NOVA IMS Information Management School

MGI

Master Degree Program in
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Development of a mapping system engineering approaches to classic product development processes of technical products

A work project of project management in product development

Ziya Serkan Demircan

Work Project

presented as partial requirement for obtaining the Master Degree Program in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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DEVELOPMENT OF A MAPPING SYSTEM ENGINEERING APPROACHES TO CLASSIC PRODUCT DEVELOPMENT PROCESSES OF TECHNICAL PRODUCTS

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A WORK PROJECT OF PROJECT MANAGEMENT IN PRODUCT DEVELOPMENT

by

Ziya Serkan Demircan

Master Thesis presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Information Systems and Technologies Management.

Supervisor: *Vitor Duarte dos Santos*

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Rules of Conduct and Code of Honor from the NOVA Information Management School.

Ziya Serkan Demircan

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ABSTRACT

The automotive industry faces the challenge of meeting customer requirements while ensuring technological advancements, fast and cost-effective development, and high-quality production. Information systems play a crucial role in efficiently designing internal processes and meeting customer demands. Personalized solutions are increasingly adopted to cater to individual preferences while maintaining up-to-date technology. Information systems are utilized to record and manage customer requirements, optimize production processes, control inventories, and facilitate effective communication between departments. Product data management (PDM) solutions are widely employed, with 77% of automotive companies implementing them. PDM encompasses the storage and management of data relevant to product development, supporting the entire product lifecycle. As product complexity grows, efficient management of product data becomes essential, along with the optimization of business processes to shorten development time and parallelize tasks. CAx coordination, involving computer-aided design (CAD), manufacturing (CAM), and engineering (CAE), ensures smooth communication and coordination across the product development process. PDM systems act as intermediaries between CAx coordination and enterprise resource planning systems, facilitating seamless integration of design and manufacturing processes. Leading providers of enterprise resource planning and CAD systems offer software solutions for product lifecycle management and PDM, enabling centralized and accessible product information, streamlining development and management processes.

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LIST OF ABBREVIATIONS AND ACRONYMS

3D	3 Dimensional
ALM	Application Lifecycle Management
AR	Augmented Reality
BPM	Business Process Management
BPML	Business Process Modelling Language
BPMN	Business Process Modelling Notation
CAD	Computer-Aided Design
CAE	Computer-Aided Analysis
CAM	Computer-Aided Manufacturing
CSM	Current State Map
DMAIC	Define – Measure – Analyse – Improve – Control
DoDAF	Department of Defence Architecture Framework
EDM	Engineering Data Management
EFQM	European Foundation for Quality Management
EU	European Union
FSM	Future State Map
IT	Information Technology
IoT	Internet of Things
MBSE	Model Based System Engineering
MMS	Modelling Methodology for Systems
MODAF	British Ministry of Defence Architecture Framework
OEM	Original Equipment Manufacturers
PDCA	Plan - Do - Check – Act
PDF	Portable Document Format
PDM	Product data management
PLM	Product Lifecycle Management
RFLP	Requirement, Functional, Logic, Testing
RPA	Robotic Process Automation
SAFe	Scaled Agile Framework
SCOR	Supply Chain Operations Reference

STEP	Standard for the Exchange of Product model data
VR	Virtual Reality
VSM	Value Stream Mapping

1 Introduction

This chapter serves as an introduction to the research project, providing an overview of the context, motivation, academic background, and objectives. In today's automotive industry, meeting customer requirements and maintaining technological advancements, efficient development processes, and cost-effective production are paramount. Information systems play a crucial role in achieving these goals by managing customer requirements, optimizing production processes, and facilitating effective communication. The automotive industry is undergoing a digital transformation driven by trends such as increased vehicle connectivity, stricter environmental regulations, and rising customer expectations. This research project, part of a master's thesis program focused on Information Systems and Technology Management, aims to provide an implementation approach for a product data management system, incorporating interdisciplinary methods, and optimizing information flow within a car manufacturer's development processes.

1.1 Context

Nowadays, customer requirements are particularly decisive for the creation and development of automobiles. It is of crucial importance that vehicles that meet customer requirements can successfully establish themselves in the automotive market. Car manufacturers are therefore faced with a dilemma: on the one hand, they strive to offer personalized cars to as many customers as possible, on the other hand, they must ensure that the technology is up to date, and that development and production are fast, cheap and of high quality. Information systems are becoming increasingly important in the automotive industry to meet customer requirements and to efficiently design internal company processes. Successful establishment in the automotive market requires close adaptation to individual customer preferences. Automobile manufacturers are therefore increasingly relying on personalized solutions to meet the needs of their customers. At the same time, they must ensure that the technology used is up to date. This means that the development and production processes must be efficient, timely and cost-effective without compromising on quality. To meet these requirements, information systems are of great importance. In the automotive industry, they are used to record and manage customer requirements, optimize production processes, control inventories, and ensure effective communication between different departments. By using such systems, automotive companies can increase efficiency, reduce costs and improve the quality of their products (Rees, 2013).

According to a study by the RAAD, it was found that 77 percent of companies in the automotive sector are already using a product data management solution. Product data management refers to the storage and management of data relevant to product development, including product defining, depicting, and presenting information. This product data is made accessible in the later stages of the product lifecycle. In addition, product data management is an essential part of product life cycle management. It is a technical information management system that aims to support the entire product development process in companies in the automotive industry. All data generated and used by technical IT applications is stored and managed via an integration platform (RAAD Research, 2011).

The efficient management of product data is becoming increasingly important in companies, which can be attributed to the growing complexity of the products as well as increased efforts to optimize business processes. The increasing product complexity is accompanied by a continuous increase in product data and their networking. The optimization of business processes usually aims to shorten the development time and leads to greater parallelization of processes. The increase in product complexity presents companies with challenges in managing and organizing the growing amount of product data. Products today often consist of many components and subsystems that are in complex relationships with one another. Linking this information is critical to enable a holistic understanding of the product and ensure the development process runs smoothly. In addition, companies are increasingly helping to optimize their business processes to remain competitive. Reduced development time enables companies to bring products to market faster and meet customer needs in a timely manner. This requires close coordination and parallelization of various processes, starting with concept development, design, and simulation through to production and marketing (Wehlitz, 2001, p. 1).

CAx coordination plays an important role in an automotive company as it ensures the efficient and smooth running of design and development processes and is responsible for communication between the different departments and teams involved in the development and production of vehicles. CAx stands for Computer-Aided Design (CAD), Manufacturing (CAM) and Analysis (CAE). It includes various software tools and technologies used in the development of products, the creation of engineering drawings, the simulation of product behaviour and the optimization of manufacturing processes. Thus, CAx coordination includes the smooth exchange of design data, the sharing of information, and the coordination of activities across the entire product development process.

The data management product fulfils a crucial role as an intermediary between CAx coordination and enterprise resource planning systems. Therefore, the current PDM systems on the market have evolved in these two directions. Well-known providers of enterprise resource planning systems such as SAP, Oracle, and Microsoft as well as renowned CAD providers such as Dassault Systemes, Autodesk and Siemens offer software solutions for product lifecycle management and product data management. These systems allow for seamless integration of design and manufacturing processes by facilitating communication and sharing of data between different departments and systems. By using a PDM system, companies can make their product development and management more efficient because information about products, components, documentation and other relevant data is centralized and easily accessible (RAAD Research, 2011).

1.2 Motivation

The automotive industry is one of the largest and most important industries worldwide and has faced several challenges in recent years. These challenges are leading automobile manufacturers to fundamentally change their traditional business models and processes. A key driving force behind these changes is ongoing digitization. Also, the automotive industry is known for its ability to quickly adapt to disruptive changes, and digital transformation has emerged as a major disruptive factor in this industry. A variety of trends, such as increasing vehicle connectivity, stricter environmental regulations, the Internet of Things, wireless solutions, and rising customer expectations are driving increased investments in digital structures and innovations in the automotive industry. Advancing technology has already permeated many areas of the automotive value and supply chain, from product design and manufacturing to distribution and dealership delivery (Pellny, 2022).

