the benefits it brings to designers.

The research employed literature review, interviews, and modeling as research methods. The literature review aimed to identify the benefits that cataloging brings in various situations and which kind of components are useful to put to library. The interview research has mapped the situation of the target company and looked for solutions to the problem areas of the library. Interviews also gathered information about the operating models of other companies related to cataloging. Modeling refers to the construction of the library and testing it with users.

The constructive research method could also be applicable to this work, as it aims to create practical solutions based on theoretical frameworks from the literature. According to Pasian (2015), the goal of constructive research is to provide solutions to practical challenges, which could involve processes, practices, or tools, while also generating scientifically relevant knowledge. Constructive research can also be considered a part of the practical aspect of action research. One difference between constructive research and action research is that in action research, collaboration with professionals working around the researched issue is essential, whereas in constructive research, it is not required as intensively.

Action research has been chosen, for example, because in this project, close collaboration was established with various professionals, and the iterative nature of action research was well-suited to this project. At the beginning of the project, it was not entirely clear what the desired outcome of the project would be, so it was known that there will be new perspectives and challenges.

3.4 Literature search and review

The work utilized a systematic literature review for information searching. A systematic literature review is a widely used approach for obtaining information. It enables the identification of relevant and crucial aspects from a large amount of data. Through a systematic literature review, the goal is to uncover all the most pertinent studies within a defined

and limited scope. Its systematic method also makes the research more traceable and reproducible. (Petticrew and Roberts 2008, pp. 2-30)

As a result of the literature review, the aim was to gain perspectives on various phases of the practical part of the work. The literature review did not seek to find a specific, precisely defined solution but rather alternative approaches to problem definition. The literature review aimed to identify effective ways to construct a component library and cases where libraries have been applied in practice. The literature review aims to answer research questions 2.1, 2.2 and 2.3 (see *figure 1*.) not completely, but so that together with literature and practical materials can form an answer to these questions.

Systematic literature review	
Used databases	Andor, Google Scholar, Scopus, Tampere University library
Key words used	"Product data management", "Product lifecycle management", "Classifying", "Standard component/part", "Standard components library", "Reuse components library", "Components reuse", "Components standardization", "Benefits of components standardization", "Component library", "Standard library" "Part library", "ISO-13584", Standard components use", "Reuse components use"

Figure 3. Used databases and keywords in literature review.

In the previous picture (*figure 3*.) has been shown used databases and keywords. In *figure 4*., the main headings of the literature review have been illustrated, serving as a guide for searching the necessary information. A component library is a comprehensive entity covering multiple subject areas, so the literature review aimed to gather perspectives on these five subject areas (*figure 4*.).

In all five topic areas, efforts have been made to find potential papers. In the end, a total of 12 main works were selected for use and their selection criteria are summarized in the accompanying table (*figure 5*). The selection criteria have considered how well the source handles matters related to a particular topic, the year of publication, whether the source is peer-reviewed and the point of view from which the source deals with each topic*. Figure 5.* shows the main articles, which have been run into categories according to the groups in the *figure 4*.

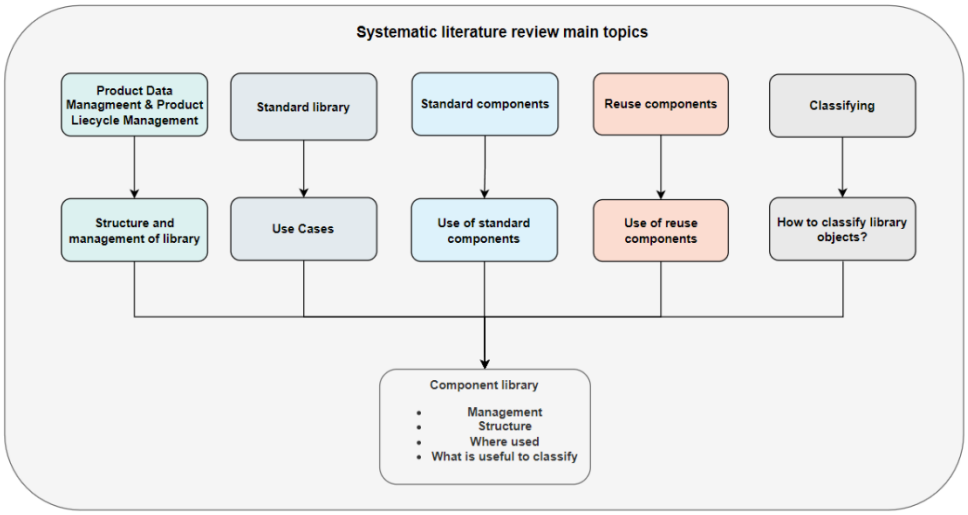


Figure 4. Main topics of the literature review

Source	Writers & year	Selection criteria
Product lifecycle management	Saaksvuori & Immonen 2008	PDM&PLM basic work to determine the uses of the systems.
Tuotekonfigurointi ja tuotetiedon hallinta	Martio 2015	The basic work of product information management, which provides good basic information for the management of items and utilization of systems in industry for example.
Dealing with Standard Components for Knowledge Intensive CAD	Culley & Theobald 1996	Design of assembly using different sub-assemblies and what kind of sub-assemblies the assembly can be divided into.
Parts Management Method for Weapon System Parts Standardization	Jung & Shim 2021	The study described the standardization of parts in a specific application, as well as the application of methods in practice. Processes related to standardization were also considered here.
Feature-Based Parametric Design of a Gating System for a Die-Casting Die	Wu and Fuh 2002	Case A: Parametric CAD model storage to library. Determination of the parameters of the model to be stored to library.
Research of 3D general parts library based on Knowledge Template	Wei et al. 2010	Case B: In this case study, a sub-library was built for the configurable parts. Knowledge Based Engineering (KBE) utilization in CAD component library.
Automation of Mold Designs with the Reuse of Standard Parts	Hak-Soo et al. 2011	Case C: Storage of standard parts in the library and the method to reuse them in efficient way.
A Guiding Design System for Pressure Vessels Based on 3D CAD	Zhang 2016	Case D: Utilization of standard parts to support design. Building a library to make reuse more efficient.
Computer-aided checking fixture design system for automobile parts	Jiang 2012	Case E: Building and utilization of sub-library in automotive jig assembly. Making design process more automated.
An analysis of design reuse benefits	Duffy & Ferns 1998	Definition, meaning and benefits of re-use of design.
Classification Approaches for Standard Parts to Aid Design Re-use	Culley 1999	Utilization of standard components in the design process and classification of components. The paper also examines the reuse of design.
Classification of Classifications: Species of Library Classifications. Cataloging & classification quarterly	Krishnamurthy et al. 2023	A basic work for classifying different objects. Different classification theories and possibilities.

Figure 5. Main references and search criteria in this study divided in five categories.

4. MOTIVATE OF THE RESEARCH

In project work, companies often must outsource the design, effectively preventing efficient organizational learning and utilization between consecutive projects. It is challenging to manage a situation where the throughput volume (e.g., projects) increases in project-based business. If issues related to project complexity, engineering skill iteration, and personal and organizational learning are not considered, the number of projects is directly proportional to the workload of the project-based company (Pulkkinen 2007). The business of the target company is also highly cyclical, and the workload depends significantly on the number of orders.

The entire design process may become a bottleneck in product delivery efforts in manufacturing companies. Using overtime for employees, hiring new workers, or negotiating longer delivery times are not permanent solutions to this problem. A better alternative is the systematic reuse of design. (Pulkkinen 2007)

Most product costs are incurred during the early phases of the product lifecycle, specifically during the design and conception phases. The opportunity to influence the amount of costs decreases significantly after the conceptual design phase. From *figure 6.*, it can be seen that the majority of costs associated with the product are incurred during the conceptualization and design phases. Therefore, it is important to manage costs from the beginning of the conceptualization phase. The impact on product costs is greatest during the conceptual phase.

Expenses associated with system delivery are incurred early in the project, during design and conception (Jung & Shim 2021). From *figure 7.*, it can be seen that about 70% of the costs for a specific system are committed during the conceptual phase, and after the design phase, approximately 80% of the costs are committed. The costs are mainly realized during the production and support phases, making it significantly more challenging to influence costs than in earlier stages.

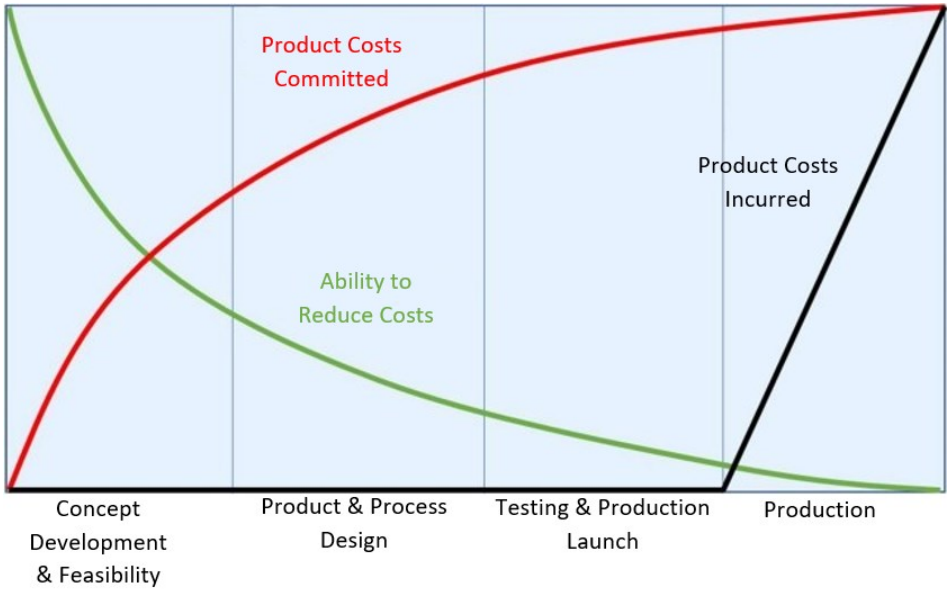


Figure 6. The cost of the product during the manufacturing life cycle (NPD Solutions, 2019)

It is essential to strive for reducing costs committed to the project during the planning phase, where significant savings can be achieved. Costs committed during the design and conceptual phases can be influenced in various ways, such as standardizing the use of components.

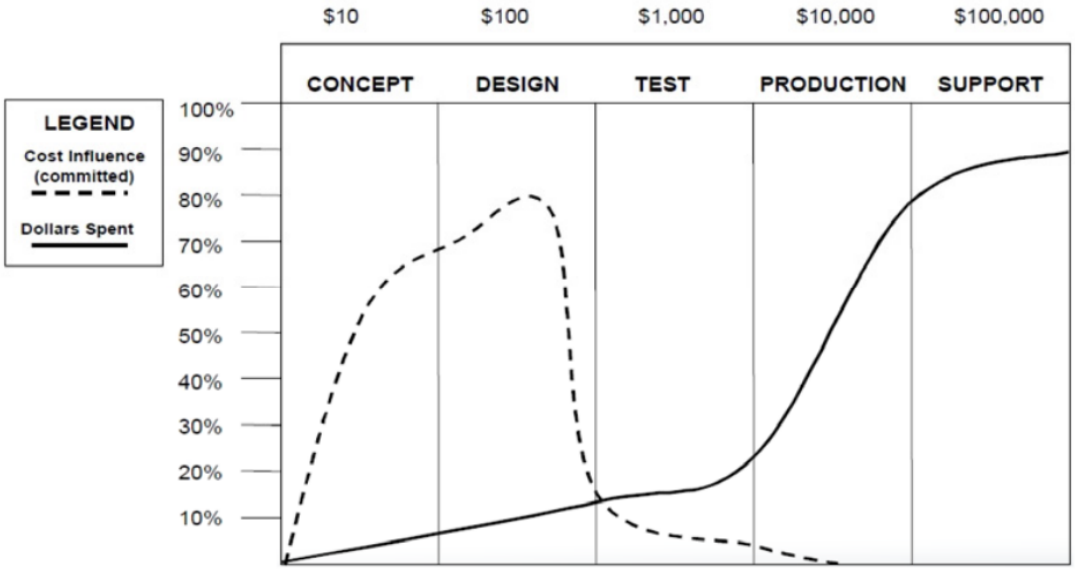


Figure 7. The total cost of system (Jung & Shim 2021)

From *figure 8.*, it can be observed that 24% of engineers' time is spent on information retrieval and sharing. Engineers also dedicate a significant portion (21%) of their work to tasks that someone has already done before. By improving the accessibility of essential information, engineers can allocate more time to their crucial tasks. Information retrieval must be straightforward and clear.

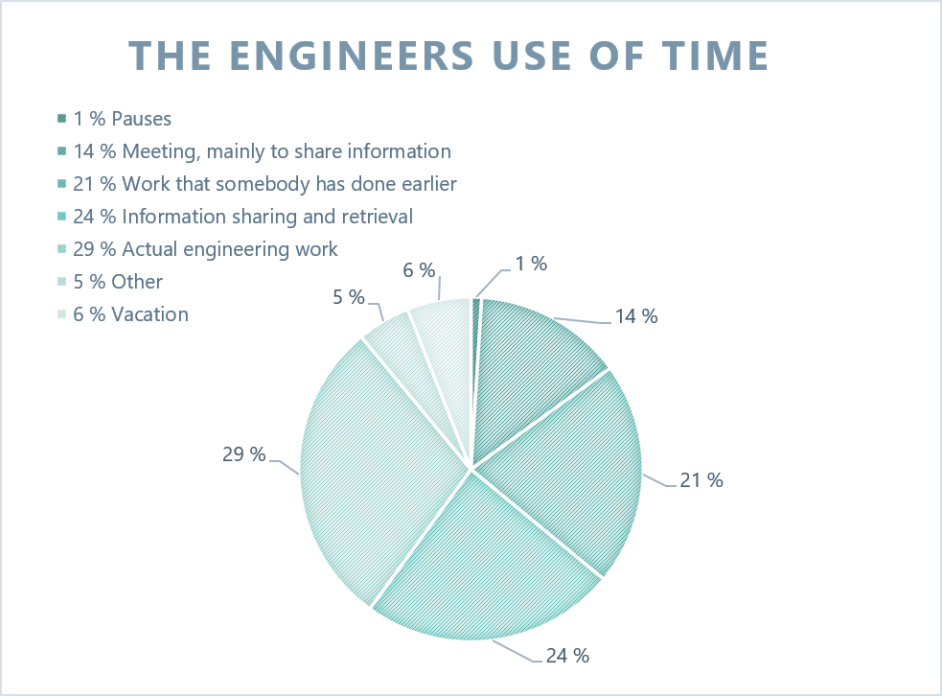


Figure 8. The engineers use of time. Accordingly (Saaksvuori & Immonen 2008)

Engineers use a lot of different information when they work, and it comes from many different places. According to Baxter et al. (2007) (cited in Lowe et al. 2004), approximately 20% of engineers time is spent on acquiring and assimilating information. Additionally, about 40% of design information requirements arise from engineers personal judgment, even though more suitable information for the situation may be available. For this reason, it is important that key information in easy to find, use and it is in right format.

Companies understand they need to continuously develop their production and processes to succeed in their constantly changing business environment. It is important that engineers can work interdisciplinary while still having their own specialization. This way, more creative results can be achieved in innovation projects. (Oskam 2009)

5. USE OF REUSE COMPONENT

One of the following approaches is frequently used in the creation of new products: completely new design, adaptable design, or variation design. Only a tiny percentage of product design is entirely novel, with the majority (70 %) falling into the categories of variation or adaptable design. Adaptive design refers to the process of modifying an existing technical solution to fit a new purpose, while variant design involves creating slightly different versions of a similar technical configuration to meet various purposes. (Ligang & Shenbo 2011)

According to Sivaloganathan and Shah (1999), design is one of the few tasks for engineers where they can exercise creativity and expertise. Therefore, the time engineers can allocate to the design process is crucial.