The realization of future mobility, be it through autonomous vehicles or shared mobility services, requires a sound understanding of digitization in all application areas. This implies that the value chain becomes increasingly dependent on information technology and communication technology-based systems and components, which in turn leads to companies in this industry becoming software companies (Wilczek, 2019). There are numerous possible applications for augmented reality and virtual reality in the automotive industry. One such application is the 3D Experience from Dassault Systemes. As part of the showrooming, customers can experience virtual car seats in real time using augmented reality and virtual reality technologies and thus get a realistic impression of what it is like to sit in different vehicle models. This immersive experience allows customers to explore the interiors of the vehicles and customize their seating position, trim options, and other details. In addition, virtual prototyping and virtual configuration provide users with the ability to visually represent the final product and understand how each component is connected. This enables more efficient product development and reduces the need for physical prototypes (Pellny, 2022).

1.3 Academic Context

At Nova Information Management School, the master’s degree in Information Management, specialized in Information Systems and Technology Management, for professionals working in information systems, Managers and technical staff who have roles in areas of Organization Management and Information Technology, in the coordination and development of Information Systems projects and representing an interface between the business needs of a company and its IT. Cross-departmental information between development engineers and IT developers must be understood quickly to promote innovation and increase process efficiency.

This work project is part of my master's thesis in the Information Management course with a focus on Information Systems and Technologies Management. The aim of the program is to train IT architects who serve as a link between the needs of the company and its IT. This includes the design of systems as well as the introduction of new technologies in the field of information technology. Quick understanding of company data is important to promote innovation and increase process efficiency. The program takes a hands-on approach, with hands-on computer courses and numerous hands-on projects that encourage team collaboration and gain industry-relevant insights. I supplemented my compulsory subjects (M) with electives (E) in the field of information systems, which included the following topics, among others:

1st semester	**2nd semester**
Information Systems Management (M)	Architectures for Information Technology (M)
Architectures for Information Systems(M)	Business Process Management (M)
Digital Transformation (M)	Research Methodologies (M)
Information Systems Development (M)	Information Project Management (M)

With the work project, I was able to combine almost all subjects. The focus was on analysing a functionality of a state-of-the-art IT solution, which represents a modified version of the existing standard product and has proven itself much faster than other products on the market. Various sub-disciplines were used to support the project management, including:

- Information systems management: Understanding how to manage information systems.
- Information project management: Creation of project plan, monitoring, controlling, etc.
- Knowledge management: Translating customer requirements into product features.
- Digital Transformation: To have an overview of the main drivers that lead companies to competitiveness.
- Architectures for information technology: Running lean and incremental software development.
- Business process management: Analysis of the current process and design of the new business process.
- Information Systems Development: Basic knowledge in the development of information systems and Software Engineering.

1.4 Objectives

The main goal of the project is to provide an implementation approach for a product data management system called 3D Experience by Dassault in a car manufacturer. The system is analysed to identify specific functionalities that can optimize the flow of information in vehicle projects. In addition, an interdisciplinary approach called Systems Engineering is integrated into the implementation approach to support the design, development, and management of complex systems in the automotive company. This approach enables a comprehensive view of different disciplines and their interaction to develop efficient solutions for complex system challenges. Therefore, the work project on a theoretical and a practical research method that aims to answer following research question:

• RQ1: What is a suitable interdisciplinary approach for implementing a product data management system?

• RQ2: How can the flow of information between the departments and the development engineers be optimized using a product data management system?

The following research objectives are proposed to answer the above-stated research questions:

• RO1: Introducing an interdisciplinary approach called Systems Engineering for implementing a product data management system.

• RO2: Developing an approach to optimize the flow of information between departments and external parties.

2 Theoretical Framework

The theoretical knowledge and framework conditions relevant to this work project come from various areas such as information systems, systems engineering, digital transformation, IT architectures, business process management regarding product development processes and automobile industry. This chapter focuses on the areas just mentioned, as these represent the core aspects of the tasks of the project. All areas were broadly covered scientifically, so that the following parts reflect the essence of these topics relevant to the work project.

2.1 Automotive Industry

The automotive industry emerged with the development of the automobile towards the end of the 19th century. The first public presentation of an automobile was made by the two gentlemen Daimler and Benz in 1885/1886 (Ellrich, 2005). Production was initially very slow, since at the beginning of the automotive industry it was only a matter of one-offs. The cars were still built by hand, so there was no question of large-scale production. In 1913, Henry Ford in the USA introduced assembly line production, achieving enormous cost reductions that made cars affordable for many people. Ford's T-model ("Tin Lizzy") is the first car to be mass-produced on an assembly line (Autohaus, 2011).

Henry Ford's vision was to build as many vehicles as possible with a simple design at the lowest possible price (Ford, n. d.). Even before the introduction of assembly line production, the vehicles were produced in the usual way at that time. During the production process, the vehicles stood on the ground and were assembled piece by piece by several mechanics (Ford, n. d.). For the first time in the history of the automotive industry, the Model T vehicle was manufactured using assembly line production. Individual production steps were standardized and assigned to the respective employees. As a result, the employees specialized in the respective work steps. The assembly of the vehicle takes place on the assembly line with the help of the individual work steps, which was driven by a steam engine. As a result, the car is no longer an expensive luxury item for the few, but becomes a means of transport for the many (Scholtissek, 2009).

Since 1911, combustion engines have been more dominant in the automotive industry than electric motors. This was due to the fact, that the powerful cranking when starting the combustion engine was no longer necessary, and it was more suitable for everyday use. This allowed the faster, cheaper petrol vehicles to overtake the old electric cars. After almost a century of oil-driven dominance, electric cars are now catching up. Rising fuel costs, stricter environmental protection regulations and new developments in battery technology require a rethink (Eichfelder, 2020). Above all, smaller companies like Tesla, which are now among the most successful in the industry, benefit from this. But the big car manufacturers Audi, BMW, Mercedes, and Co. are also riding in the slipstream of the electric boom. Chapter 2.1.4 deals with this in more detail.

The following chapter goes into the term automotive industry, shows the processes and areas in which the creative and engineering processes and in the end the challenges and opportunities will be presented.

2.1.1 Concepts

The automotive industry is proving to be one of the most significant cultural symbols of the twenty-first century. It has already been proven that the automotive industry is one of the most important economic assets of the century (Jong, 1981, p. 187). According to the European Automobile Manufacturers' Association, the automotive industry directly and indirectly provides jobs for more than 13 million Europeans, accounting for 7% of total employment in the EU. It can thus be said that in the European Communities one in thirty-fifth employed person is employed in the motor vehicle and motor vehicle parts industry (ACEA, 2022). The jobs of at least as many others - in the steel industry, in the rubber and plastics industry, in retail - depend closely on the vitality of the automotive industry. These industries complement the automotive industry by providing raw materials as well as products. These industries just mentioned are called suppliers and are therefore necessary for the automotive industry to produce finished goods in the form of motor vehicles (Jong, 1981, p. 187). Accordingly, the terms "automotive industry", "automotive manufacturers" and "supplier" will be introduced.

According to the Association of the Automotive Industry, the term "automotive industry" means manufacturers of motor vehicles and engines, trailers and bodies, and manufacturers of automotive parts and accessories. The focus of this definition is therefore on the actual production, although the term is sometimes even broader in the literature and companies that are downstream of vehicle manufacture are added (Wallentowitz et al., 2009, p. 1). Furthermore, logistics services are also often viewed as belonging to the automotive industry.

"Automobile manufacturers" or synonymously "Original Equipment Manufacturers" (OEM) are companies that combine self-manufactured or externally procured components, modules and products into complete vehicles and offer them to end users on the market (Wallentowitz et al., 2009, p. 1).

The term "supplier" includes all economic units that deliver industrial pre-products or provide corresponding services for a company downstream in the value chain within the framework of an inter-company division of labour. Suppliers are often structured according to the form of cooperation with the OEM. A distinction is made between the following development suppliers: pure development service providers, production suppliers, development and production suppliers (Wallentowitz et al., 2009, p. 1).

At the top of the pyramid is the automotive industry. Suppliers who are directly upstream of the automotive industry are referred to as "1st tier suppliers". The 1st tier suppliers supply the manufacturer with prefabricated components for his product. It can be brake systems, car seats or infotainment consoles. These components must be available at the right time, in the right place and in the right quantity to meet the demands of modern just-in-time production. The 2nd tier suppliers are on the second level and the 3rd Tier suppliers on the third level. The suppliers are assigned to the respective level according to their dependency on the automotive industry. The automotive infotainment console requires a screen, some computer chips, and other electronics. This is where the second-tier component manufacturers come in to supply the first-tier supplier.

The screen maker, one of the second-tier suppliers, also needs parts and materials to build a touchscreen-capable screen for a car. He gets it from the Tier 3 supplier who specializes in this market. If there are bottlenecks in the supply chain of this third-tier supplier, such as a shortage of computer chips, this can quickly lead to a production standstill at the OEM. There are also “Tier 0.5” suppliers like Karmann, Valmet or Magna. They manufacture complete vehicles on behalf of the automotive industry and coordinate the suppliers. In the broadest sense, the group of logistics service providers can also be counted among the providers (Wallentowitz et al., 2009, p. 1). Figure 1 graphically depicts the supplier pyramid in the automotive industry. The business processes of an automotive company are presented in the following subchapter.

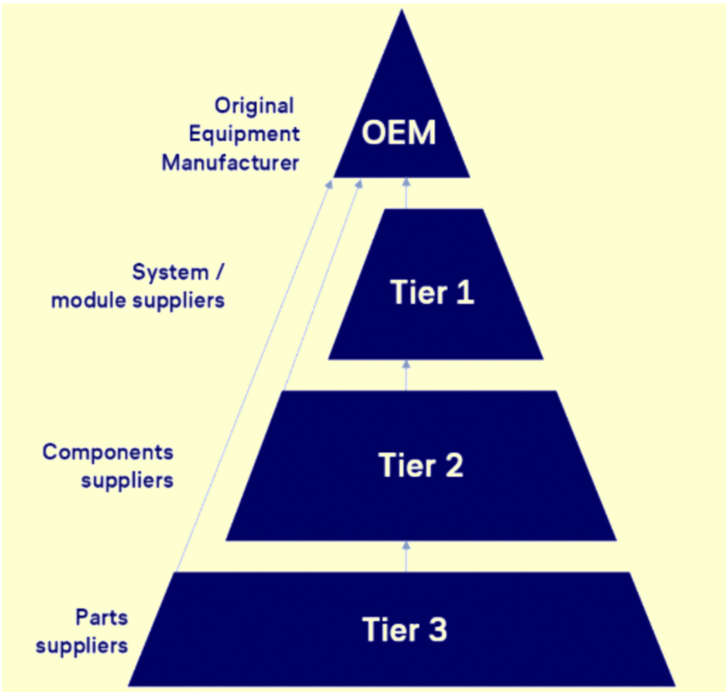

Figure 1: Supplier pyramid in the automotive industry. Adapted from (time:matters, nd).

2.1.2 Areas and Processes

Motor vehicle manufacturers, motor vehicle equipment suppliers, suppliers as well as motor vehicle trade (distribution) form together the automotive industry. Here it is important to mention that enterprises concerning maintenance and repair of automobiles, such as motor vehicle repair shops and car rental companies are also included in the automotive industry. These different players in the automotive industry are connected with the support of supply chain management (Wallentowitz et al., 2009, p. 3).

Supply chain management is a comprehensive concept for planning, controlling, and integrating company activities along the value chain. The holistic approach to the entire value-added process and the methods used reveal potential for improvement at the internal and external interfaces (Durst, 2019). The focus here is on a harmonious connection between the actors involved in the supply chain processes. Decisive advantages are achieved here through the management of the cross-functional business processes. Thus, not only the productivity but also the effectiveness is significantly increased by the supply chain management. In addition, when an order is received, all contributors are immediately informed. Accordingly, long communication routes are eliminated.

In the automotive industry, this not only leads to an increase in production internally, but also offers associated cost reductions (Wiesinger, 2022).

The Supply Chain Operations Reference (SCOR) model breaks down the supply chain into ideal business processes and process categories, as well as supports the planning and optimization of logistics for all members of a supply chain through standardization. The goal of the SCOR model is to plan and optimize the logistics of all members of a supply chain. The reference model was developed by the Supply Chain Council (SCC), an independent board. The model generally describes all internal and cross-company business processes along the entire supply chain. Everything is covered, from procurement from the supplier to delivery to the end customer or consumer (Durst, 2020). Figure 2 graphically depicts the supplier pyramid in the automotive industry.

Thus, a standardized structure is a cross-company analysis of all information, financial and goods flows of the value chain is possible. Automotive companies can use the data analysis to plan in the long, medium and short term, increase the efficiency and effectiveness of supply chain management and coordinate and compare processes between suppliers, manufacturers and customers (IONOS, 2020).

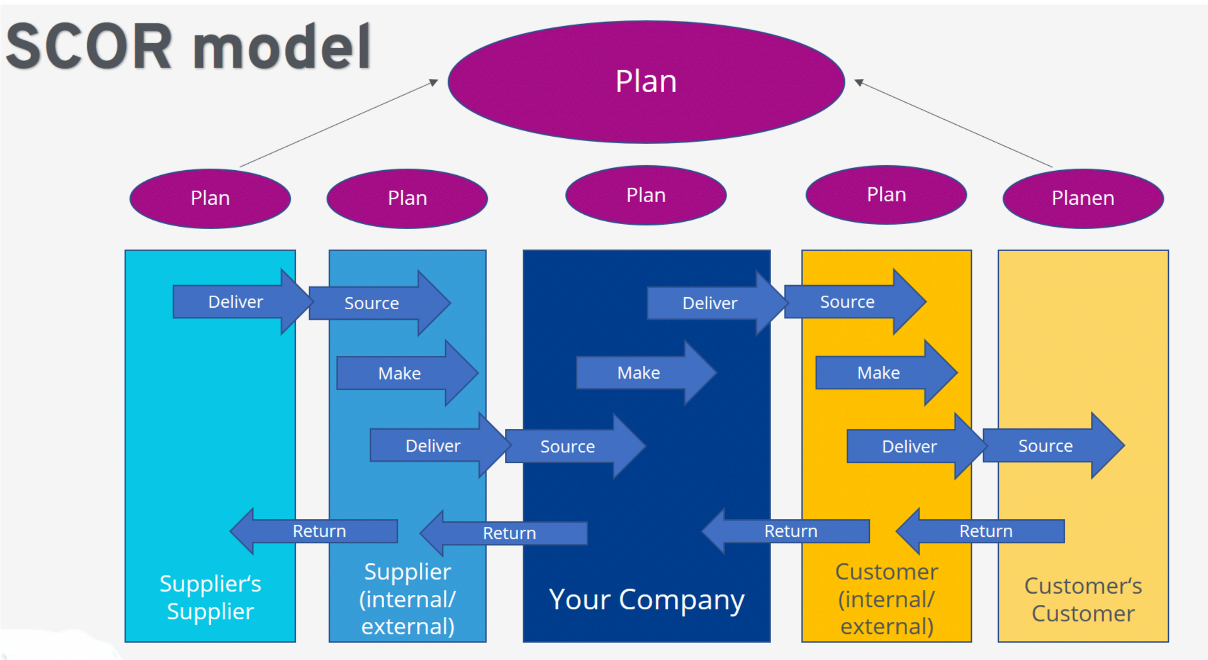

Figure 2: SCOR model. Adapted from (IONOS, 2020).

The four essential processes in the automotive industry are the processes of development, supply, order processing and disposal. From the customer's point of view, order processing represents the actual provision of services and is also one of the core process chains from the company's point of view, as it has many interfaces with the customer. For this reason, improvements in order processing are particularly suitable for differentiation from the competition and serve to directly add value. Therefore the design of this process is so important, since improvements can bring significant and directly tangible competitive advantages (Baumgarten & Walter, 2001, p. 7).

2.1.3 The Creative and Engineering Processes

In the following, product engineering will be introduced, and the relevant systems will be presented, which are necessary for the development of technical products such as vehicles.

Information systems are used in practically all companies to manage business processes. Automotive companies use enterprise resource planning systems to cover commercial processes in areas such as materials management, resource management, production planning, controlling and sales. Depending on the type of company, information, and data about the self-manufactured or traded products are also managed. Accordingly, automotive companies need information systems to be able to manage the information and data generated during product development process. Even if some product data can be managed in enterprise resource planning systems (e.g. parts master data and bills of materials), the designers, especially in product development, need systems with which the diverse technical aspects of modern technical products can be stored and processed (Mechlinski, 2021, p. 1).