5.1 Reuse components and use

Well-executed design reuse benefits not only the company but also the customer. Therefore, it is important for companies to identify the elements where design reuse could be leveraged. (Pakkanen et al. 2016) According to Busby (1999), the benefits design of reuse is recognized, but its implementation seems to be challenging. One challenge may be, for example, that designers may not readily accept products created by others.

The term "reuse" can also be defined through "Design by reuse" and "Design for reuse." "Design for reuse" means that the design is done in a way that the product is intended to be reusable in applications beyond just one. "Design by reuse," on the other hand, refers to the reuse of existing designs and components (Duffy & Ferns 1998). Component reuse, parametric design (both generative and variant), and KBE systems are examples of CAD/CAE-based design reuse techniques (Andrews et al. 1999).

In this context, the term "reuse" generally refers to the reuse of components. Reuse means using the same component in multiple different locations. In PDM software that could mean that same item ID is used in multiple assemblies. The reusable component can be a standard component, a common part, or a part or assembly designed for reuse. The reusable component can be a purchased part or an in-house designed component. Their use aims to reduce, for example, the repetitiveness of similarities.

The most significant benefits of reuse include cost reduction, improved quality, reduced time spent, and enhanced performance. Predicted future benefits are expected to result

from cost reduction and improved quality, attributed to reuse libraries (22%) and industry domain models (21%). (Duffy & Ferns 1998)

Reuse components are widely used in industry, for example, in manufacturing. The use of reuse components enables more efficient utilization of resources, as the same components can be utilized in various projects. In the software industry, a reuse component can refer to a program library that is used in multiple projects. Zhang et al. (2003) states since standard components are tried-and-true products with a good of development and application use behind them, including them in a design is a typical example of design reuse.

With the advancement of software development, the use of reusable components has been made more efficient. According to Busby (1999), the primary reasons for situations where reuse is not utilized are that it is known to be beneficial but not practiced. Another reason for underutilization was the unexpected efforts arising during reuse. A challenge was also seen in the lack of motivation among designers or their perception of new designs as inadequate.

5.2 Standard components

Standard components are frequently utilized, and their application is generally understood. Common design components are widely available with a wide range, such as bearings, seals, springs, and so on. The advantage of using these products is that they are generally much more cost-effective, and their physical performance is well-known. Major component manufacturers test their products and receive feedback from their customers, so it is highly likely that a product purchased from a supplier is better than an in-house designed product. (Culley 1999) Reinemuth and Birkhofer (1993) state that standard components can be thought of as components purchased from an external supplier or finished products purchased from external manufacturers.

Standardizing component management can reduce costs incurred during design. Standardizing component usage can help manage the problem of different designers selecting different components for similar applications. The use of standard parts can improve system usage and maintenance. For example, managing spare parts becomes much easier if the use of parts is standardized. (Jung & Shim 2021)

Culleyn (1999) states that the use of an electronic component catalog has the following benefits:

a. Better chances of finding a component suitable for assembly.

b. Accelerating the selection process.

c. The use of standard components is allowed instead of designing special components.

d. Common selection procedure.

e. All component types and variants can be modified more easily.

f. Choosing the optimal component without bias.

Fulfilling these requirements requires that the library be in a clearly understandable format and easily accessible to anyone who needs it.

Standard components are important to the composition of assemblies, particularly when it comes to mold and fixture design. Mechanical products can be roughly categorized into three categories based on their characteristics. (Wei et al. 2010)

About half of all mechanical items fall into the standard component category (sometimes called Category C), which includes products with the same structure that vary only in size. Forty percent of the components are different in size but have a similar structure. These parts are also referred to as Category B and fall within the general parts category. Merely 10% of the components fall into the new component category, or Category A. A general components library is very important for cutting production costs, shortening product design and manufacturing cycles, and raising product quality. As a result, general parts library research has gained popularity, and numerous businesses have created and utilized standard parts libraries to suit their unique needs. (Wei et al. 2010)

Managing changes for purchased standard components is challenging because the supplier may make changes to the delivered component, but the component is interchangeable with the old component. This type of information may not necessarily be sent to the component buyer. In such a situation, reacting to the change is challenging. Many companies have decided not to revise their purchased standard components for this reason. (Martio 2015) Revising purchased components would only cause additional work in this case.

Technical components are defined in the literature in various ways, but one possible method of definition is the division of components into three main categories. According to Culley and Theobald (1996), three primary categories *(See figure 9.)* may be used to classify technical components:

1. Custom-Designed components, also Company specific components (for example specific shaft or valve pump)

2. Standard-Designed Components (for example bolts and nuts)
3. Standard-Selected Components (for example bearings or clamps)

“Custom-Designed” components refer to those components that are not standardized. The proportion of "Custom-Designed" components in designed products is approximately 40%. The purpose of these components is to address a specific challenge or problem (Culley & Theobald 1996).

“Standard-Design” components refer to components that are neither “custom-design” components nor “standard-selected” components. “Standard-design” components are designed according to specific standards and are not products of a particular supplier. Well-known standards include, for example, the International Standard Organization (ISO) and the German Institute of Standardization. (DIN) (Culley & Theobald 1996).

“Standard-selected” components are those components that can be purchased ready-made from a supplier. These components can be selected based on supplier catalogs, and it is the designer's task to choose components that fit their own design (Culley & Theobald 1996).

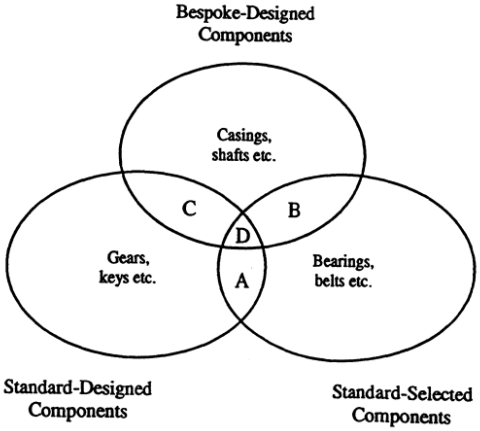


Figure 9. Different types of engineering components (Culley & Theobald 1996)

5.3 Classifying objects

Companies require data classification in many different places and with various types of data. With appropriate data classification, necessary information can be found efficiently and utilized more easily. Maintaining and updating classified information is much easier.

Classification is very important, especially when using reuse components. In classified groups, objects are linked to each other based on common characteristics. Common features are highly situational and depend heavily on the desired end result. (Pahl and Beitz 1990, p. 474) According Krishnamurthy et al. (2023) a structural arrangement of

particular classes in a methodical and deliberate order is known as a classification system. Data classification is important for organizing information. According to Laranjeiro et al. (2015), poor-quality and poorly crafted information, or "poor data," annually causes significant costs for companies and challenges for many areas of the company. Poor information classification is one aspect of low-quality data.

Various hierarchies can be broadly categorized into top-down (Divisive) and bottom-up (Agglomerative) approaches. In the top-down method, the idea is that there is an upper category that divides into various subcategories. In the bottom-up method, the intention is that lower categories consist of one or more upper categories (see *figure 10*.).

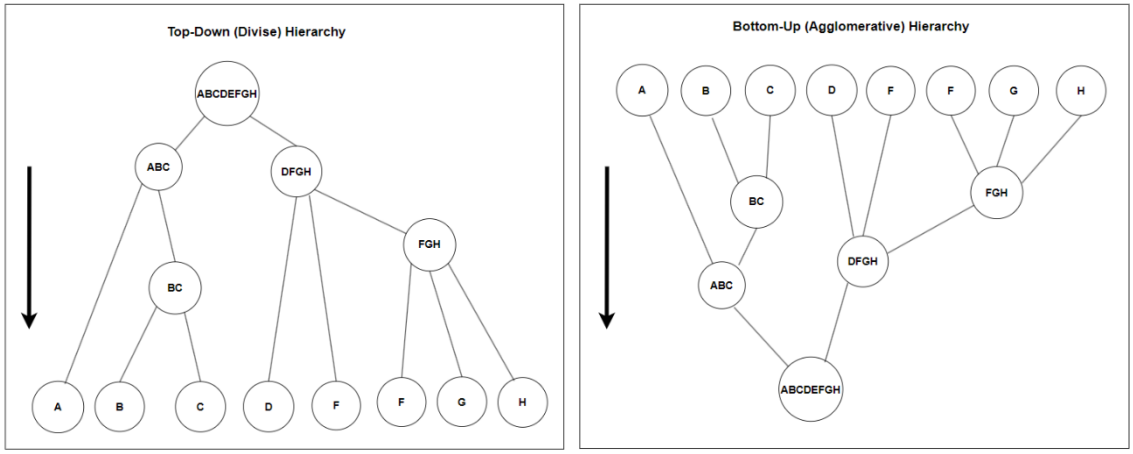


Figure 10. Top-Down and Bottom-up library hierarchy (Adapting Krishnamurthy et al. (2023))

The classification of information can be broadly divided into two parts: enumerative systems and faceted systems. In enumerative systems, classes are predetermined and listed hierarchically, whereas in faceted systems, main classes are further categorized based on different features or "facets." Each main class is divided into subcategories called "facets," representing conceptual categories. These facets, in turn, are divided into "Isolates," which are individual units of knowledge resulting from the application of a specific feature. In a faceted system, each classifiable resource does not have to be linked to every parameter. (Krishnamurthy et al. 2023)

In enumerative classification (*figure 11.*), it is predetermined how things are classified. In this case, the user can only classify things using predetermined parameters, potentially overlooking the user's own goals regarding classification.

Figure 11. Example about enumerative Classification.

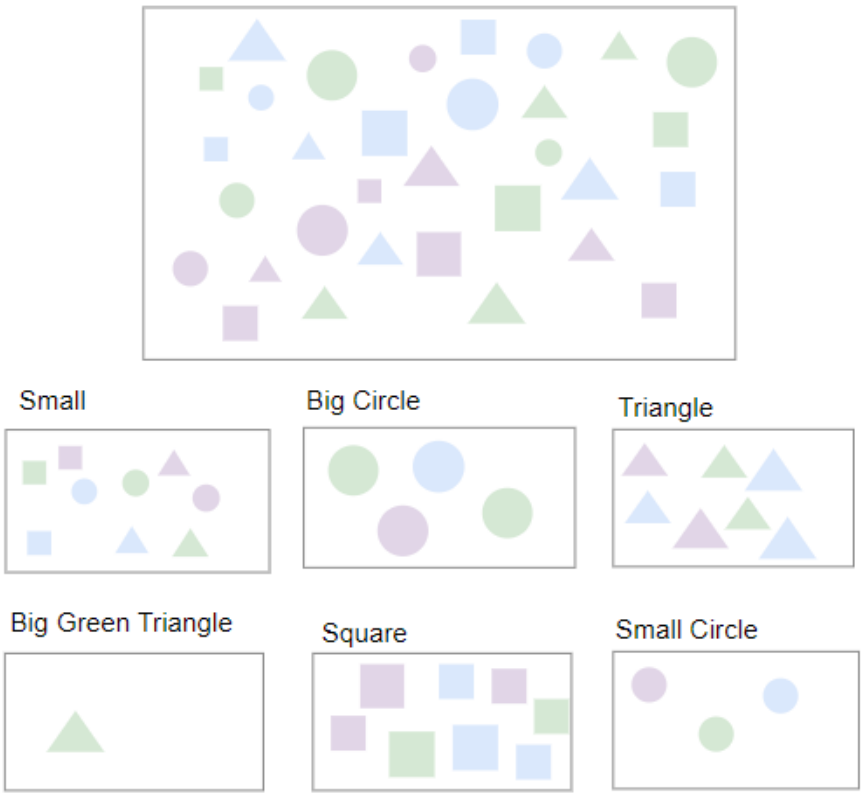


Figure 12. Example about faceted Classification.

In a faceted system, classification is not predetermined, and things can be categorized based on the parameters needed at any given time. *Figure 12.* provides an example of classification according to the faceted system.

Teamcenter's Classification library utilizes a faceted classification system, making the classification flexible and versatile. The faceted system is specifically employed in the part of the library where different components are cataloged. The library's hierarchy itself can be considered enumerative, as the user sees only a specific hierarchy and must select all hierarchy levels to reach the class where components are cataloged. In the class where components are cataloged, the resources being cataloged do not have to be linked to all the parameters of the same group, and various combinations of parameters can be made, allowing the library to serve the user in the most efficient way possible. The hierarchy of Teamcenter's Classification library is often constructed using the top-down approach.

5.4 Structure and design of the standard library

A well-designed library, reusable parts are significantly easier to use, and new components can be added to the library more easily (Duffy & Ferns 1998). Therefore, it is important to design the library carefully from start to finish, considering the end user's preferences and requirements.

Standard components can be classified using only the parameters of the components to be classified, or design information (Knowledge Based Engineering, KBE) can be included in the classified components. (Wei et al. 2010) Most classifying methods are primarily related to the classifying of standard components rather than general components. Most scientific papers relate especially to applications containing design information.

To facilitate information sharing, integration, and exchange regarding standard component libraries, the International Organization for Standardization developed the international standard ISO 13584-1. Offering a neutral method for the transmission of part libraries. The primary aim of this standard is to provide parts library data that is not dependent on the application systems that use the parts library data system. The standard is suitable for both exchanging parts and serving as the database foundation for sharing and building component libraries. (Yang-Dong et al. 2006)

Companies often build part libraries based on national and internal standards, even though there are international standards guiding part library management, such as the ISO 13584 standard. Companies desire seamless integration of the library into their systems to enhance efficiency in its use. (Jiang et al. 2013)

The physics layer states the implementation mode of the information model of the parts library, including the neutral document format and memory operation format. The application layer defines the framework of the part library as well as the updating and exchanging mechanisms. The logic layer describes the information model of the part library and resource components (Yang-Dong et al. 2006). Layers are described in *figure 13.*

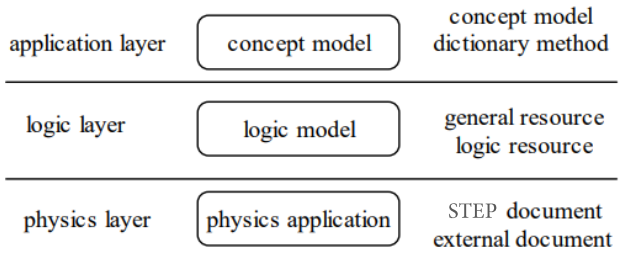


Figure 13. Standard architecture for parts libraries (ISO-13584 Cited from the source Yang-Dong et al. 2006)

The description of the parts model is divided into two layers: the component class, which contains the class identification, class attribute, and other information, and the part's attribute, which includes the part's name, identification data type, and other information.

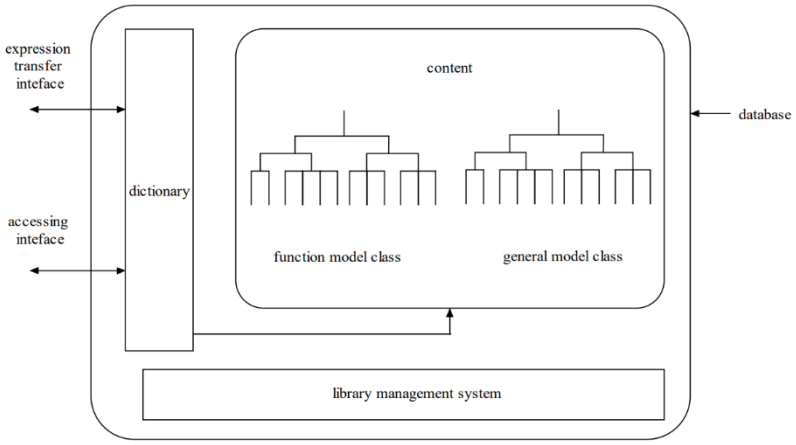


Figure 14. Reference model for the parts library (ISO-13584 Cited from the source Yang-Dong et al. 2006)

A library provides the situations for each class, and a dictionary explains the component class and its attribute. The information model of the dictionary and library content is expressed in the logic layer of the components library information model, which was explained in Express language. A library management system is a piece of software that enables users to search through, select items for their libraries, and integrate vendor libraries *(See figure 14.)*. (Yang-Dong et al. 2006)

In the specification of a parametric component in the standard library, one should start by analyzing the reusability of components. The creation process of the standard library has four main stages. The first phase involves the analysis of components to determine their reusability and to ensure that a particular component is usable as a reusable component. In the second phase, parameters are defined for the components to manage their technical characteristics. The third phase involves creating a catalog where parameter values and other related attributes are collected. In the fourth phase, a library is created with the necessary parameters. (Yang-Dong et al. 2006)

In the part library, each part is interpreted as an object with attributes. A class is formed from parts that have similar attributes. A subclass inherits all the attributes present in the parent class. *Figure 15.* shows the example of the class hierarchy.

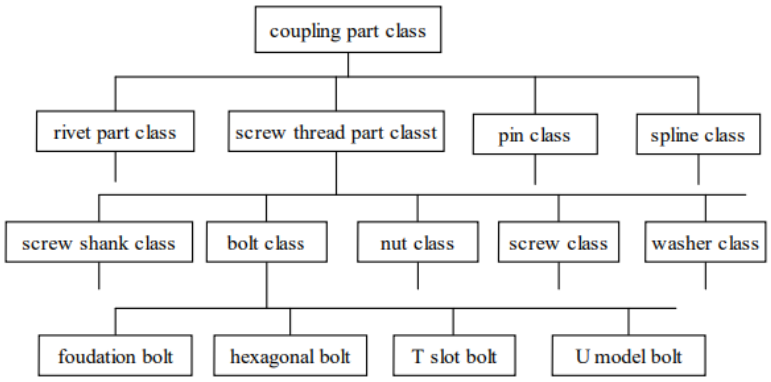


Figure 15. Class layer for standard parts (Yang-Dong et al. 2006)

Machine tools can be classified using a method where the first-level classification is based on the process, meaning the purpose for which a specific product group is used. The second-level classification is based on function. The third and subsequent levels are a combination of the two previous levels. (Cao & Zhang 2014)

In the next example *(figure 16.)*, machining tools are initially classified based on the machining process: lathe fixture, drill plate, and boring machine jig, etc. In the second level, the classification is made based on the functions represented by each group, such as positioning element, tightening parts, and supporting component. The subsequent groups utilize the classification from the previous levels.

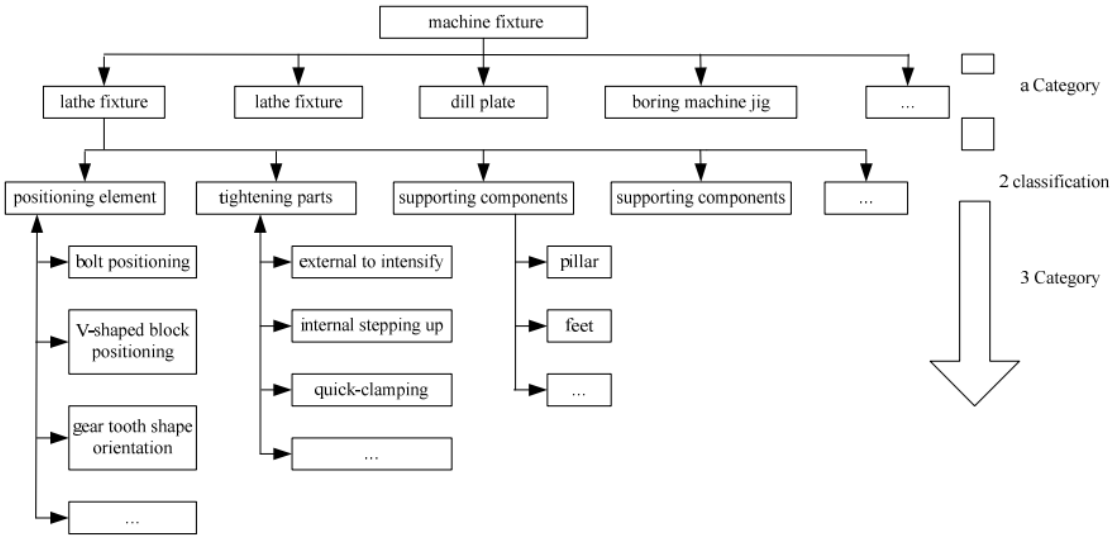


Figure 16. Library of fixtures and jigs components (Cao & Zhang 2014)

Classification of machining tools, the top-down method has been utilized, reducing the additional work done by designers and improving their efficiency in design as well as in finding the necessary components. (Cao & Zhang 2014) A typical library usage process is described in *figure 17*.

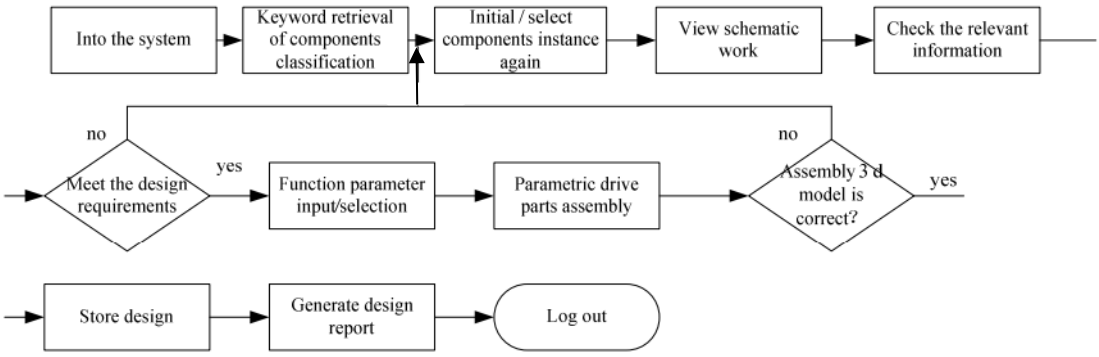


Figure 17. Typical process for using structural components libraries (Cao & Zhang 2014)

If there is no clear procedure for managing the standard library, there is a risk that the library will contain parts that are not intended to be used as standard components. In such cases, the concept of standardized parts in the library is not as clear, and the library may not function in the way it is intended. (Jung & Shim 2021) In the production planning of the defense industry, there is a procedure for the classifying of standard components *(figure 18.)*.

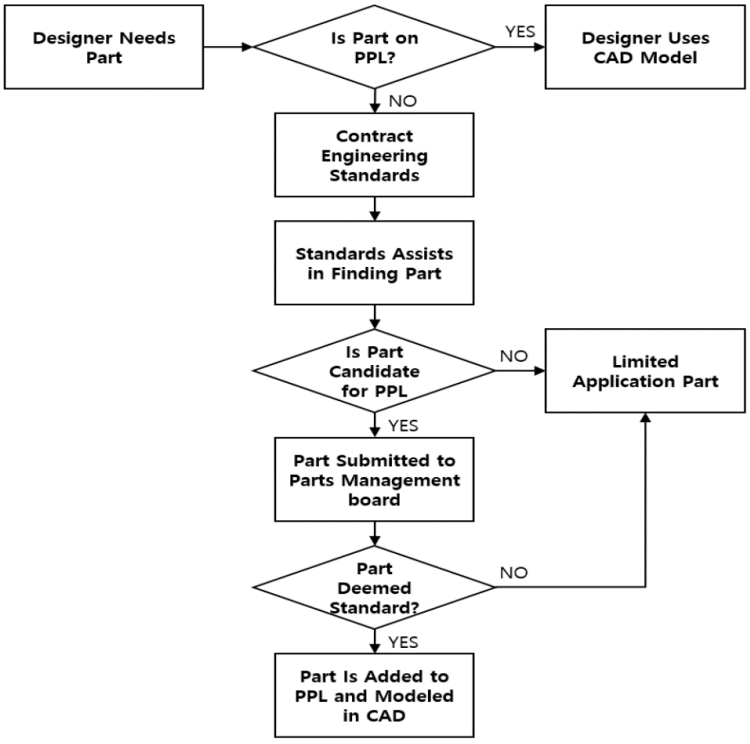


Figure 18. Standard parts selection process. (Jung et al. 2021)

It is not an ideal situation for the library to be so challenging to build that the user needs to be trained as a programmer. A programming-based component library poses numerous challenges for the user and is difficult to update. The challenging construction of the library leads to an increase in design costs and low efficiency. (Tong et al. 2020) The complexity of library usage affects how easily the end users adopt its use.

5.5 Component standardization

In the industry, standardization is an essential part of the operation of a modern production ecosystem. Standards provide the foundation for uniform operations and enable the development of product, service, and process characteristics. When companies use to common standards, it facilitates the integration of products, which, in turn, promotes competition and innovation. Standards can be international or national, created by various organizations such as ISO (International Organization for Standardization) or SFS Ry (Finnish Standards Association), or internally defined standards within companies, such as design guides for standardizing design practices.

In the context of standardization, there can also be discussions about the standardization of component usage. According to Perera et al. (1999) when multiple components are swapped out for one that can handle all their functions, this is referred to as component

standardization. Another name for this circumstance is the component commonality. Component standardization can be divided to three different sections:

1. Component standardization: When a product has multiple unique components, they are swapped out for a common component.
2. Product component standardization: A common component replaces a number of distinct components found in many products.
3. Standardization of components throughout product generations: Over time, common components are employed in many products or in improved products.

The standardization of components can achieve benefits throughout the life cycle of a product. The uniform use of components can make the system more reliable and predictable. The number of different spare parts in stock can be reduced, making it easier for maintenance to store correct components and react to broken components. (Perera et al. 1999)

5.6 The use of standard components

The proportion of standard components, including both self-designed and purchased parts, is already over 60 %. The time spent on traditional production planning should be halved, and costs should decrease by 80 % when component libraries are implemented. CAD software library modules have benefited designers, reduced design time and minimizing repetitive work. (Ketai et al. 2004) According to Wei et al., (2010), the proportion of general components in mechanical parts is approximately 50%, as reported by statistics.

Wang et al. (2009) categorizes mechanical components into three groups. Group C consists of components with the identical shape but varying in size, and they belong to standard components. About 50% of mechanical components fall into this category. Group B refers to parts with similar shapes but varying in size, and they belong to general parts. Approximately 40% of mechanical components fall into this category. Group A denotes newly designed parts, accounting for only 10% of all mechanical components.

Companies have observed the benefits of general component libraries. These libraries save production costs, speed up the design and manufacturing cycles, and make the final product quality better. Wang et al. (2009) Quality improvements can be immediate or indirect due to the time freed up by the introduction of the library. Standard components libraries were developed to increase design efficiency, reuse resources, and shorten the design cycle (Yang-Dong et al. 2006).

The choice between using self-designed, standard parts, or supplier-made components is not always clear and is influenced by multiple factors. According to Pahl and Beitz (1990), assemblies should aim to use parts that do not need to be purchased on order but are, either self-designed reuse parts, standard parts, or supplier-made purchase parts. The profitability of using standard parts depends on many factors, such as:

- Number of units (single, serial, or large series manufacturing)
- A single product on demand or a series of products aimed at the market
- Work materials, purchase parts or acquisition status (cost, acquisition period)
- Possibilities of manufacturing equipment used by the company
- Manufacturing load situation

The choice between the use of purchasing components or a self-designed one can be quite tied, in which case the decision between the two must be made on a situation-by-situation basis. (Pahl & Beitz 1990)

Niftylift Hydraulic utilizes consistent design in their processes, employing "Standard components" that can be both purchased and internally designed. The use of standard components helps reduce the number of components in the final assembly. (Andrews 1999) Standard components are less expensive and simplify the design process. Because it uses components that have been tested, it can reduce the lead time for manufacturing and enhance die quality. (Zhang et al. 2003)

Companies need to address the challenges posed by the development of manufacturing automation and CAD/CAM technology by constructing 3D-parametric libraries for parts and components. Such libraries enable effective responses to various needs, especially the requirements of mass customization. (Hou et al. 2009)

5.6.1 Case A

Wu and Fuh (2002) carried out research with the goal of simplifying die-casting mold design. Developing better options for gating element design was the aim. The result was a classified parametric model that could be applied to various castings. Several parameters were assigned to the cataloged component, enabling engineers to select a suitable mold based on their design requirements.

Previously, the design of the gating element relied on first calculating the required element and then starting the modeling from scratch. This process was repeated for each casting, significantly consuming designers' time. (Wu & Fuh 2002)

As a result of the study, the time spent by designers decreased from the previous 3-4 hours to approximately one hour. The most significant benefits in this case example were

that designers no longer had to build gating elements from scratch; instead, they had a functional library from which to choose a suitable model. It's noteworthy that the earlier design of the gating system involved a substantial amount of calculations, a task that largely diminished with the adoption of the new system. (Wu & Fuh 2002)

5.6.2 Case B

Wei et al. (2010) presents a case example where significant benefits were achieved in the design process of a hanger frame using part library. In the context of the study, a parametric model was constructed for the hanger frame design domain, which was then added into the library. This parametric model included design information about the hanger frame, and its utilization significantly reduced the time required by designers.

The advantages of the library were based on the quicker accessibility of components, as they could be rapidly accessed using the "Drag and drop" tool. Engineers no longer needed to search through manuals, as all necessary technical information was available in the library. The library also facilitated the standardization of design solutions between other engineers. Standard components of the assembly needed to be modified or updated as the design progressed. Taking everything into account, the time spent by designers on hanger assembly design decreased from the previous one hour to approximately 10 minutes. (Wei et al. 2010)

The study emphasized that the library encompassed design information that would otherwise require the designer's individual investigation. Such information included calculations for the durability of beams and subsequent selection of suitable beam profiles. For hanger design, a standard library was created, as approximately 90% of the components in the assemblies under consideration were standard components. (Wei et al. 2010)

5.6.3 Case C

Mok et al. (2011) created a user interface for utilizing standard components to facilitate the work of designers. Through the interface, a designer can construct the necessary mold design, which is automatically built from predefined standard components within designer requirements.

They have developed an efficient user interface that allows for easy reuse of parts and retrieval from the system. With the built module, designers can effectively utilize standard parts and modify their parameters as needed. (Mok et al. 2011)

The system was applied to mold design and the standardization of its components. The benefits of the system resulted in increased efficiency and reduced failures among designers. They also created process related to the use of adding components to library *(See figure 19.)*. (Mok et al. 2011)

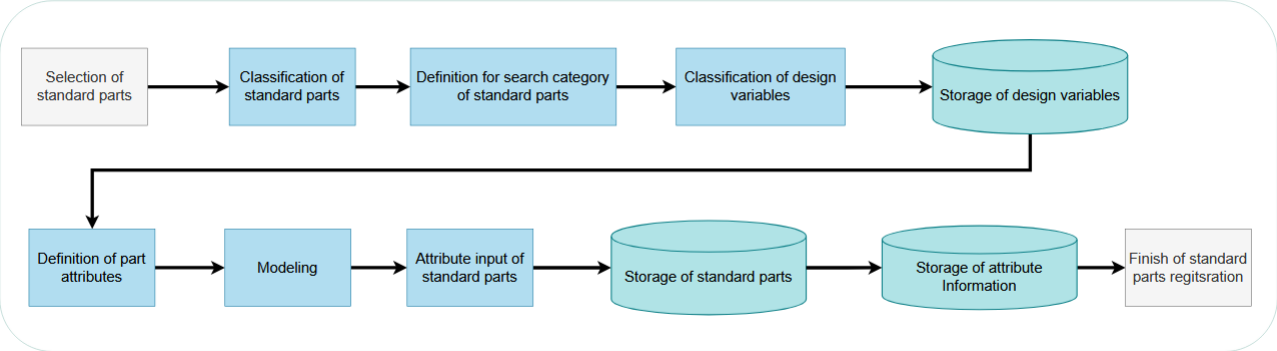


Figure 19. Procedure for standard parts and part attributes registration. (Mok et al. 2011)

5.6.4 Case D

According to Zhang (2016), in the pressure vessel industry, a library of common and standard parts is used to reduce repetitive tasks for designers. In this industrial sector, there are many common and standard parts, so the library needs to be user-friendly. According to Zhang et al. (2012), for the standard component library to be used in industrial applications, it should be customizable.