Product data management systems (PDM systems) have established themselves on the market for this purpose. The first product data management systems were created between 1970 and 1980. At that time, the manual paper-drawing-based design that had been customary until then was being replaced by computer-based systems (Computer Aided Design). The drawing management system was created to manage the resulting CAD files. These data management systems gradually evolved into powerful and feature-rich Engineering Data Management (EDM) systems. Product data management systems were mostly created based on Engineering Data Management systems by including other aspects of products. This also includes supporting the chronological progression in the product life cycle (Mechlinski, 2021, p. 2).

The VDI Guideline 2219 defines product data management as follows:

“PDM systems represent technical database and communication systems that are used to consistently store and manage information about products and their development processes or life cycles and make them available transparently for all relevant areas of a company. They thus represent an integration platform for the various generation systems or CAx systems that are used throughout the product development process. [...] PDM systems form a building block within the overall information technology infrastructure of a company and must be integrated with other IT systems (e.g. business administration standard software) can communicate or be compared with them.” (contact-software, n. d.).

For the exchange of product data, STEP (Standard for the Exchange of Product model data) has established itself as a standard that formally describes both the physical and functional aspects of products and maps product information throughout the entire life cycle. STEP is formally defined in the ISO 10303 standard (contact-software, n. d.).

A product is created in many different disciplines or domains. Mechatronic products, such as cars, are typically brought to production maturity with the help of the domains of mechanical construction, electrics, hydraulics, industrial design, software development and production process planning. In companies, these domains are usually housed in different organizational units. The knowledge about a product is created and "lives" in these departments and structures.

In the various phases of the product development process and in the different domains, product-related data is created at many points. They relate to the description of product properties based on characteristics (master data, material characteristics), requirements, geometric product representations (CAD data), parts lists. Some of this data is structured and can be managed by databases (metadata), while the other part is in the form of documents or files (user data). PDM systems essentially manage the product data in these two forms. Without comprehensive product data management, the respective data is often managed in departmental data silos without the domains involved being able to use the shared information. A comprehensive product model that unifies all views can leverage a variety of synergies and keep everyone involved up to date (Mechlinski, 2021, p. 5).

Accordingly, PDM systems are nowadays seen as a partial solution of a comprehensive product life cycle management. In addition to product development and product creation, the product life cycle includes several other sub-processes. This means the business of managing a company's products throughout their lifecycle in the most effective way. In addition, the product life cycle includes from the product idea to the archiving or elimination of the product data in the product data management system (Stark, 2016, p. 1).

Figure 3 shows the generic product lifecycle phases. It is important to note that in each of these five phases, the product is in a different state. In the imagination stage, the product is just an idea in people's minds. The ideas are translated into a detailed description in the definition phase. At the end of the realization phase, the product is in its final form (e.g., as a car) in which it can be used by a customer. In the use/support phase, the product resides with the customer who uses it. In addition, in this phase, the product data is archived or reused to find new ideas in the imagination phase. At some point, the product enters a phase where it is no longer useful. It is discarded by the company and disposed of by the customer (Stark, 2016, p. 4).

Figure 3: Generic product lifecycle phases. Adapted from (Stark, 2016, p. 3).

Here it is important to mention that in the realization phase the production of the finished product is supported by the Enterprise Resource Planning System. This includes areas such as delivery, accounting, order management, distribution as well as sales, purchasing, demand planning and production planning (Mechlinski, 2021, p. 3).

The main goals of the product life cycle are to increase product sales, reduce product-related costs, maximize the value of the product portfolio, and maximize the value of current and future products to customers and shareholders. The five activities just mentioned that take place during the life cycle can differ from industry to industry. Accordingly, companies in a particular industry may have a product life cycle view specific to their industry. Regardless of the company or a specific industry, the five activities can be mapped to the five phases of the general product life cycle (Stark, 2016, p. 2).

Product lifecycle management is an overarching business activity. All subordinate product-related activities of a company are combined in the product life cycle management (Stark, 2016, p. 2). Figure 4 shows some of these activities.

managing a well-structured and valuable Product Portfolio
maximising the financial return from the Product Portfolio
managing products across the lifecycle
managing product development, support and disposal projects effectively
providing control and visibility over products throughout the lifecycle
managing feedback about products from customers, products, field engineers and the market
enabling collaborative work with design and supply chain partners, and with customers
managing product-related processes so that they are coherent, joined-up, effective and lean
capturing, securely managing, and maintaining the integrity of product definition information
making product data available where it's needed, when it's needed
knowing the exact technical and financial characteristics of a product throughout its lifecycle

Figure 4: Activities within the scope of PLM. Adapted from (Stark, 2016, p. 2).

2.1.4 Challenges and Opportunities

The automotive industry is undergoing major structural change. Terms such as electric mobility, digitization and increasing automation are becoming more important today. For decades, the core markets have experienced constant growth and have been the driving force behind the European economies. Due to the Covid-19 pandemic, the automotive industry faces an enormous challenge to meet the global demand for motor vehicles. This had an enormous impact on the automotive industry, such as production downtime and a weakening shortage of semiconductors, through to an acute shortage of workers and global bottlenecks in the supply chain. For this reason, consumer demand has probably never been so difficult to predict. During the Covid 19 pandemic, people have been confronted with new regulations such as lockdowns, health concerns and an evolving transition to remote working. Compared to the past, the price of motor vehicles and fuel has increased enormously for the end customer (Robinson & Tummalapalli, 2022).

As explained in the previous chapter, Product Lifecycle Management promises to achieve better product quality, efficient collaboration, and faster deliveries. In contrast, some challenges are encountered (Gutierrez, 2021). The challenges of the PLM are explained below.

Organizing and tracking design concepts, development models, technical drawings, and components may not seem like a problem at first. However, over time, more and more revisions, versions, change orders, and change messages accumulate, causing the system to get out of control when searching, reusing, and managing data. It is not uncommon for busy product developers to reconstruct data when searching for an existing model is too time-consuming. Worse still, important data is often lost or overwritten. Despite this, PDM/PLM solutions (Product Data Management/Product Lifecycle Management) can already solve this problem today, at least for large companies. A recent study showed that eight out of 10 manufacturers use commercial PDM/PLM systems (PTC, n. d.). The lack of transparency between internal teams and departments is a challenge that can cause problems, especially in large organizations. Here, communication is often blocked, and employees struggle to share information, priorities, goals, and tools (Iyer, 2020).

This affects the productivity and efficiency of the departments. To close this communication gap, it is important to develop effective strategies. This involves setting up a platform for teams and departments to communicate with each other. This is where product information software can be of great help as it allows all the information to be brought together in one place and eliminates confusion. With the introduction of systems engineering-based projects in the automotive industry, companies face many challenges. Below are some of the challenges (Iyer, 2020).

2.2 Business Process Optimization

In the following, the optimization of business processes will be discussed, which was an important feature of the project. In addition, the approaches and methodologies, business process optimization tools and the creative and engineering processes optimization are discussed.

2.2.1 Concepts

Over the past decade, companies have shifted the focus from optimizing individual business functions to optimizing entire business processes. This trend was originally triggered by the growing importance of information technology and the trend towards globalization and was referred to as business process reengineering. Accordingly, in recent years, due to the increasing volatility of the economic environment and the competitive pressure between companies, the importance of rapid, often incremental improvements in business processes has increased further. (Niedermann et al., 2011, p. 123).

Business process optimization is an area of process management that focuses on the analysis and improvement of business processes using specific and specially developed methods. Therefore, business process optimization refers to the analysis, revision, and improvement of business processes to ensure they are efficient, effective, and aligned with the needs of customers and organizations (Wirtschaftslexikon24, o. J.). Moreover business process optimization is triggered by the constantly changing IT environment, high management and process costs, long delivery times, changing process specifications or customer requirements and the standardization of process patterns (Safar, o. J.). The aim is to save time and money, increase productivity and achieve greater customer satisfaction. Furthermore, Gunasekaran and Kobu claim that a business process must be fundamentally changed to achieve significant performance improvements. Performance improvement is made possible by automating processes, eliminating redundant steps and introducing new technology solutions to enable better monitoring and traceability (Vergidis et al., 2008). This can be accomplished through a few methods.