In this case example, a design model was built to make it easier for a pressure vessel designer to choose customized models. A design model was adopted for general vessels and components, but direct modeling was used for atypical constructions. With the design model, the designer automatically obtains drawings for the selected construction. According to Zhang (2007), about 20% of components in the pressure vessel industry are atypical and do not suit this type of design model.

The design model increases the designed product's accuracy, standardizes plans, reduces routine work, and decreases failures made by designers. Considering that the

design model automatically generates drawings for the selected model, it can be stated that the efficiency of the designer's work is improved by over 80 %. Taking into account drawing modification work, efficiency can be improved by at least 50 %. (Zhang 2016)

5.6.5 Case E

Checking fixture is a quality control tool used in the automotive industry to inspect whether the manufactured parts are within the standards. According to Jiang et al., (2013), checking fixture design largely includes standard components. In the case example, a design system was implemented to assist in designing the checking fixture using computer-aided methods. To support the design system, a flexible and intelligent component library was built, which the system utilizes. A flexible library means that it can be adapted to meet also future requirements (Mertins 1992).

In this case example, the design system automatically calculates how the car part is positioned on the table. The system determines the locations where the car part is to be placed and provides suggestions for suitable library components, such as various clamps that meet the fixation point requirements. The intelligent library also proposes other components related to the clamp assembly. (Jiang et al. 2013)

Jiang et al. (2013) declare that using a lot of standard components is a part of mechanical design. The use of such components results in cost savings and shortens the product manufacturing cycles. Standard components may be used more easily when the design system has an intelligent part library. Adding data to the library components allows them to be automatically placed in the correct locations in the assembly.

5.7 The main points of the literature review

In literature, there are several examples of constructing a flexibly functioning component library, specifically focusing on the software aspect of the library. In these examples, the goal is to build libraries that are both flexible and easily integrable, for instance, into CAD design programs. Adding design information to the library components gives even more the benefits. When identifiable parts suitable for library inclusion are found, which enable the integration of design information into the library, it significantly makes the designers work more efficient. Such design information may include data related to strength calculations.

Building libraries is beneficial for standardizing the use of components, facilitating, and speeding up the work of designers, and reducing errors, such as the use of incorrect models. Through the library, the necessary components are also available to everyone who needs them. Library management is also beneficial in item management if some

PDM software is used with the library. An efficiently functioning library must be easily adaptable in the future as well. The library needs to be functional to produce benefits, for example, making it easy for designers to use, and ensuring that all necessary parts are available. It is not advisable to limit library components only to “standard components”, in addition to them, easily libraryable components include, for example, “standard-selected components” and “company-specific components”.

Data classification is important when building a component library and, in general, when storing any data. With good classification, data can be reused, and it becomes more easily manageable. Good classification helps minimize the storage of unnecessary data (poor data).

In addition to utilizing a specific system in building the library, it is essential to establish processes that guide users on how to operate in a common way. For example, it is important to create processes for using and updating the library so that future library management is efficient and consistent.

6. PRODUCT INFORMATION MANAGEMENT CONCEPTS AND TERMS

Product Data Management (PDM) generally refers to a method of storing and using data. Product data management can be implemented in various ways, and data management can be facilitated by different systems and software. Terms like Product Data Management (PDM) and Product Lifecycle Management (PLM) are frequently used in discussions about product data management. PLM includes product life cycle management, which includes ideation, design, and distribution of spare parts. PDM include document and other data management as well as the management of all product-related information. PDM is considered part of the overall PLM framework. The topics related to this work are described in *figure 20*.

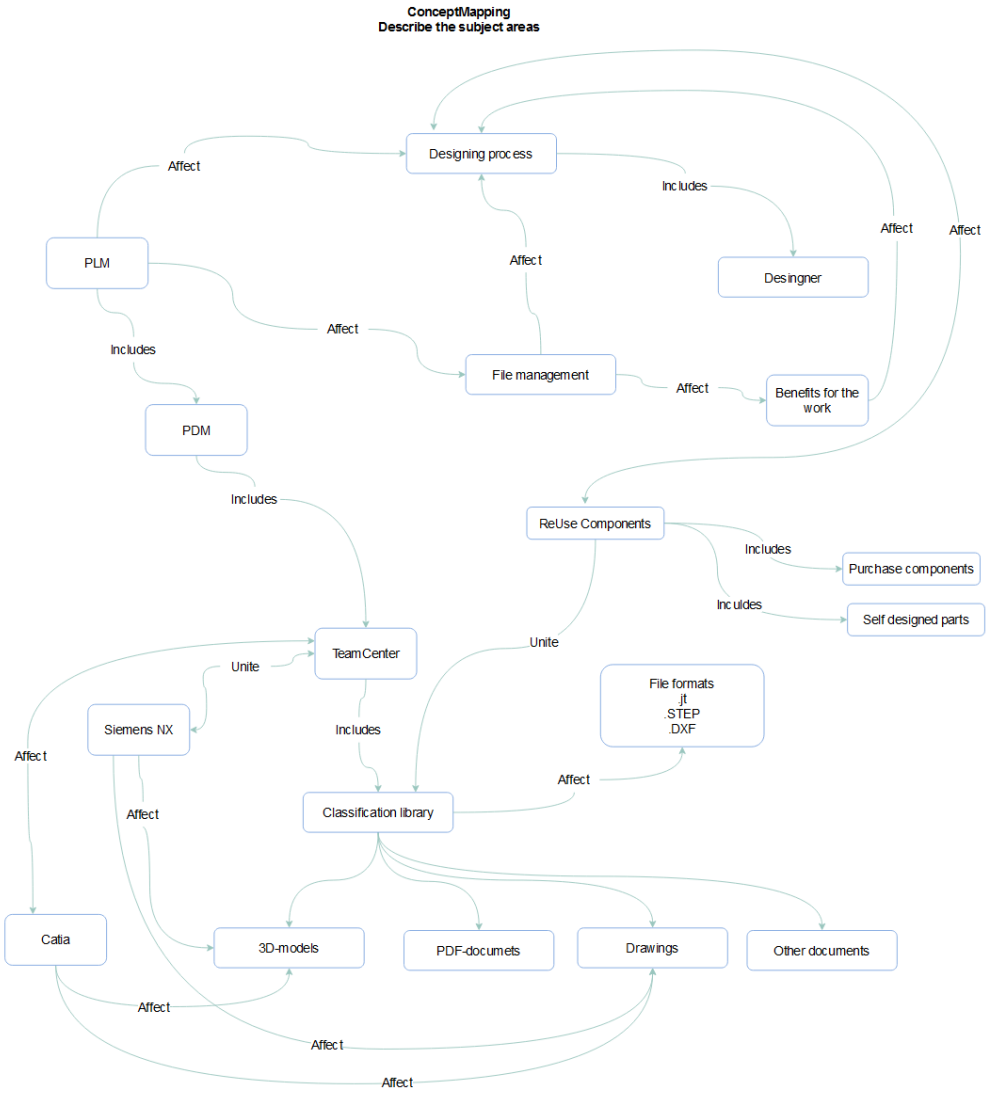


Figure 20. Concept mapping related to topics of that work.

6.1 Defining of the systems

Nearly all bigger businesses utilize some form of PDM system, and PLM (Product Lifecycle Management) and PDM (Product Data Management) software are essential tools for many businesses. This work focuses on the use of Siemens Teamcenter, along with integrated CAD systems, Siemens NX, and Dassault Systèmes Catia, in the target company. There are various software options for product data management on the market, each with slightly different features. Choosing the right system is a complex process and is significantly influenced by factors such as what the company wants the system to accomplish. Other systems available in the market include, for example, SolidWorks PDM and Dassault Systèmes CATIA and ENOVIA.

6.1.1 Definition of PLM and PDM

A methodical and regulated approach to the creation and administration of goods and product information is called product lifecycle management, or PLM. Product Lifecycle Management (PLM) facilitates the management of product lifecycle information and product processes, including product development, productization, and product marketing. The development of information systems for product lifecycle management and product data management is frequently referred to by the acronyms PLM and PDM. Product lifecycle management's primary goals are to generate, store, and arrange product-related data and make it easier to retrieve that data quickly and easily for subsequent use. (Saaksvuori & Immonen 2008, pp. 3-6)

Product lifecycle management, also known as product data management, is a concept or model for managing product information and is defined as a comprehensive functional entity. PLM or PDM does not refer to a computer program or a specific method but more specifically to the entirety of the concept (Saaksvuori & Immonen 2008, pp. 9-13). Various software has been developed for product data management to systematically manage data.

Three categories may be used to categorize product data and information: product lifecycle information, product definition information, and metadata that describes the information. (Saaksvuori & Immonen 2008, pp. 7-8)

6.1.2 Functionality of the systems

Companies have different requirements for a PLM system, for example, because existing systems or practices create demands for a new system. According to Saaksvuori & Immonen (2008), nine categories may be used to group common PLM system characteristics.

1. File status control over lifecycle

With a PLM system, the functional status of files can be automatically managed. Creating new files in the system or editing files can be done in two ways. The user either utilizes a feature in the system that allows the file to be locked for editing by only one user with the Check Out or Check In function. Another option is to create files on their local drive and then upload the finished files to the system.

2. Creating a documents

The creation of new documents, such as 3D models or manufacturing drawings, is done through an approval process where the designer submits their drafts for approval, after which they proceed in the process. The process ensures that all created documents undergo a thorough review. This feature in Teamcenter is known as "Workflow" *(See figure 21.)* and it may be applied in a variety of ways. For instance, it allows us to view the status of the components that have been classified.

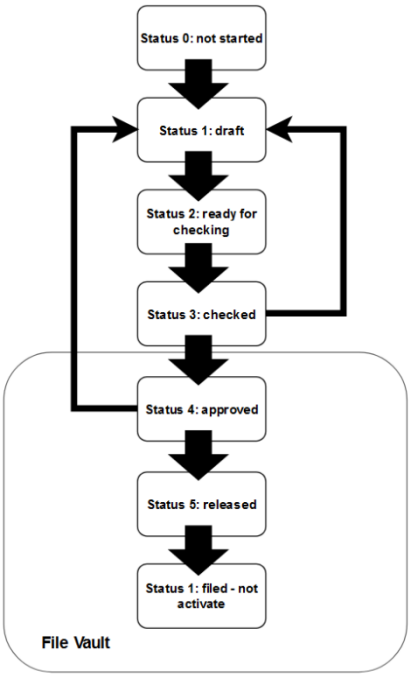


Figure 21. Example of documents status during its life cycle (Saaksvuori & Immonen 2008, p. 29)

3. Management of sharing of documents

The system allows for the management of document sharing to various destinations, ensuring that documents progressing in the process are up to date. Distribution management includes actions such as sharing an approved document, as illustrated in *figure 21.*, as it moves forward in the process.

4. Looking through and seeking information

PDM systems facilitate data retrieval and categorization through various means. Data in the system can be divided into different items, and specific attributes can be assigned to each item to facilitate data retrieval. The system allows for keeping track of existing items, and it enables checking whether the required item already exists in the system. Creating a new item may be easier than rediscovering an item already present in the system. For this reason, proper classification of information is particularly important.

5. Product structure management

The management and upkeep of the product structure is one of the main duties performed by the PDM system. It is easy to see where each part is used thanks to the product structure, which also makes it possible to manage relationships between assemblies and parts. With the system, product structures can be filtered and constructed for various purposes, such as design or sales use, manufacturing, or for the maintenance of spare parts. It is possible to make different kind of list from same assembly for different purposes for example for engineers and for maintenance.

6. Change management in documents, items and structures.

The system enables clear and consistent management of document, item, and structure changes. The stages of change processes can be easily tracked, and the status of the change process can be determined. The change process is also highly traceable, allowing for an examination of who made the changes, when they were made, and what were modifications.

7. Data transfer and conversions

The system can be built in a LAN, WAN, or Internet environment, so the user does not need to be aware of where the files are stored. Various file formats can be stored in the system, and, for example, with CAD programs, there can be many different file formats for example Excel, Word and PDF documents.

8. Task and message management and communication

One could think of this as concurrent engineering's cornerstone. Information sharing is made possible by the system for all parties impacted by its operation.

9. Image data management

This can be used, for example, in a situation where a company wants to digitize paper drawings into the system. This allows attributes to be assigned to documents to facilitate their retrieval and facilitates the sharing of documents.

6.1.3 Teamcenter software

Teamcenter is Siemens' commercial PLM software. Currently, Teamcenter is one of the world's leading developers of software related to product lifecycle management. The software is designed to assist companies in managing and optimizing the entire product lifecycle, from idea to design, manufacturing, usage, and maintenance. Teamcenter provides versatile tools, and often, companies customize their orders with specific packages of software components. The main features of Teamcenter can be divided as follows:

a) Management of products and documents

b) Design and simulation tools

c) Manufacturing process management

d) Quality assurance and maintenance through documentation and various tools.

e) Collaboration and teamwork, e.g. between partners or design and production.

f) Extensive integration with the company's own systems.

A number of different systems can be integrated into the Teamcenter environment for example the Enterprise Resource Planning (ERP) system. It is very company and industry-specific that what kind of functionalities are needed and what systems are integrated into it.

6.1.4 Teamcenter Classification library

The Classification library is a functionality in the Siemens Teamcenter program where a wide range of product information can be stored. With the help of the library, the data can be easily accessed and easily found using defined parameters. The purpose of the library is to structure the information to be reused so that it is easy to use and edit. A library can be assigned such a hierarchy as is necessary for each case.

In Classification library you can:

a) Create library hierarchies

b) Add (Classify) different objects

c) Find and use classified objects

d) Add and change the parameter of the objects

e) Delete classified objects

6.2 Utilization of systems in industry

Large companies manage a vast amount of data. Especially for companies that produce millions of units customized for each customer, it is extremely challenging to succeed without effective data management. In modern industrial companies, various information systems are almost universally used to aid in design, production, and product deliveries. This illustrates the challenge that a company's information system can be fragmented into small parts and unifying it can be difficult. Transferring files from one system to another is challenging but possible. The networked operating environment of today's companies poses challenges for file management and editing, as all parts of the network must have access to the information system. Departments or subcontractors of companies operating around the world need to have access to the latest versions. Companies worldwide may have their information systems, but they need to work together. The technology related to integrating different information systems already exists but applying it to the specific needs of a particular company is challenging and requires expertise. (Saaksvuori & Immonen 2008, pp. 5-10)

A company must have a thorough understanding of its business processes in order to implement a product information management program, which is a complex project. A significant portion of the organization's areas are impacted by the handling, storage, and application of product information. Product information management is not only the responsibility of the ICT department but requires a lot of collaboration between different departments. (Saaksvuori & Immonen 2008, pp. 5-10)

In today's companies, product information management challenges can be roughly divided into three categories.

1. The company has not clearly defined concepts related to product information management and product lifecycle information management. How product information is utilized in that particular company may also be unclearly defined.

2. Companies have a lot of information that they need to be able to use in a different environment than where it was originally made. For example, information generated by design may be used for sales. In most cases, this means that software

integration is not comprehensive enough, so that data cannot be automatically transferred from one program to another.

It is a challenge to ensure the similarity of data created in different departments of companies. This is because different departments use different methods for processing and storing data. One challenge this poses is to keep track of the latest versions of documents, because the document can be stored in multiple locations at the same time and if it is possible to edit the same document simultaneously by multiple authors. (Saaksvuori & Immonen 2008, pp. 9-15)

PLM software is a very big help in managing the day-to-day information management of a company, but PLM software is just a tool for more efficient management of processes. PLM software does not solve problems in itself, and it requires the company to continuously develop the program and create processes alongside the software. PLM software can be used to gain a competitive advantage over other companies. (Saaksvuori & Immonen 2008)

6.3 Items and itemization

Software for managing different product lifecycles is very often based on the use of different titles. By using a nomenclature, products, product elements or modules, components, materials or services can be organized and managed. With the help of nomenclature, the management of various product information is a systematic and standardized way. The scope of the nomenclature and the names the company uses depend on their needs, operating models and products. (Saaksvuori & Immonen 2008)

The itemization of the company and what item are found there greatly influences how the data is processed in the PDM system and therefore it is important to find out what data the items want to manage within the system. In some companies, items can be divided so that the oils, welding consumables and paints used in production are defined as items. (Martio 2015, pp. 51–53) See example items in *figure 22.* and some Valmet Automotive's items on *figure 23*.

Physical Items

- Systems, assemblies, parts, components
- Basic materials (Steel rods)
- Purchase components (Screws, Clamps)
- Self-designed components
- Spare parts

Process documents

- Quality handbooks
- Process diagrams
- Process descriptions

Manufacturing documents

- Drawings (Mechanical, electricity, electronics)
- 3D-Model
- Assembly and test introductions

Project documents

- Project plans
- Project schedules
- Memos

Figure 22. Example of different items (Martio, 2015, p. 52)

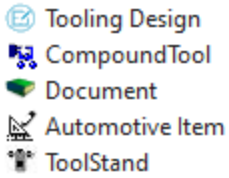


Figure 23. Some examples of Valmet Automotive's Teamcenter Items

The overly complex classification and division of items into subcategories leads to a slowdown in the process and causes much more work to be done in the management of the itemization. Good documentation of the nomenclature will make it easier to manage the itemization in the future. (Saaksvuori & Immonen 2008)

When designing an itemization, it is important to consider the processes of the company and what benefits each item brings to the information management of the company. Creating each new item costs money because it causes more work to manage them. The creation of each new item should be considered and made for some longer-term purpose. (Martio 2015, p. 51)

6.4 Component supplier management (CSM)

Purchasing component management (CSM) is an integral part of the PDM system. There are also separate systems for managing purchasing components, as well as service applications running on the Web. Purchasing components usually involve the fact that components from the same manufacturer may be found by several different suppliers. There are standards for component data management. ISO 13584 defines a general way in which component information could be presented. (Martio 2015, p. 87)

Companies may have contracts with certain manufacturers or suppliers. Depending on the construction of the products to be built, they may contain much or little less components to be purchased. The number of components purchased, as well as the number of different suppliers, affects the management of the company's purchasing components. For example, if very often the same components are tendered out to the supplier, it will cause the company's internal purchasing power libraries to have to be updated, at least for subscription codes.

The company may use the same parts from different suppliers, but the suppliers use a different order code. This needs to be considered while building a library to avoid building one that is exclusive to one editor, but to preserve the possibility of using multiple editors. For example, delivery difficulties may be the reason for having to change supplier.

7. BUILDING OPERATION MODELS FOR LIBRARY MANAGEMENT

Library project began by investigating the current practices within the target company and identifying the future needs for the library. One requirement for the library was that it must work in both Catia and NX since the target company's Teamcenter is integrated into both systems. After specifying the library requirements, components began to collect to be added to the Tooling Design library. The collection of components was done in close collaboration with tooling design designers. Once the necessary components were listed, parameters were defined to easily locate them in the future. After collecting the components and defining the parameters, the required 3D models were built, and other product information related to the components, such as manuals, was collected.

Library construction was firstly made on the target company's Teamcenter test server, after which it was reviewed with a specific group. Feedback was gathered on the library on the test server, and its functionality was tested. Once inspected the library built on the test server were inspected and addressed any issues that arose, the library could be set up on the target company's main server.

Before this project, the target company had some components already classified for other user groups than tooling design engineers. For example, there are libraries for robot components on the simulation side. The issue is that previous libraries were mainly created by external parties, resulting in a lack of knowledge transfer for in-house use. This work aims to make better in-house expertise in libraries.

In a Product Data Management (PDM) system, creating a library is a multifaceted procedure, as it must consider the requirements of the library's end-users and the library's capability to meet those requirements. Therefore, it is important to collaborate closely with the ICT (Information and Communication Technology) department and the design area during the process. The design department must understand their own requirements for the library, and they also need to understand what can be demanded from the library.

7.1 Analysis of the current situation

Current states were surveyed the current state by interviewing company employees. The interviews have included guiding questions, but the atmosphere has been very conver-

sational and open. The purpose of the interviews of the target company was to get information on how to act now and how one would like to act in the future. In the interviews, were also tackled the problem areas and their caused. For other companies, the purpose of the interviews was to obtain information mainly about their operating models in the use of standard libraries.

7.1.1 Present situation of the target company

Valmet Automotive has a long history of manufacturing cars, and they have continuously developed their production and production processes. Indeed, continuous development is one of the preconditions for continuity of action. In the target company, PDM has long been made using the so-called "File-based" method, in which a data hierarchy is built from shared Windows folders. In this case, employees are given access to the files they need in the same way that PDM programs only allow access to the project that you have been granted access to. The advantage of a "file-based" system is the speed of the system and as a system it is very clear and quick to learn. The file-based system differs from PDM software most in that it does not have a system for accepting files, which brings its own challenges then the number of files increases.

The file-based system is familiar to the target company and its use has been well adopted by the employees. The system itself poses challenges, as the File-based system does not itself include operating models but requires the development of its own processes and ensures that all employees operate according to the same processes. Whereas PDM programs can create stages that follow a specific type of workflow. One of the challenges of the target company is to harmonize operating models between different areas and business units.

The target company's future goal is to unify and streamline operating models to avoid unnecessary mistakes. The main problem with the file-based system is that due to ambiguities, false drawings or models are sent to the manufacture, which generates unnecessary costs. The challenge is also not to be sure that the most updated models are being worked on, for example in simulation. The introduction of Siemens Teamcenter aims to solve these challenges. Teamcenter has been in use for about 4 years and its use has been expanded year by year. The introduction of Teamcenter has been seen as a challenge with the large amount of data and the use of Rich Client (desktop version) in particular. Introducing the program requires a good knowledge from the user as it is quite challenging to use. Teamcenter's philosophy is very different from the file-based system. Teamcenter is also used differently in companies, as the configurations of the program are often different. The aim of developing the use of Teamcenter is to enhance

and facilitate design work. In particular, the process of approving files will change significantly with Teamcenter.

The introduction of Teamcenter also involves challenges and goals related to the harmonizing the use of purchasing components. The company uses catalogues for the selection of purchasing components and they are often pdf-format documents. There is not always full certainty about the location or accuracy of the documents, and it causes unnecessary misunderstandings regarding the selection of components.

In terms of the use of purchasing components, the challenge in the target company has been that designers use different purchasing components for some places even if it is possible to use the same ones. Or designers don't use purchasing components in situations where it makes sense to use them. The price of the part designed and made inside the house compared to the component purchased from the supplier can be significant. Situations like this have been exemplified using jig control pins. The result of using different purchasing components is that there will be a need for more different spare parts. Their aim is to unify the use of purchasing components and to increase their use in situations where it is justified.

The library process is an important part of Teamcenter's comprehensive deployment, as the library needs to be as comprehensive as possible before it can be efficiently transitioned to Teamcenter. File-based planned configurations are moved to Teamcenter, so that each component that is not already in Teamcenter will have its own item ID. This means that the Teamcenter comes with a huge number of item IDs, many of which are the same components, which again complicates the management of the components. With a library, it is possible that the components of the assembly that are later imported into Teamcenter can be replaced with components found in libraries, insofar as they are in the library. In this case, the number of item IDs required is reduced and all the same components can be on the same item ID and can be avoided the challenge of having the same component appear on many different IDs.

7.1.2 Other companies view on the standard libraries

Interviews have been conducted not only with the target company but also with two other companies operating in the industry. The focus was particularly on the utilization of Teamcenter's Classification Library in the operations of the companies.

The first company uses Siemens Teamcenter as its PLM system. Other PDM systems are integrated into Teamcenter, but Teamcenter is also utilized as the primary PDM. The

products supplied by the company, as well as their product structures, are often classified. Through library management, it is easy to determine, for example, what has been delivered to a customer when they request spare parts.

Approximately 10% of the items in Teamcenter have been classified, and the Classification library is actively in use. Different classified things, for example:

- Product portfolios for engineering and sales
- Raw materials
- Component libraries
- Manufacturing resource library
- Purchase components
- Design data
- Delivered equipment
- Service plans

Only the necessary attributes are aimed to classified objects. Extra attributes increase the workload in management and cause unnecessary confusion for end users. It doesn't make sense to assign all possible attributes to each item revision. Currently, Classification is the best way in Teamcenter to flexibly manage the attributes of objects. In the Classification library, attributes can be managed flexibly, including removal, addition, and modification.

They have duplicates of some classified objects because their users tend to operate independently, for example, in different business units. In such cases, classifying shared components can be laborious, and it might be easier for each to classify their own, even if some are duplicates. The existence of duplicates is almost a necessity in some cases if the library hierarchy is complex, and it is not possible to place two different users under the same hierarchy. Overlapping geometries can be interpreted later if deemed necessary. In the case of this company, the library hierarchy is so multidimensional that it has not been possible to define it as a single hierarchy tree.

The company utilizes the Geolos system, which allows the examination of similarity between 3D models. Similarity can be explored with a certain percentage of confidence. In Siemens NX, this is achieved through the "Shape Search" function. This functionality enables the interpretation of whether there is already a design in the Classification library or Teamcenter. For example, it can be used to see whether a 3D model from a supplier's catalog is already cataloged or available in Teamcenter.

In the case of this company, design reuse components were used without the Classification library. These components were created before the Classification library was actively in use. Reusing components and searching for them is done through the item's attributes. This is more challenging and not as efficient as using the Classification library. There is a future project to transfer these components to the Classification library. Making changes to a Teamcenter item is more challenging compared to modifying Classification attributes. Updating an item and its attributes in Teamcenter may cause system disruptions.

The second interviewed company also uses Teamcenter for both PLM and PDM purposes. They have implemented the Classification library with product updates. With the introduction of a new product, design processes are updated, and one aspect is the adoption of the Classification library. A part library is constructed to assist in the design of the new device, and this is utilized through the Classification library.

Previously, they have searched for reuse components based on item attributes. This has resulted in many duplicates and additional costs, as the same part is ordered under several different item numbers. For example, they have addressed this challenge by introducing the Classification library.

The company has classified commercial components as well as some custom-order components from certain suppliers. The company sees harmonizing smaller, in-house designed parts as a challenge since it can be difficult to find them in the library, and finding parameters for them may also be challenging. In situations like these, costs for classifying components could arise, but the components must be efficiently locatable in the library. For purchased components, they have classified only the item revisions.

They utilize the Classification library, especially in conjunction with Siemens NX's routing tool. The library contains components and the necessary "smart parameters" pre-configured to work seamlessly with the routing tool. Smart parameters, for example, enable connectors to automatically position themselves correctly. The components added to the library are always validated and ensured to be of the correct type. Managing the right components is made easier with the help of the library.

They have their own team responsible for maintaining the Classification library, ensuring that all parts are of the correct type and that there are no duplicates. If a user or designer would like to add one or more new components to the library, they fill in the component information on a pre-filled Excel form. The library team processes the request and veri-

fies if the requested part is already in the library. Once decided, the team adds the components using the information from the Excel form. The Classification team is the only entity authorized to add components to the library.

7.2 Classifying of the components

It is important to remember that the implementation of PDM in a company is a process that includes not only its adoption but also changes to the company's operating models. Updating the operating models in connection with the implementation of the PDM system is crucial because that's when the system can yield its benefits. (Martio 2015, p. 279) Teamcenter's Classification Library is one of those aspects that requires changes to operating models across various departments in the organization. It is not enough to create a functional library; in addition, models for library usage and updates must be established.

According to studies, there is a lot of evidence that standardizing components reduces the time engineers spend and improves product quality. This is especially true for products that utilize standardized design data, meaning that the designer selects the part from the library that includes design information. Incorporating this design information into the library component reduces, for example, the calculations engineers need to make.

In this work, the components to be cataloged are limited to jig components and their purchased components. The cataloging of in-house designed components for future consideration were also explored, but the main focus of this work has been on purchased components. Those in-house designed components were also briefly examined that might be reasonable to classify.

The target company had PDF catalogs for certain components that were utilized as support for design. The PDF catalogs primarily served as lists of the components intended for use in the design process. These catalogs were mainly created for Tünkers clamps and Festo grippers.

7.2.1 Library hierarchy

In this project, the design of the Tooling Design library hierarchy *(See figure 24.)* has been approached on a user group basis. The aim has been to create a library hierarchy that is as user-friendly and clear as possible. A clear library is more efficient to use and better serves its intended purpose. The library hierarchy has been defined using a "top-down" approach, where the main heading is divided into smaller units. The sub-library's main heading, "Tooling Components," indicates that this library is used in the Tooling

Design department, such as in the design of jigs. The target company's library has separate library hierarchies for other user groups, for example, the "Resource Management" library used by the simulation department.

In the first subgroup (Subgroup I) of the Tooling Components library, an activity-related categorization method has been employed. For example, components related to gripping and positioning form one group. The next subgroup (Subgroup II) is divided based on component types, for example to Clamps and linear motion.

Building the library hierarchy is always library-specific, and a classification like this may not necessarily fit the creation of a different type of library. In this case, a relatively low hierarchy was successfully created for the library, ensuring that subgroups are informative for the library user. The information contained in the headings helps the user navigate the library more quickly, thus finding the required component as efficiently as possible. In addition to informative headings, there are images in all the library's groups, enhancing efficient navigation.

In many places, it was a challenge to decide whether to build a hierarchy for different groups or to put them in the same hierarchy but with their own parameter. For example, the subgroups under the "Measuring and sensing" library could have put together a subgroup and separated by parameters. However, in this case it was more clear-headed to put them into their own groups, then it will be faster for the library user to navigate to the library of the appropriate sensor group.

Group	Sub group I	Sub group II	Sub group III
Tooling Components			
	Gripping and positiong		
		Clamps	
			Tünkers Heavy Clamps
			Tünkers Mini Clamps
			Tünkers Standard Clamps
		Linear motion	
			Linear guides
	Locating and Positioning		
		Misumi Pins	
			Diamond
			Round
	Measuring and Sensing		
			Cameras
			Distance sensors
			Inductive sensors
			Photoelectric sensors
			Sensor mounting items
	Mounting		
			Fixture Risers
			Gripper tubes
	Standard equipment		
		NAAMS NC Blocks	
			I-Shape
			L-Shape
		Rough guides	
			I-Shape
			L-Shape Inside
			L-Shape Outside
		Shims&spacer	
			Shmis
			Spacers
	Turn tables		
			Tünkers Expert
			Weiss TC Rotary Indexing tables
			Weiss CR Heavy Duty Rotary Indexing Ring

Figure 24. Tooling Component library hierarchy.

7.2.2 Classified components

In this work, purchase components used in the Tooling Design department were catalogued. The selected components were chosen from suppliers' catalogs, and only the variations deemed useful were cataloged. In this project, choices were made based on the components the target company had previously used in their past assemblies and those anticipated for future use. The goal was to simplify the selection of components by including only those that are used in almost every project.