In the literature, the terms "process management" and "business process management" are often used as synonyms. Accordingly, the term business process management can be understood as the systematic design, control, monitoring and further development of a company's business processes. It includes strategic process management, process design, process implementation and process controlling (Allweyer, 2012, p. 12). It is thus established that process management deals with the optimization, control and (re)design of business processes. The person responsible for the process benefits from the shortening of the throughput time in processes, the increase in process quality and the cost reduction of processes. The process management cycle runs through a sub-process, which consists of the specification of requirements, analysis, and evaluation of the existing processes as well as the redesign and modification of the organizational processes (Mieke & Wikarski, 2011, p. 40). Chapter 2.2.4 illustrates the relationship between business process management and systems engineering. Almost all companies have dedicated business process improvement people who are tasked with both continuous improvement and the execution of large-scale improvement projects. Technically, the goal of BPO is to select the right process designs and apply the most appropriate optimization techniques (Niedermann et al., 2011, p. 123).

Various techniques are used to overcome these challenges. One of these techniques is process analysis. Companies shouldn't be analysed by their individual functions or products, but by the key business processes they perform. Due to the complexity of designing and controlling business processes in modern companies, special analysis techniques are required. The term business process analysis is commonly used in the literature in a broad context and encompasses a variety of tactics such as simulation, diagnostics, verification, and performance analysis of business processes. Existing processes are examined to identify weaknesses and opportunities for improvement. In this way, the competitiveness of a company can be increased, and its business results can be improved (Irani et al., 2002, p. 73). There are various types of analysis related to business processes. A visualization of these different forms of analysis can be represented by the Venn diagram in Figure 5. The different types of process analysis are assigned to the three-business process modelling sets.

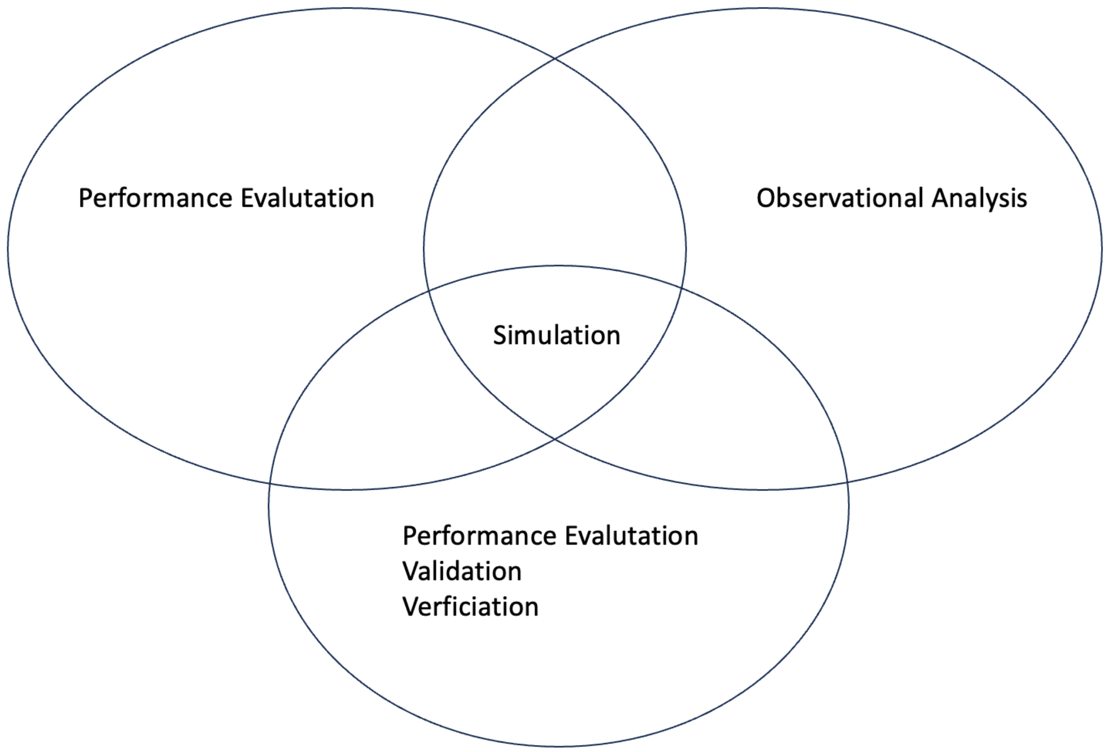

Figure 5: Different types of process analysis in contrast to sets of business process modelling. Adapted from (Irani et al., 2002, p. 73)

In the field of business process modelling, only one type of analysis is available for diagrammatic models, namely observational analysis. This analysis refers to how the process structure changes when looking at the diagrams. Diagram analysis is the most common approach in the literature when it comes to visual models of business processes. There are several ways to redesign a process, e.g., B. removing unnecessary activities, simplifying activities, merging activities, parallelizing activities, and automating activities. However, this analysis approach can be time-consuming and depends heavily on the experience of the modeler, who often bases his conclusions on his knowledge of the business domain in question and his skills (Irani et al., 2002, p. 73).

To analyse a business process, more advanced mechanisms are required than the simple qualitative analysis of static diagrams. A quantitative analysis of business process models is very important, as this is why process models with formal underpinnings based on mathematical model sets have been developed. These formal modelling approaches provide a solid basis for determining performance indicators that measure the achievement of strategic goals and objectives by relating them to core processes. Key performance indicators can be used here to measure the status of the achievement of the objective. To fulfil this purpose, analysis methods are required that consider both dynamic and functional aspects of the process. According to van der Aalst, most techniques for analysing formal business process models come from operations research (Irani et al., 2002, p. 74). The concept behind business process languages is to make a process executable and thus amenable to quantitative analysis. In addition, however, some process languages have associated analysis techniques that can be used to examine process properties. These techniques can then be relied upon to provide insight into the behaviour and properties of a business process model specified in the language (Irani et al., 2002, p. 74).

Accordingly, the Business Process Modelling Language is a platform-independent meta-language for the specification of process descriptions based on XML. Web services can be linked to business processes using BPML. The processes in the Business Process Modelling Language can be represented graphically with the Business Process Modelling Notation (BPMN). The goal of the Business Process Modelling Language is to graphically represent all parts of a business process such as transactions, exceptions, data flows, scheduled events, roles, and security. In the authors' opinion, this level of modelling and execution of business processes (i.e., using a process language) is best suited for the application of all analysis techniques. Expressions that can be expressed with the process language and thus integrated into the process model (Hertkorn et al., 2019).

Another technique is the automation of existing processes. Here, manual processes are automated using technological developments to save time and resources and achieve greater accuracy. In the technical literature, robotic process automation (RPA) is described as a software and algorithm-based technology that aims to automate repetitive human tasks. RPA is mainly based on simple rules and business logic and interacts with various information systems through existing graphical user interfaces. One of the benefits of RPA is that it allows employees to focus on more complicated tasks that can bring value to the organization. According to reports from consulting firms, RPA is recognized as an emerging and disruptive technology that is already delivering value (Di Ciccio et al., 2019, p. 281).

In contrast, Robotic Process Automation is defined by the IEEE as preconfigured software that uses business rules and predefined activity choreographies to complete the autonomous execution of processes, activities, transactions, and tasks in one or more independent software systems to produce a result or service with to deliver human exception management (IEEE Corporate Advisory Group, 2017, p. 14). Robotic Process Automation (RPA) technology enables the interaction between humans and computers to be automated without affecting the existing IT infrastructure of a company or organization. Compared to previous digital transformation methods, RPA can therefore be implemented quickly. There are three different RPA models, namely attended, unattended and hybrid models. The supervised model deploys RPA as a personal assistant to the individual employee and works by executing a command given by the employee. The unintended approach uses RPA to automate the process of multiple workers without human intervention. Between these models is the hybrid model. The hybrid model automates some processes while still allowing for user intervention in some parts that require cognitive decisions (Afriliana & Ramadhan, 2022, p. 53).

Thus, RPA is an innovative technology approach that can be used in a digital transformation initiative to automate business processes within an organization. RPA is characterized by specific characteristics and definitions that make it an emerging and advanced technology that can be used in the optimization and transformation of processes. Overall, RPA can be considered as a promising technology that can play an important role in the digital transformation of companies (Afriliana & Ramadhan, 2022, p. 53).

2.2.2 Approaches and Methodologies

Successful companies implement continuous process improvement to achieve efficient and lean business processes and to maintain an optimal cost structure. The optimization of processes and an efficient process architecture leads to greater flexibility, which enables the company to react to changing customer requirements and to use existing resources more quickly and in a more targeted manner. Increasing competition, changing stakeholder requirements and new technologies require companies to make rapid and significant changes. To survive in the complex business environment and respond to these changes, companies continuously strive to improve and manage their business processes. While the common understanding of business process management (BPM) still relies primarily on process automation technology, business leaders are now adopting a new holistic approach to BPM that involves people, processes, systems and strategy (Seethamraju & Marjanovic, 2009, p. 920).