The selection of components also had to consider the scenario when an external designer begins using the library for component selection. The library must contain a sufficiently broad range of components so that a majority of components can be selected using it. When used by external designers or those with less experience, the library also serves as a guiding function in the design process.

In this project, also the classifying of configurable components in Teamcenter's Classification library were explored. Classifying configurable components is necessary, for example, in the case of profile beams, and in this instance, for Gripper tube beams used in the construction of jigs. In the case of Gripper tubes, the same tube profile can

be ordered in various lengths, leading to a large number of different variations. Therefore, the library classifying method used for other components in this work would not be practical or would be very labor-intensive, given the enormous number of cataloged variations. This project did not go into deep configurable components classification. It was acknowledged that it is possible but requires further investigation. Challenges arise, for example, from the fact that the target company's Teamcenter is integrated with two CAD systems (NX and Catia), and the configurable graphics builder of Teamcenter's Classification library inherently collaborates only with the NX system. Consequently, it would not be possible to use configurable components directly from the library in Catia; they would have to be loaded into Catia through NX.

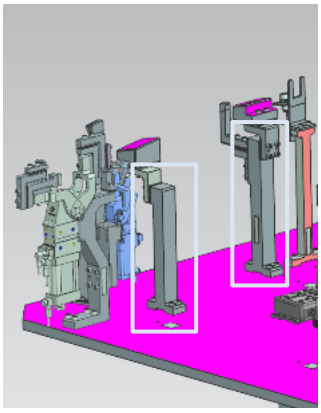


Figure 25. Fixture Riser in floor standing Jig

The need for cataloging internally designed components were also identified. Fixture riser components *(see figure 25.)* are crucial supports used to elevate components such as clamps from the jig's table surface upwards. These components are very similar, with the primary variation being in height. Currently, these components are primarily designed one by one in a customized way. In order to catalog these components, it would require further research into reusable components to standardize both the components and their usage.

7.2.3 File formats

Target company uses multiCAD systems so, it was wanted that the library would work in both Siemens NX and Catia. One option to achieve this is to create the original file in Catia and generate a JT file under the same item number *(see figure 26.)*. This way, the classified component can be used in both CAD systems. However, in this case, any modifications to the component would need to be made based on the original Catia file. To teamcenter's Classification library can be classified a variety of file formats, but when classifying components containing 3D data, compatibility between systems and file

formats must be considered. The library is directly compatible, for example, with original NX part/assembly files, but in this case, it cannot be directly utilized in Catia. For Catia, it would be necessary to convert, for example, to the STEP file format. Currently, there are no an automatic script in the target company's Teamcenter for converting STEP files.

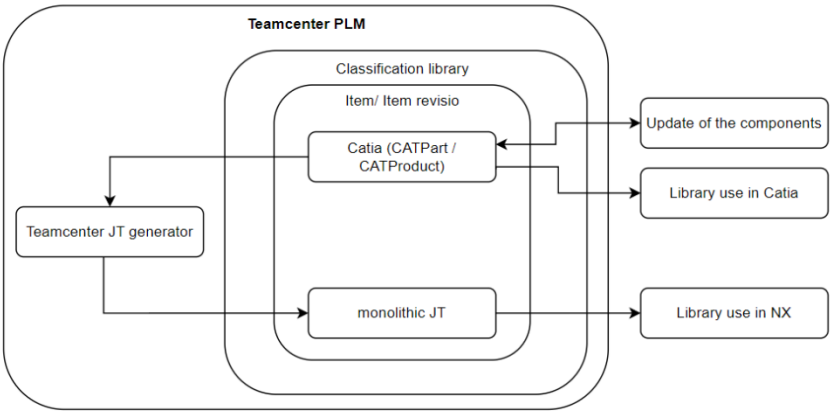


Figure 26. Target company file formats Tooling design library

7.2.4 Definition of the parameters

In determining the parameters, the approach was to keep it as simple as possible. Initially, only the components to be classified were assembled, and the consideration of parameters began only for the selected components. Parameters were assigned to components only to the extent necessary to fulfill all design requirements and to the extent needed to differentiate all variants from each other.

In the supplier catalogs, components have multiple parameters defined to differentiate variants from each other. When classifying, the selection of parameters was design-oriented, considering the information the designer needs when selecting components. Parameters included both features related to, for example, the direction of a clamp arm, and dimension-related aspects, such as the installation thread of sensors.

The parameters for many components were significantly simplified compared to the parameters provided in the supplier's catalog *(see figure 27.)*. Only the most essential parameters for the designer in the selection process were chosen. The remaining parameters can be found on the data sheet of the classified object.

Library parameters	Supplier catalog parameters
Supplier Version Type Clamp Arm version	Version Type Arm type Sensing system Holding torque max. Clamping moment at 5 bar Corresp. piston Ø (mm) Weight ~ (kg) B1...B22 L1...L21 S
4 Parameters	*55 Parameters*

Figure 27. Parameters in library and supplier catalogue in Standard Clamps

7.2.5 Library management and processes

As mentioned earlier, the system itself does not solve problems, it requires additional processes to function efficiently. The target company has not defined a process for classifying components. Effective use and management of a standard library require clear processes to support the operation. Managing a standard library requires strong collaboration between the ICT department, designers, and other library users. The following proposal outlines a possible process for library management in the future. This process is primarily designed for cataloging objects containing 3D data.

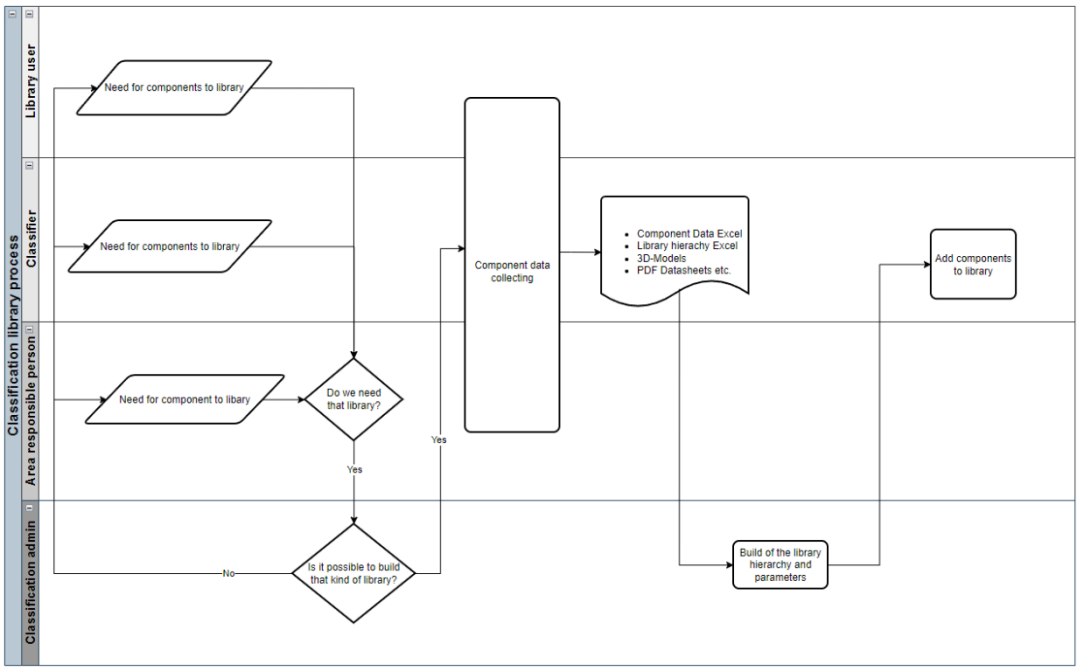


Figure 28. Suggestion of Classification management process

This process *(see figure 28.)* defines four different roles related to classifying and its use. The "Library user" is a person who utilizes the library and can be, for example, a designer or any other party browsing component libraries. The "Classifier" is a user with the authority to add components to the library. The "Area responsible person" is an individual responsible for a specific area of the library, such as the Tooling Design library. They make decisions about what is added to the library and how components are removed. It is crucial for them to have a clear understanding of the components used in their area to choose suitable ones. The "Classification admin" is a person responsible for constructing the Classification library structure in Teamcenter according to the given specifications. Their responsibilities also include managing the attributes of the library. The components data collecting process is described in *figure 29.*

The library needs to be updated in situations where there is a desire to use new suppliers or if a supplier discontinues the delivery of a certain component. The "Area responsible person" makes decisions related to updating the library, ensuring control over the process. Components can be added to the library within the existing library hierarchy and with existing parameters. There may also be situations where new parameters need to be created within an existing category.

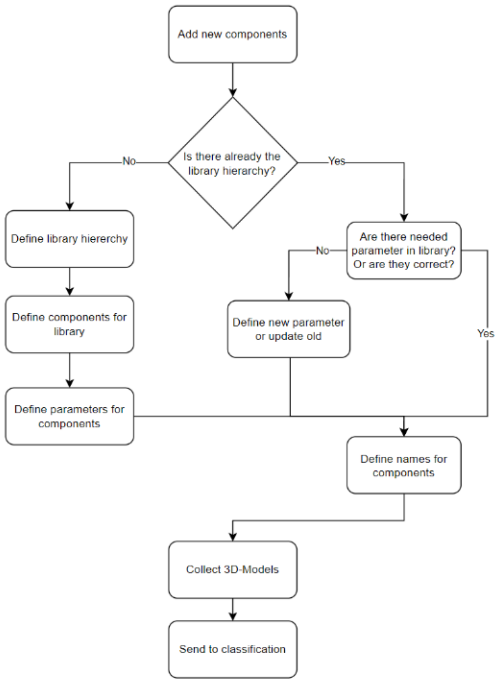


Figure 29. Data collecting process

7.2.6 The challenges related to library management

The construction and use of the library involve many aspects that could be approached in various ways. It is crucial to find a suitable operational model and decide to use it. Some challenges are related to the general library management of standard components, while others are specific to the company, depending on factors such as different system integrations. Common challenges in library management include, for example:

- Classifying item or item revision *(see figure 30.)*
- Update of the components → New Item or Item revision
- Supplier update the catalogue but the library doesn’t update automatically
- Wrong component/3D-model/parameter in library
- The library does not have the necessary components
- Library and library attribute management

Most companies, especially when it comes to purchased components, have chosen to classify the specific item revision. When an item is classified, the latest revision is also updated in the library. In many cases, for purchased components, they are not revised; instead, when the component is updated, a new item is created. Classifying only the item revision can simplify change management, ensuring that the classified object doesn't get updated accidentally if it is revised. In situations where a classified component is revised,

and there's a desire to have both the new and old revisions in the library, it becomes crucial to classify only the item revision.

Updating components can be done either by revising the old component or by creating a new item, classifying it, and removing the classifying of the old item.

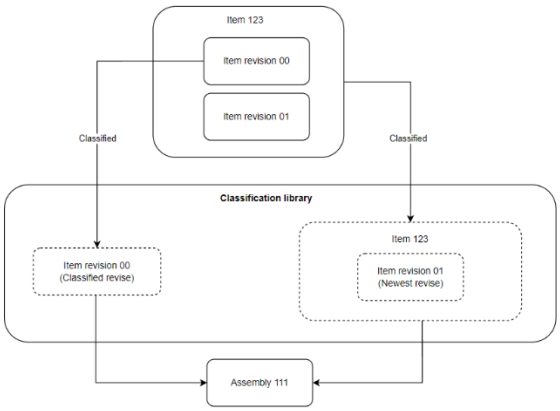


Figure 30. Classified Item and Item's revise

When the supplier updates their catalog, it may not necessarily provide information to the buyer. In such cases, it is important to keep one's component library up to date. This can be done, for example, by requesting information from the supplier about any changes to the catalog before each major project and updating the library accordingly.

Managing the library can pose challenges if the operating procedures are not defined. Defining operating procedures is crucial to prevent each individual from managing the library in their own way. Managing the attributes of the library is already a challenging task that requires clear practices.

The challenges faced by the target company in terms of classification library are as follows:

- Needs of kinematics
- Classify part or assembly → Affects to adding the kinematics *(see figure 31.)*

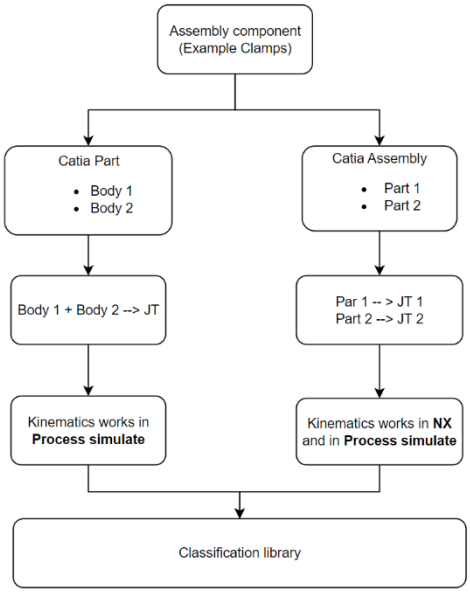


Figure 31. Kinematics to Part or Assembly

The library processes of the target company mainly relate to the utilized multi-CAD system. Library processes based on Catia can be done in two ways: as a part or as an assembly. Kinematics can be applied to a part, but it only works in Process Simulate and not in NX. If library processes are done as an assembly, it is possible to create kinematics that work in both Process Simulate and NX. In the target company, the need for kinematics is situational, depending on when it is required. Library processes for purchased components are simpler as parts if there is no need for assembly.

7.3 Benefits in the design process

The library has not been implemented during this project, so describing the benefits of the library is based on evaluation, challenges, and source material. The target goals for the company regarding the use of the library include standardizing component usage, managing duplicates, and providing guidance to external designers on the components to be used. Duplicate management becomes particularly relevant when a File-based system assembly is transferred to Teamcenter. In this case, each component receives its own Item ID, resulting in multiple Item IDs for the same parts. Managing assemblies where each identical component has its own ID can be challenging. With the library, duplicates can be replaced with components found in the library.

The library enables the management of components that designers are intended to use. Components in the library can be easily and flexibly updated. Searching for components in the library is also significantly easier than using Item attributes, which could be another option for component reuse. A library based on Item attributes is also much more

challenging to update, as it lacks a dedicated user interface, unlike the Classification library.

It can be assumed that the designer's work will speed up when the necessary components are easily accessible, and 3D models can be obtained directly from the library. However, with this information, the exact time saved by the designer when using the library cannot be assessed, a more detailed examination would be needed for such an evaluation. In this work, two different jig assemblies were analyzed to investigate what percentage of the components in these assemblies were included in the library in this project. All components in the assemblies, either with their own drawings or ordered as a single unit, were counted. First, the Gripper Jig *(see figure 32.)*, which is attached to a robot arm, was examined.

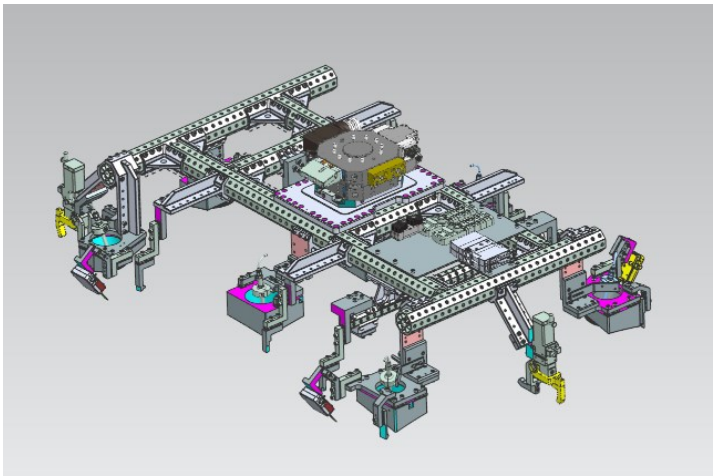


Figure 32. Gripper Jig

For the Gripper Jig, 17% of all counted components have been classified in this project, and 10% of all the various components in the assembly. In the assembly of the Gripper Jig, the percentage of design components is small compared to all counted components, but it is nearly half when considering all the different components *(see figure 33&34)*. This assembly contains many of the same purchased components.