The various excellence models used worldwide, such as the EFQM Excellence Model, the Malcolm Baldrige National Quality Award Model, and the Deming Prize Model, have the improvement of business processes at the core of their concepts. In practice, numerous organizational activities are essential to improve business processes. This includes, among other things, the process mapping and analysis, which lead to a better understanding of the processes and may also make it necessary to redesign the processes. A significant motivation for improving business processes can be the international standard ISO9001:2000, which is widespread around the world. Based on a powerful representation of the "process model," this standard promotes managerial accountability for quality, recourse management, meeting customer requirements, and the product or service realization process (e.g., design, manufacture, and delivery). In addition, higher quality is achieved by collecting customer feedback and prioritizing improvements based on measurements and analysis (Bendell, 2005, p. 969).

Many companies have started to analyse and map their business processes or have received ISO 9001:2000 certification. However, only a few companies use serious strategic approaches such as Six Sigma or Lean Organization to improve their processes. Instead, many companies try small parts of different initiatives, create individual approaches, or develop supposed hybrids like "Lean Sigma". On the contrary, it brings with it some challenges. The figure 6 shows this procedure graphically (Bendell, 2005, p. 970).

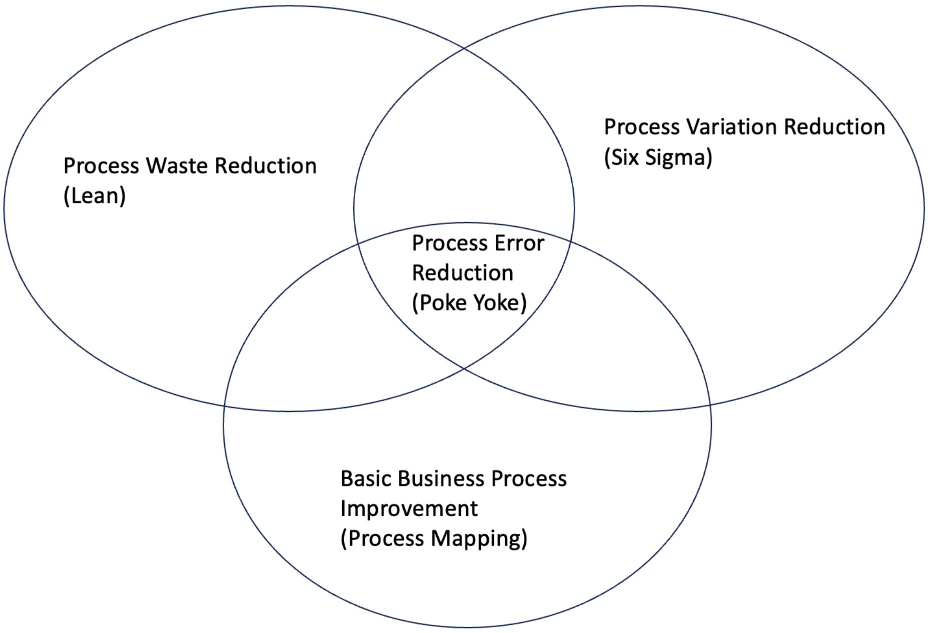

Figure 6: Holistic model for business process optimization. Adapted from (Bendell, 2005, p. 970).

Six Sigma shown in the graphic on the right is a methodical approach to improving processes that can be viewed as an actual quality goal both for quality management and from a statistical perspective. The term "Six Sigma" derives from the Greek letter σ, which is used as a symbol for the standard deviation in the normal statistical distribution, also known as the Gaussian bell curve. The designation "Six" refers to the English pronunciation of the number six and indicates that the quality objectives to be achieved must be within a tolerance of six times the standard deviation (both positive and negative) from the average value. The main objectives of this methodology are to improve the quality and increase the efficiency of processes by applying the Lean approach, specifically Lean Six Sigma, to save costs by avoiding waste such as production scrap or excessive use of resources. These measures are intended to increase value creation and customer satisfaction and retention by providing higher quality, cheaper or even customized products and services (Klanitz, n. d.).

In addition, this approach is based on project-by-project improvement and is led by specially trained professionals. The project is either led by full-time improvement engineers or managers, known as "Black Belts," or overseen by part-time improvers, known as "Green Belts." These Green Belts have at least 20% working hours and are often supported by supervisors. In the DMAIC method, they use numerous statistical tools in each of the phases: define, measure, analyse, improve, and control. The cycle is based on the classic PDCA cycle by William Edwards Deming, the "Plan - Do - Check - Act", but focuses on mathematical-statistical methods (Bendell, 2005, p. 971). Before the training starts, the first

Black and Green Belt projects are selected. As a rule, projects are not approved, and black and green belts are not certified before the intended financial savings have been independently verified. This ensures that the transition from method to first application is made effectively. The Six Sigma approach represents a process-oriented approach to the optimization of business processes, which is seen both in the context of quality management and as a benchmark for virtually zero error tolerance (Klanitz, n. d.).

The Six Sigma approach represents a process-oriented approach to the optimization of business processes, which is seen both in the context of quality management and as a benchmark for virtually zero error tolerance. The DMAIC core process, which is used as part of Six Sigma, represents a management task, whereby the employees on site are regarded as important input providers for identifying weak points and errors and for carrying out measures to eliminate them. According to the Lean philosophy, these employees are referred to as "practitioners at the point of action" (Klanitz, n. d.).

To successfully introduce and implement Six Sigma in an organization, all people involved in value creation are of central importance. The training program is very intelligently designed by asking Black and Green Belt candidates to select a pre-training project to work on during the training modules and then need to demonstrate externally validated savings/payback before signing off on their first projects and achieving black or green belt status. In doing so, process and customer-oriented perspectives should be taken into account, and not only the management or executive level, but also all departments involved in production, purchasing, administration, logistics and sales should be taken into account (Bendell, 2005, p. 971).

The second methodology of business process optimization is discussed below. Lean management is a modern concept for optimizing value chains and processes, which has the main goal of maximizing customer satisfaction. The Lean Management method focuses on the identification of waste and inefficiency within the production of one's own company to convert them into value-adding activities. The value chain includes all processes from the supplier (upstream) through internal business processes to the customer (downstream) (Helmold, 2021, p. 1). John Krafcik gained knowledge of the automotive industry through his participation in the MIT International Motor Vehicle Program (IMVP) under the direction of Daniel Roos, James Womack and Professor Daniel Jones. There he studied the production methods introduced by Taiichi Ohno at Toyota after the Second World War and coined the term "lean" to describe this new production technique. In their publication entitled "The Machine That Changed The World," Daniel Ross, James Womack, and Professor Daniel Jones made reference to a set of techniques developed by Toyota, which they subsequently integrated into their concept of "Lean Thinking" (Bendell, 2005, p. 972).

According to the work of Womack and Jones, five essential principles of the lean organization are identified. These include eliminating waste, also known as muda, identifying the value stream, achieving process flow, using a pull (or kanban) signal to regulate the pace of work, and continuously striving for perfection (Bendell, 2005, p. 972). Waste refers to any activity, service, process, or product that does not add value to customers and consequently is not monetarily rewarded by them. In the context of the lean management approach, the customer and his satisfaction represent a central objective (Helmold, 2021, p. 2). A combination of techniques from different approaches such as just-in-time, theory of constraints and total quality management are often used to implement these principles.

The goals of the lean management philosophy are to promote the generation of sustainable customer benefits by optimizing resources and to establish a continuous and efficient workflow based on the actual requirements of the customers. The effort is aimed at avoiding waste of time, effort, resources, and costs by subjecting all steps in a business process to analysis and examining the potential for waste. Individual processes that do not generate any value or do not contain any added value can be revised or eliminated entirely (Helmold, 2021, p. 2). Accordingly, the Lean philosophy is designed to achieve perfect value through a systematic reduction of waste in all aspects of an organization's operational processes. In order to achieve this, it is necessary to have a clear focus on the value element of all products and services and to gain a detailed understanding of the business processes that represent the value stream, i.e. the supply chain from the raw material to the end product or service (Bendell, 2005, p. 972).