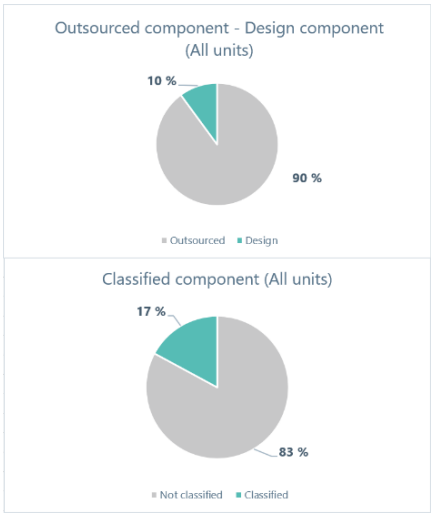


Figure 33. Components in Gripper Jig (All units calculated)

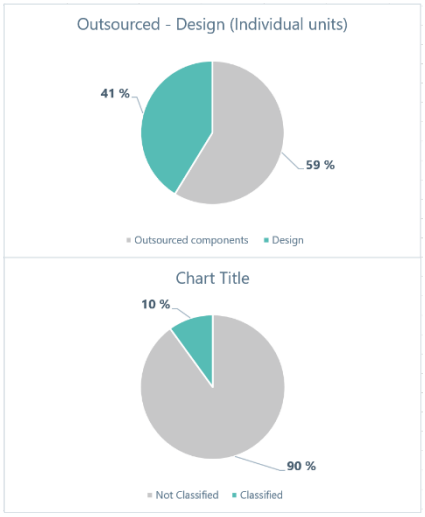


Figure 34. Components in Gripper Jig (Every different unit calculated)

For the floor-mounted jig *(see figure 35.)*, the results are very similar. The main difference is that the number of in-house designed components (design components) was higher. For the floor-mounted jig, 23% of all components have been classified, and for all different components, it is 12%.

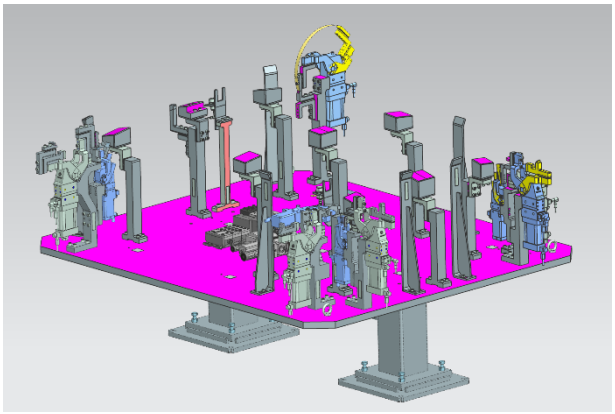


Figure 35. Floor mounted jig

When analyzing two different assemblies, components were identified that could be classified in future projects. For purchased components, potential candidates for classifying could be the support brackets and extension brackets of the “Gripper Tube” system (*figure 32.*). The components of the Gripper Tube system are purchased parts and come directly from the manufacturer's catalog. Another potential area for classifying could be “Fixture Risers”, which are used to raise components from the jig table (*figure 25.*). Standardizing the use of these components requires further research as it involves their redesign. Through redesign and classifying, costs could be adjusted, and the work of

designers could be facilitated. Currently, almost every Fixture Riser is designed separately with its own drawing, even though the most variable parameter is the length.

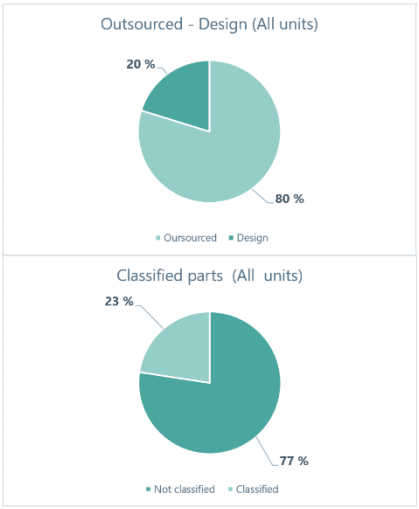


Figure 36. Components in floor standing Jig (All units calculated)

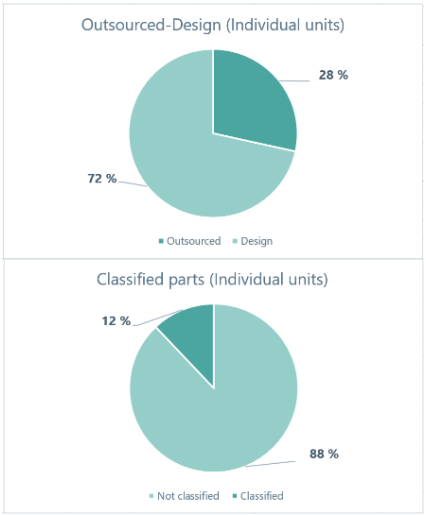


Figure 37. Components in floor standing Jig (Every different unit calculated)

There are numerous advantages to component classification for the design process. The designer can quickly locate the necessary part in the library. The library makes it easier to standardize the use of components both within the company and for external designers. The use of the library efficiently manages duplicates.

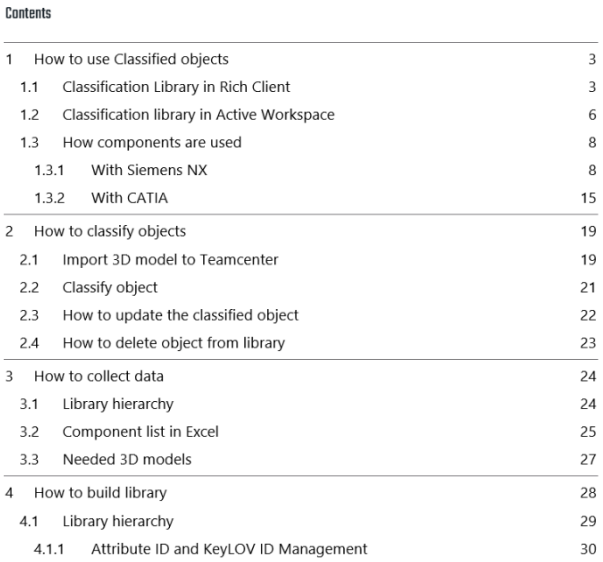
7.4 Instructions for using the library

The usage instructions for the library have been created to better the target company's skills in using and building the library. As mentioned earlier, the company has mostly outsourced the construction of libraries, resulting in insufficient internal expertise. The creation of instructions also plays a crucial role in establishing common practices. The purpose of the instructions was to provide users with the necessary skills to start using the library.

The instructions were created as a four-part document *(see figure 38.)*, considering the stages of the library process and the participants at each stage. The goal was to make the instructions to each user group. For each user, instructions were written with sufficient information without any unnecessary details about the library or library processes.

The section topic “How to use classified objects”, intended for basic users, covers the basic usage of the library. It explains how to search for components in the Teamcenter Rich Client and Active Workspace, as well as how to use components in Catia and NX.

The section “How to classify objects”, designed for slightly more experienced library users, provides information on how to classify an object into an existing library and how to



Contents

Figure 38. Classification guide Table of contents

update or remove classified objects. For those responsible for collecting component data, the “How to collect data” section includes instructions on the information that needs to be gathered before classifying a component, along with an explanation of the Excel templates used for data collection. The “How to build library” section is intended for library admin users and outlines the procedures for constructing the library.

The library instructions were a valuable addition to the target company's library project. Teamcenter's Classification Library is a new concept for many employees at the target company, and not everyone has the expertise to use it. The instructions help facilitate the effective utilization of the library in the future.

7.4.1 Building the library for Teamcenter

Building the Teamcenter Classification Library involves using the Classification Admin application *(see figure 39.)*. With the Classification Admin application, library hierarchies, parameters, and many other library-related features can managed. The construction of the library begins by creating an appropriate hierarchy. After finishing the hierarchy, the correct parameters are created and linked to the groups within the hierarchy.

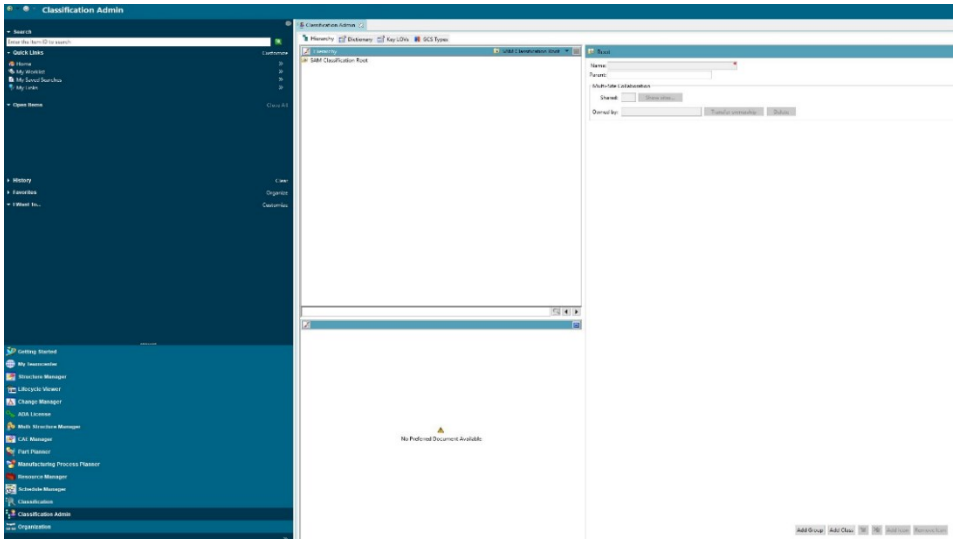


Figure 39. Classification Admin application in Teamcenter

1. Add needed hierarchy levels to library *(see figure 40.)*

In the Classification Library, library hierarchies and groups with various functionalities can be created. For instance, an “Abstract Class” can be established, where attributes added to it are inherited by subcategories. In the part of the library hierarchy where components are stored, a “Storage Class” is assigned.

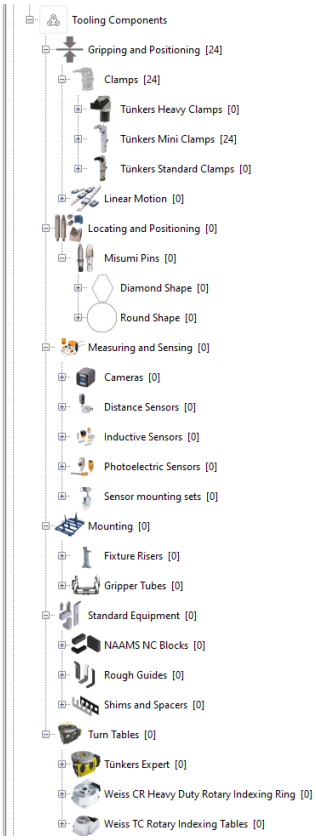


Figure 40. Tooling library hierarchy in Teamcenter

2. Add ”View” in every group where will be objects

Each class that stores components is supplemented with a “View” *(see figure 41.)*, which refers to the interface where attributes will be added in a later stage. The view is the perspective that the library user sees in Teamcenter's Rich Client. The view can be extensively customized, for example, in terms of the order of parameters. With the view you can build the user interface for each group *(see figure 42.)*.

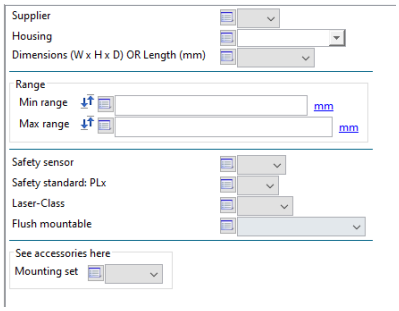


Figure 41. Sensor library User view in Teamcenter Classification library

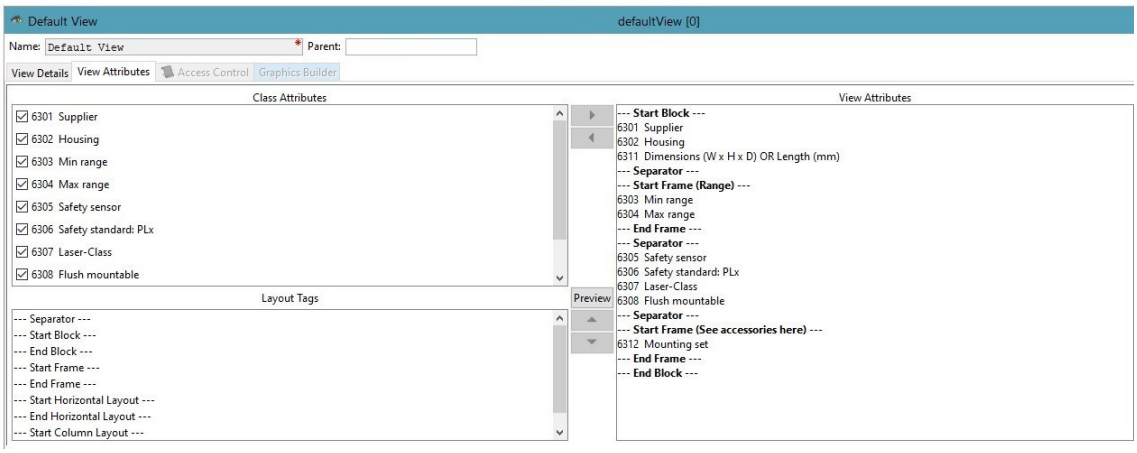


Figure 42. Sensor View in Classification Admin application

3. Create needed KeyLOV (Key List of Values) lists

Parameters can be created either through KeyLOV lists, in which case the parameter gets a so-called “Drop-down window” from which the user selects the parameter from predefined values. Another way is to create a parameter as an open parameter, allowing the definition that the user can input text, an integer, a decimal number, or a date into it. In *figure 41.*, for example, the “Safety sensor” parameter is built using a predefined list, and the “Range” parameters are open parameters where only positive integers can be entered. With “Open attributes” you can define that user can add there text, decimal numbers, integers or even date format.

4. Create needed attributes and add those to KeyLOVs, if needed

Each created parameter needs an attribute, and these are created on the “Dictionary” tab in *figure 39*. If a list of predefined options is to be added to the attribute, they are created on the “Key LOVs” tab in *figure 39*. If a list of predefined parameters is added to the attribute, the created list ID must be linked to the attribute.

5. Add attributes to classes

The desired attributes can be added either to the parent class, in which case the attributes inherit to all its subclasses. The attribute can also be added straightly to the class where components are stored.

6. Add attribute to View and build Rich Client user interface

After adding the necessary attributes to each class, they must be added to the views. Views make the parameters visible to the use.

In this work, the detailed process of building the library in Classification Library is not extensively covered. Building the library involves numerous details, and it can be customized extensively according to the needs of the company.

7.4.2 Collecting the component data

As a one result of the work Excel template were made for collecting component information. During the project, Excel sheets were developed for managing the library hierarchy and attributes, primarily by the company's other personnel. The Excel template was designed to streamline the classification process and ensure that all essential information is gathered when classifying components. The use of Excel makes the classification process significantly clearer and easier to implement in Teamcenter Classification.

By using the Excel template *(see figure 43.),* it can be ensured that those who compile the components for library classification create a comprehensive list with all the necessary information for classification. This way, the data collector doesn't need an in-depth understanding of the classification library's functionalities but the library will be build with corect inforamtion by library admin.