The improvement with the help of lean management takes place in a step-by-step, selective perfection or optimization of a product or process. This methodology facilitates joint management and responsibility. Continuous improvement ensures that every employee contributes to the improvement process. The management method serves as a guide to building a successful and solid organization that is constantly evolving, identifying, and solving real problems. There is also a strong connection with lean management and kaizen. Kaizen describes both a Japanese philosophy of life and work as well as a methodical concept that focuses on striving for continuous and infinite improvement. Kaizen means change and change for the better in small steps. At the heart of this philosophy is the pursuit of continuous and never-ending improvement (Helmold, 2021, p. 3).

2.2.3 Tools

The effectiveness of a method for improving business processes largely depends on the tools and techniques used. More and more companies rely on a process-oriented approach to achieve improved integration of the various processes and thereby achieve advantages. This perspective replaces the traditional functional perspective (Bal, 1998, p. 342). There are many variables that can affect the success of this approach. However, a critical component is the ability to model and represent the process. A model has as its primary function: “reduce the complexity of understanding or interaction with a phenomenon by eliminating the detail that does not influence its relevant behaviour” (Curtis et al., 1992). The PDCA model already presented is supported using various tools. This is the Ishikawa diagram and the 5-why method. These tools are presented below.

The Ishikawa diagram, also known as the fault tree, fishbone or cause and effect diagram, is a qualitative method of modern quality management developed by the Japanese scientist Kaoru Ishikawa. It belongs to the Seven Statistical Tools of Quality Control and the Seven Quality Techniques, which are usually based on mathematical-statistical principles and are used to identify problems and analyse their causes. These techniques have the common goal of promoting error prevention and thereby ensuring a consistently high quality of processes and products. The preventive measures are aimed at maintaining a consistently high process and product quality. The Ishikawa Diagram has several goals towards which it is directed. One of these goals is to avoid errors in the first place by identifying and eliminating possible causes in advance. In addition, the diagram should help to make processes less sensitive to disturbance variables and thus achieve greater process stability. Another goal is to consider the wishes and requirements of the customers and to include them in the process.

Finally, the Ishikawa diagram should also be used to monitor the scattering behaviour of the processes and, if necessary, to optimize them in order to achieve higher quality and efficiency (Syska, 2006, p. 63).

The leader in management made significant and specific strides in improving quality using the Cause-and-Effect Diagram, also known as the Ishikawa or Fishbone Diagram. The design of the diagram resembles the structure of a fish skeleton, which is built from right to left. Each main branch of the fish is divided into smaller branches that contain more details. Fishbone diagrams thus represent a method to identify and visualize the causes of a specific problem. The present technique is based on a diagram-based approach designed to consider all potential causes of a problem. This procedure enables a thorough analysis of the respective situation. The use of the tool is divided into four steps: The first step is to identify the problem in question. Subsequently, the relevant factors involved in the problem must be worked out. In the next step, possible causes are identified. Finally, the diagram is analysed. The causes are usually grouped into main categories to identify the various influencing factors. Typical categories include (Liliana, 2016, p. 2):

• People: everyone involved in the process.

• Methods: The way the process is carried out and specific requirements such as policies, procedures, rules, regulations, and laws.

• Machinery: Any equipment, computers, tools, etc. needed to carry out the work.

• Materials: raw materials, parts, pens, paper, etc. used to manufacture the final product.

• Measurements: data generated during the process and used to assess its quality.

• Environment: The conditions under which the process takes place, such as location, time, temperature, and culture.

The 5 Whys method is a useful tool for determining the cause-and-effect relationship of an encountered problem. It is a simple method that does not require statistical analysis and is used to identify the cause of an error. The application of the 5-Why-Method includes the analysis of the problem and the systematic inquiry with the question "Why?". The answer to the first "Why?" will be the basis for the next "Why?" taken. Usually, five such questions are sufficient to determine the cause of a problem. The method is easy to use. Instead of just treating the symptoms, the cause of the problem is sought. The name "5-Why method" describes the procedure in which a problem is repeatedly examined with "Why" questions. Through the in-depth questions, an ever-higher level of detail is reached and finally the actual cause within a process or process step is recognized. The method is particularly useful for root cause analysis after a Gemba observation. This allows the problems discovered during the observation to be analysed quickly and easily. A detailed analysis requires that information be collected in small steps during the Gemba observation in order to establish a traceable connection between the individual steps (Angerer, 2018).

First, a brief description of the problem is given, using quantitative data or sketches as an aid. This is followed by multiple requests for a cause analysis. During this analysis, one should avoid jumping to hasty conclusions and accurately grasping every detail. Sticking with the facts is crucial, as incorrect assumptions can distract from the root cause. As soon as the underlying cause has been determined, suitable measures can be derived and implemented (Angerer, 2018).

Value Stream Mapping is an extremely powerful lean management tool that combines material processing steps with information flow and other important data. It is a lean process improvement technique introduced by Rother and Shook (1999). Value Stream Mapping is arguably one of the most powerful Lean tools for a company looking to plan, implement and improve their Lean journey. This tool allows users to create a solid implementation plan that makes the best use of available resources. It is typically developed to understand value-adding and non-value-adding activities from both information and material flow in a value stream. Therefore, Value Stream Mapping is about initiating change and decluttering the process of non-essential activities that do not add value but waste time and resources (Shou et al., 2017, p. 1).

Based on the Value Stream Mapping research in the manufacturing sector, scientists in other fields have made extensive research efforts to introduce VSM and increase productivity. As an example, it has been used as a Lean methodology to examine waste, inefficiencies, and non-value-added steps in the product development process. In addition, this tool is also used as an efficient management system to improve the performance of building materials supply chains, building ecology and house building activities execution (Shou et al., 2017, p. 1).

A critical step in the value stream mapping process is documenting the relationships between the manufacturing processes and the controls, such as production planning and production information, used to manage those processes. In contrast to other process mapping techniques, which often only depict the basic flow of materials, value stream mapping also considers the flow of information within the system. Information about where materials are stored (e.g. raw materials or WIP) and which processes trigger the movement of materials from one step to the next is of great importance (Singh et al., 2011, p. 799).

Rother and Shook (1999) proposed a value stream mapping approach to identify waste in a single value chain. This release focuses on the systematic application of Lean strategies to eliminate waste and enable continuous improvement from a user perspective. Value-adding and non-value-adding activities are made clear in both information and physical flows. The four phases of value stream management that support the identification and improvement of production processes are presented below. The process consists of the following steps (Shou et al., 2017, p. 2):

1. The selection of a product family to study and improve.
2. Draw a Current State Map (CSM) to identify value-adding and non-value-adding activities. Process data is collected for this purpose.
3. Drawing a Future State Map (FSM) based on the VSM theory by Rother and Shook (1999). Here, systematic improvement guidelines for the future state are defined.
4. Achieve future state through the development of a value stream map and management policies (Shou et al., 2017, p. 2).

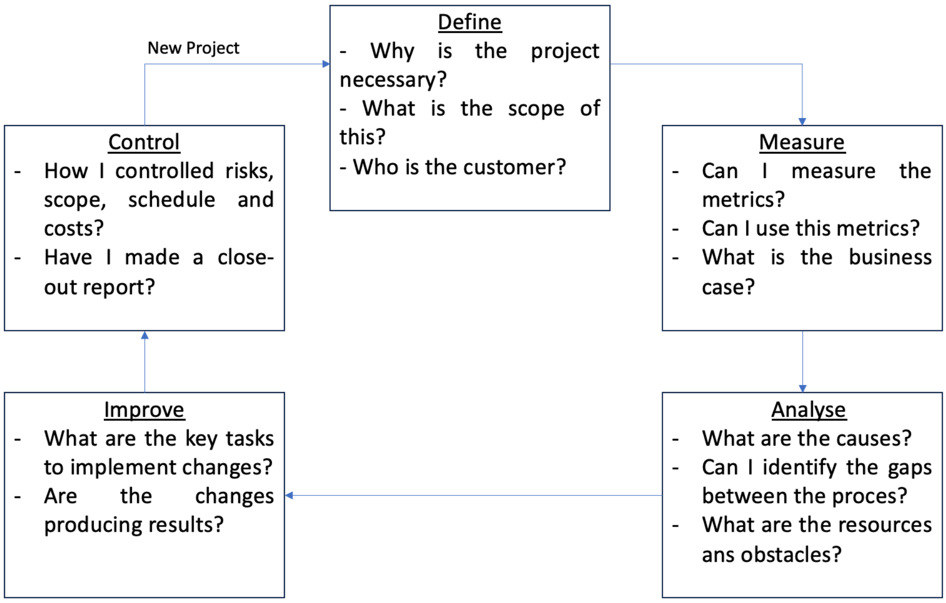

Figure 7: DMAIC cycle as a methodology of Six Sigma. Adapted from (Sokovic et al., 2010).