	Ordering code (Component's name)	Supplier	Version	Type	Clamp Arm version
TC Attribute ID		*6002*	*6003*	6005	6006
TC KeyLOV ID (Option)		*-6002*	*-6003*	-6005	-6006
		Tünkers	*V*	40.5 BR2	*A00 (No arm)*
		-	*V2*	40 LW	*A10*
		-	-	-	*A11*
		-	-	-	*A12*
		-	-	-	*AL10*
		-	-	-	*AL11*
		-	-	-	*AL12*
		-	-	-	*A50*
		-	-	-	*A51*
		-	-	-	*A52*
		-	-	-	*A60*
	Mini Clamps				
	V 40.5 BR2 VARIO CLAMP				
	V 40.5 BR2 A00 T12	Tünkers	V	40.5 BR1	A00
	V 40.5 BR2 A60 T12	Tünkers	V	40.5 BR2	A60
	V2 40.5 BR2 A60 T12	Tünkers	V2	40.5 BR2	A60

Figure 43. Excel template for data collecting in Mini Clamps

8. PROCESSING AND ANALYSIS OF RESULTS

The results of the thesis were obtained through a literature review, interviews, and active involvement in building the library. As a result of the work, an efficiently functioning component library was constructed for the target company, consisting of standardized purchased components. Additionally, guidelines for using the library were developed, along with a proposal for the target company's future library management process.

The thesis includes a literature review, which was used to investigate the functionality of PLM/PDM systems and their utilization as part of company processes. It also explores the use of standard components in various case studies and generally in engineering. The literature review aims to clarify the concept of reusable components and how they are utilized. In the literature review, efforts were made to find case examples of different component libraries and how these libraries have been used. The theoretical section also covers alternative methods for object classification. Information related to the use of the library was also obtained by interviewing employees from two other industrial companies.

In the practical phase, the initial situation, and motives for building the library in the target company are described. It outlines how the library is constructed and what needs to be considered during its construction. The practical section also includes a proposal for the library management process in the future. The practical section also evaluates the benefits that a library built as a result of the work brings to the planning process of the target company.

Research questions were formulated to address issues with no straightforward answers. The answers to these research questions provide alternative ways to operate, as the methods depend on the companies and application contexts. The intention was not to find a single solution but rather to identify solutions that suit the needs of the target company.

8.1 Main findings

The result of the work was the creation of a component library meets to the needs of the target company, along with an instruction document for the use and management of the library. The documentation for the library is divided into four areas based on each user group: *How to use classified objects*, *How to classify objects*, *How to collect data*, and

How to build the library. Since there are multiple user groups involved in the use, construction, and management of the library, it was crucial that each user group receives information tailored to their specific needs. The document is important also in the sense that it makes the future use of the library easier and facilitates its adoption by an increasing number of employees.

In the specification of the objects to be included in the library, the faceted classification method is used. This means that parameters do not need to be used in a hierarchical order. By doing so, the objects stored in the library become easier and more efficiently discoverable and usable for various needs. The library hierarchy itself can be enumerative, as this allows for faster navigation since the hierarchy is predefined. In many cases, the library hierarchy remains similar, so it is easier navigate with enumerative method.

Surprisingly, the structure of the component library built as a result of many studies shared common features with Teamcenter's Classification library itself. The Classification library is flexible to use, modify, manage, and can be easily integrated into various systems, such as CAD systems, allowing components to be easily utilized. The adoption of the Classification library does not require significant efforts. Although this work did not involve building the structural functionalities of the library but rather utilized the library in the roles of a basic user and an admin, it provided valuable insights into the fact that the Classification library is an excellent place to store objects. Teamcenter continually upgraded its software, so the research results and customer needs are reflected in the library's structure.

8.2 Significance of the study and limitations

As a research method, action research was well-suited for this study. There was a lot of collaboration, and many employees from the company participated in the project. The end result of the work has been an iterative process influenced by various employees. The project involved employees with different areas of expertise, providing diverse perspectives. The use and construction of the library require collaboration from employees in various areas, and it was beneficial that they were involved in the entire process of this work from start to finish. And the project was iterative process and that kind of situation there are no one right way to work but there are many ways to do that.

In this work, compared to many others on the same subject, the construction of the library is at a slightly different level. In many studies, the entire structure of the library is built from scratch, but in this work, the structure provided by Teamcenter's Classification library has been leveraged and adapted to the needs of the project. Another significant

difference from other studies is that they often focus on the storage of design information containing components and parametric components, unlike in this work, which concentrates on standard and general components that do not involve this type of design data. Other studies do not address the suitability of potential commercial applications for the researched topic; instead, they aim to independently solve the challenges related to library management.

The scientific novelty of the thesis is not very significant, but it has successfully generated applied knowledge for the target company. When viewed at a general level, the novelty value of the work may not be as significant. However, within the target company, new knowledge and practices have been achieved. The scientific aspect has supported the practical part of the work, but it could be more comprehensive and provide better answers to the problems. The novelty value of the work could have been increased if a more in-depth examination had been conducted, for example, on the utilization of reusable components in design and when it is beneficial to use them.

The validity of the study may be affected by the inadequate adherence to the research method. The most significant challenge related to validity in this work is undoubtedly the attempt to find answers to the benefits a new library brings to the design process. The methods used to investigate this were not sufficiently reliable, and the results cannot be considered very meaningful. The findings are mainly based on interviews and assessments of potential benefits, but the benefits generated by the library were not measured with very precise methods. The benefits of the library were also measured by evaluating the quantity of different components in jig assemblies and comparing previous assemblies to the moment when the library is used, with the calculation of the library components used in the assembly. The benefits could have been assessed more accurately, for example, by measuring the time spent by the designer during the previous process and comparing it to the time spent when the library was utilized.

In this work, the research process is relatively well documented, so the research replicability is reasonably good. Also, the literature review section is fairly well documented, so replicating is possible. A similar study could be replicated in various technical companies with similar needs. Library management is also utilized in many other fields, so in that sense, it is possible to implement the findings of this work in other industry companies. However, if a company does not use Teamcenter, then this work can only be partially replicated. The general theories discussed in this work regarding library management are applicable to various types of libraries, or this work can be viewed as one alternative library model. Still, the technical construction of the library itself is only beneficial in the context of Teamcenter's Classification library.

The main limiting factor for generalizability in the thesis is that the library is built using Teamcenter's Classification library. Matters related to component standardization can be generalized, but a library of this kind can only be built if the company uses Teamcenter. However, the benefits of the library are somewhat generalizable, but it is crucial to consider what components are being library and for what purpose they are used. Regarding external interviews, it would have been possible to interview companies that do not use Teamcenter as their main system. This would have provided a perspective on how libraries and component standardization are utilized in different types of systems. The target company's field is operation are not such a limiting thing because same kind of processes are used also other business sectors.

The research process may involve various errors, and in this case, potential sources of error could include the results obtained from the literature review. The literature review is not so well-documented that there might be a possibility that some essential articles were not found, or assumptions have been made based on old research results, leading to a distortion of the research findings. It is also possible that the information or theories found in the literature review are outdated. For example, articles dealing with component reuse and design reuse were written before the year 2000, so they may not fully correspond to the current knowledge on this topic, given that this subject has been extensively researched in the last 20 years. Communication between the researcher and the company's employees may have introduced errors into the practical results if, for example, the needs of the employees were not sufficiently understood, or if the researcher made incorrect assumptions. The automotive industry was relatively new to me at the beginning of the study, so a lack of knowledge about the industry may have led to errors in the practical results of the study. Errors could also have been caused by inadequate adherence to the research method.

8.3 Answers to research questions

Answers to questions which were previously presented.

1. *What is the biggest reason that there are no standard libraries?*

The target company took use the Teamcenter PDM system about 4 years ago. Four years is a relatively short time for such a significant change in operating models, especially when the transition to the system has been gradual. The implementation of the target company's PDM system has been carried out gradually, building different parts of it over time. Standard libraries were previously created mainly on a project basis and by outsourcing the work to an external party. As a result, there hasn't been sufficient in-

house expertise in library management. The target company lacks clear procedures for library management, which is one reason for the absence of libraries. Additionally, the target company has not had a designated responsible person specifically related to the Classification library.

Although the target company has already took use the Teamcenter PDM system, not all design work is done in Teamcenter; some of it is done in a file-based system. Therefore, there hasn't been an urgent need for a tooling design library in Teamcenter Classification. In other areas, such as simulation, robot libraries have been implemented earlier.

2. *How standard library promote design process?*

Companies often choose components from suppliers' catalogs for use in their designs. These selected components are listed in a document or system. If it is desired that designers use these specified components, they must be easily accessible, up-to-date, and may include a 3D model. Previously, tool designers had PDF catalogs listing components intended for use. The challenge with a PDF catalog is that finding the right components is slow, and it does not provide a 3D model. Parameters cannot be linked to a PDF catalog to enable searching for components.

The library provides the right parameters and updated 3D models for components. With parameters, it is significantly easier to find components, and the designer's work speeds up when the 3D model from the library can be directly integrated into the assembly being worked on.

When using a PDM system, the management of items is an important part of efficiency the use of system. Through library management, the number of items can be reduced, and the same component can be easily used with just one item. This helps avoid challenges, such as ordering the same components with multiple items.

3. *Which parts of the Jigs should be put to library so that they are useful in production design?*

Generally, companies have classified both purchased components and design components. Classifying design components involves many more challenges than classifying purchased components, and this work did not delve into classifying design components. The focus of the thesis was to identify the purchased components of jigs that are worth classifying.

The target company had catalogues ready for the use of certain components, and all components from those catalogues were placed in the library as they were. For example, in the sensor catalog, about 17 components related to sensors were collected, and it was

necessary to classify them. In the case of components that had already been standardized by the company in advance, the decision on which components to classify was easy.

For those components where the company had not standardized, the commonality of component usage was assessed. Only the variations of selected components that are used very frequently were chosen, and all rarely used components were left out of the library. The selection of components was largely guided by how and what kind of components designers had used previously. In library management, the goal was to avoid classify unnecessary components, as having those variations in the library does not bring any added value to the designers. Components that were considered unnecessary for library management, for example, were the variations of components used very rarely or not at all.

It is useful to catalog at least all purchased components of jigs, the use of which is repeated in multiple jig assemblies. It is also beneficial to catalog design components of jigs, but for these components, they must be specifically designed for reuse to ensure that the classified component works in multiple applicable applications.

4. *Which parameter should be used libraryable parts so that designer can find them effectively?*

Parameters are an important part of classifying and component reuse. Through parameters, a designer or library user can efficiently find the components they need. Parameters can be defined in many different ways. In this work, the components were of such as this that they did not contain design information, meaning information that the designer needs to determine when selecting a component.

A component containing design information may include, for example, strength calculation-related data, or in the case of clamps, it could be the required compressive force at a certain distance. In such cases, the system selects a suitable component based on specific requirement parameters. In this situation, the designer does not have to determine the type of clamp needed for a particular application. Instead, they choose a parameter that meets the requirement and obtain a clamp that satisfies the specification.

In this work, the components that were cataloged do not contain design information, as it has not been deemed useful for these components. The specified parameters have been determined primarily based on the properties of the components. For each component group, components have been defined from the perspective of how designers choose components and which features are important to them. In the case of clamps, for example, compressive force or the dimensions of the clamp were not essential infor-

mation for the designer, so they were removed as a parameter. For mini clamps, parameters such as the opening direction of the arm, cylinder version, and arm version were defined. With these parameters, all the different variants selected for these components can be determined in the library.

5. *How should the hierarchy of the component library be made so that it is useful for designers?*

The library hierarchy is strongly related to how efficient it is to navigate within the library. There is no definitive answer to what kind of hierarchy is advisable to build in a standard library. The library hierarchy depends heavily on the types of components a company intends to catalog or the quantity of components. It also significantly influences the library hierarchy to consider what types of user groups the library serves.

In this work, the structure of the library hierarchy was approached based on user groups. The hierarchy follows a "Top-down" approach, where the entirety is presented first, followed by its subgroups. The library has one branch for each clearly defined user group. In this work, the user group was Tooling Design Engineers. This allows placing all components important to a specific user group in one place, eliminating the need to search for components in multiple locations within the library. The library hierarchy was made to be “low” so that it would be quick to use.

Defining the library hierarchy based on user groups carries the risk of creating duplicates if multiple groups want the same components in their respective libraries. For example, in the Tooling Design library, some sensors may be used by both Tooling Design Engineers and Automation Designers. From the perspective of library usability, it might be easier to manage duplicates than to build a library hierarchy that is efficient for all user groups.

In the sub-hierarchies of the library, the practice was followed so that in the first sub-level, components are grouped into their own categories based on function of the component. In the next sub-group, components are further divided based on component type. After that, subsequent sub-groups are a mixture of the higher hierarchies.

When contemplating the hierarchy of the library, there are situations where one must consider whether a certain level of the hierarchy should be a parameter or a separate part of the hierarchy. For example, in this work, the clamp library includes subgroups: "Heavy Clamps," "Mini Clamps," and "Standard Clamps." This could have been done using a parameter, eliminating one subgroup and simplifying the library hierarchy. In this case, library would be more illustrative, and different clamps would be easier to find if the clamps are divided into its own groups. Another reason was that these three different

clamps had very different parameters, and adding parameters to the library group that don't apply to all components in that library would have been necessary.

The most important aspect when building the library hierarchy is to consider who will be the end user of the library and from what perspective the library is created. It is also crucial to take into account the types of components that are being classified and the requirements they impose on the hierarchy. A challenge when considering the library hierarchy may be, for example, that the company is divided into business units, each with its own practices, but they all use the same library.

8.4 Affects to design process

The standard component library built in this work has not been implemented at this stage. Implementation requires a project that is done entirely in the Teamcenter environment. The results regarding how well the library serves users are subject to interviews and evaluation. Based on the interviews, an assessment can be made of how the library's use affects Jig design.

The library facilitates Item management, making it easier to manage duplicates since the components in the library are easily accessible to everyone. Duplicate management may not be a significant issue for an individual designer, as duplicates are probably not used in a specific designer's assembly. However, in a situation where a smaller assembly is integrated into a larger whole, there may be duplicates within the assembly.

In Teamcenter, it is easy to see where each component has been used. This is helpful, for example, in spare parts management, as it allows for a quick overview of how many of each component is in production.

From the designer's perspective, the library provides easy access to components and their 3D models. Designers don't have to spend time searching for 3D models on suppliers' websites. In addition, not all suppliers offer all the necessary 3D models for download; some need to be requested separately, making the process of obtaining 3D models laborious.

Overall, designers benefit from the implementation of the library, especially in terms of time saved. In some cases, the library can replace self-designed parts with purchased components, resulting in cost savings.

The library's benefit is also undoubtedly in the ability to manage the usage of components, ensuring that not all designers choose their own kind of components. The library allows for an easy way to specify the components that designers should primarily use.

This can also lead to cost savings if the same components can be ordered in larger quantities.

8.5 Development proposals

The target company's library is not entirely complete, and its development needs to be ongoing. During the project, a few other areas for improvement were identified, which could be worth exploring in more detail.

From the library's perspective, the possibility of librarying configurable components remained unresolved in this work. For instance, the rail of linear rails, which can be ordered from the supplier with a customized length. Storing all variations in the library may not be practical in this case, as many variations are likely unnecessary and not used. Classifying a configurable 3D model could address this challenge, but it is still unclear how this would be technically sensible to implement.

For future research, it could be worthwhile to delve into standardizing many other in-house designed parts of the jigs. Such parts may include, for example, Fixture Risers or components of the jig's base. Jigs also have potential for modularization, and, for instance, the bases of jigs could be modularized to use a few different variations. Through modularization, the design time could be reduced, allowing for better responsiveness to market demands.

Concerning the librarying of in-house designed parts and their drawings, it is essential to consider the multi-CAD system used in the target company, where components must be compatible with both Siemens NX and Catia. The original 3D model and drawing cannot be in the same format; for example, one system may use JT model or STEP AP242, while the drawing might be in PDF format.

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