DMAIC refers to a data-driven lifecycle approach to Six Sigma process improvement projects. It is an essential part of a company's Six Sigma program. As mentioned earlier, DMAIC is an acronym for five interrelated phases: Define, Measure, Analyse, Improve and Control. The simplified definitions of each phase (Figure 7) are as follows (Sokovic et al., 2010, p. 480):

- Define by identifying, prioritizing, and selecting the right project,
- Measurement of key process characteristics, range of parameters and their performance,
- Analysing by identifying root causes and process determining factors,
- Improve by changing the process and optimizing performance,
- Control by maintaining profit.

To sum up the application of DMAIC technology, if you can't define your process, you can't measure it. That means you can't use DMAIC in your development efforts if you can't express the data. Consequently, you cannot improve and maintain the quality. It is also systematic, fact-based and provides a rigorous framework for results-oriented project management. The methodology may seem linear and explicitly defined, but it should be noted that the best results are obtained with DMAIC when the process is flexible, thus eliminating non-productive steps. An iterative approach may also be required, especially when team members are new to the tools and techniques (Sokovic et al., 2010, p. 481).

2.2.4 The Creative and Engineering Processes Optimization

An organization in the automotive industry must continuously control this and adapt to changing environmental conditions. The processes, tasks, responsible persons, resources, and goals for the operation as well as the processes introduced find their framework in continuous process management (Neumann et al., 2005, p. 299). An important aspect when optimizing creative and technical processes is continuous process management. In the literature, the continuous process management is described as a constant, incremental improvement of the process organization in addition to the support of the process implementation. The improvement measures carried out should correspond to the specified company goals and be carried out with the involvement of all those involved in the process based on the existing organization. The concept of continuous process management shows similarities to other concepts such as continuous improvement or the Japanese concept of kaizen and is thus distinguished from process-oriented reorganization approaches that are characterized by uniqueness and usually have special triggers (Neumann et al., 2005, p. 299).

Kaizen is a Japanese management philosophy and is understood as a continuous improvement process involving employees, which is characterized by a bottom-up approach (Boesing, 2006, p. 13). Here, the employees are put in a position to develop specific suggestions for improvement in order to constantly improve the work processes (Koch, 2015, p. 127). Accordingly, the focus here is not on the result, but on the process orientation. The value-adding processes of a company are continuously improved in small steps by involving employees (Gadatsch, 2017, p. 42). A company's investments are therefore geared towards the skills of the people and not towards the technology (Boesing, 2006, p. 13). The Kaizen concept pursues the goal of achieving a permanent increase in process performance and process quality through improvement in small steps in order to achieve long-term competitive advantages (Kirner et al., 2006, p. 2).

As part of continuous improvement, "waste" is specifically identified and eliminated. For this purpose, special working groups are formed, consisting of employees of the company. Waste occurs when productive forces and resources are used unnecessarily or inappropriately. An optimal combination of resources also requires that capacities are neither overstretched nor under stretched. According to Henry Ford's philosophy, anything that doesn't add value is considered a waste. In production plants, the three factors human, material, and machine are arranged in an interrelationship with each other. The sensible combination of these factors results in an optimized workflow in which man and machine carry out a specific work together with the help of the material (Koch, 2015, p. 128).

This waste includes overproduction, unnecessary movements, waiting times and delays, unnecessary work processes and machining, production errors and rework, unnecessary transport, and high material inventories. The goal of identifying and eliminating these wastes is to ensure the most efficient production possible, where each step adds value to the product (Koch, 2015, p. 129).

A key success factor for companies is to optimally coordinate all work processes from planning to implementation of a project to create a harmonious overall picture. Effective coordination and integration of work processes can help minimize friction, delays, and wasted resources. A proven method to achieve this goal is workflow management. A workflow is a formally described business process that is fully or partially automated. It contains time, technical and resource-related specifications that are required for automatic control of the workflow at the operational level. The work steps that are triggered here are intended for execution by employees or application programs. A workflow instance, which designates a concrete execution of the workflow, is to be distinguished from a workflow as a type or scheme of a partially or automated workflow (Gadatsch, 2017, p. 6).

Workflow management is an operational process management strategy that aims to analyse, present, and optimize existing work processes in terms of their spatial and temporal sequence. Here, both the design of individual workflows and the optimization of all workflows are aimed at with the help of a special software solution in one system (Zeller, 2023). The actors within a process can benefit from a professional workflow management strategy. On the one hand, those involved in the process can be optimally coordinated and exactly the necessary expertise can be provided for each workflow. In this way, errors and redundancies can be avoided, making the company work more productively and economically. A workflow management system also guarantees continuous controlling of all work processes and workflows in order to be able to react as quickly as possible to problems and difficulties in the process (Zeller, 2023).

When optimizing business processes with the help of workflow management systems, the same workflow is usually carried out. Before a process can be improved, a process to be optimized must first be selected and clearly distinguished from other processes. Examples of such target processes are, for example, the release and change management in development and construction or order processing. These processes usually have a clear structure and time optimization can be of great benefit to the company. In the next step, the process to be optimized must be formally described to create a basis for the optimization. Successful reengineering based on workflow management systems is only possible if the methodology allows the modelling of all process-relevant entities and relationships, enables powerful simulation and analysis functions and software tools are available for later process implementation. Finally, a simulation is carried out. A simulation enables the use of real or fictitious process parameters to study a formally described process represented by a modelling method. The aim of such simulations is to uncover weak points in the process and to gain information for process optimization (Horn & Brockhaus, 1995, p. 378).

3 Methodologies and Tools

The methodologies and tools implemented and used in the project are presented in the following chapter.

3.1 Systems Engineering

Systems engineering provides a methodology and framework to plan, design, implement, and monitor complex systems. This includes identifying platform requirements, designing the architecture, integrating hardware and software, managing risk, and reviewing and validating the system. By applying system engineering methods, the implementation of complex systems can be made more effective and efficient, which can help increase the project's chances of success and minimize the risk of errors and problems.

3.1.1 Concepts

There are a variety of interpretations and schools of systems engineering in industry and research. Furthermore, a basic understanding of systems engineering is conveyed by presenting the core components using the definition.

The methodology of systems engineering was developed to deal with the growing complexity of multidisciplinary technical systems and to reduce risks. These risks can arise due to the difficulty of understanding between the different disciplines, reaching the limits of system resilience and the integration of artificial intelligence into the system functionality. Project organizational risks, on the other hand, can lead to the amortization period of a development project being extended due to the failure to meet user needs, exceeding the time and cost framework, or even jeopardizing the entire success of the project. The concept of systems engineering aims to develop complex technical systems while adhering to a predetermined time and cost framework. This is done through the application of systemic thinking and a methodical approach in which various disciplines are structured using models and networked with one another to achieve an interdisciplinary optimum. Overall, systems engineering represents a holistic approach to the development of complex technical systems (Graessler & Oleff, 2022, p. 15).

Accordingly, one can conclude that systems engineering is a management technology that assists in policy design, planning, decision making and resource allocation or action deployment. This is done through a quantitative and qualitative formulation, analysis, and interpretation of the effects of alternative courses of action, considering the needs, values, and institutional perspectives of the users. The structural definition of systems engineering emphasizes the key words formulation, analysis, and interpretation, which represent the essential components of the phases in the life cycle of a system. Therefore, systems engineering can be understood as a process that is composed of these components and contributes to the development of an effective system (Sage, 1992, p. 4).

The information science basis poses a particular challenge, since information is not a fundamental quantity, but results from the structure and organization of natural and management sciences, as well as from its application in science and the realization of operating systems. As a result, there are different design concepts for physical systems, management systems and information systems, all of which can support the management process. The technology includes information processing, matter, and energy processing.

A combination of physical systems and information systems design can be grouped into a category called technological systems design (Sage, 1992, p. 3). This is illustrated in Figure 8.

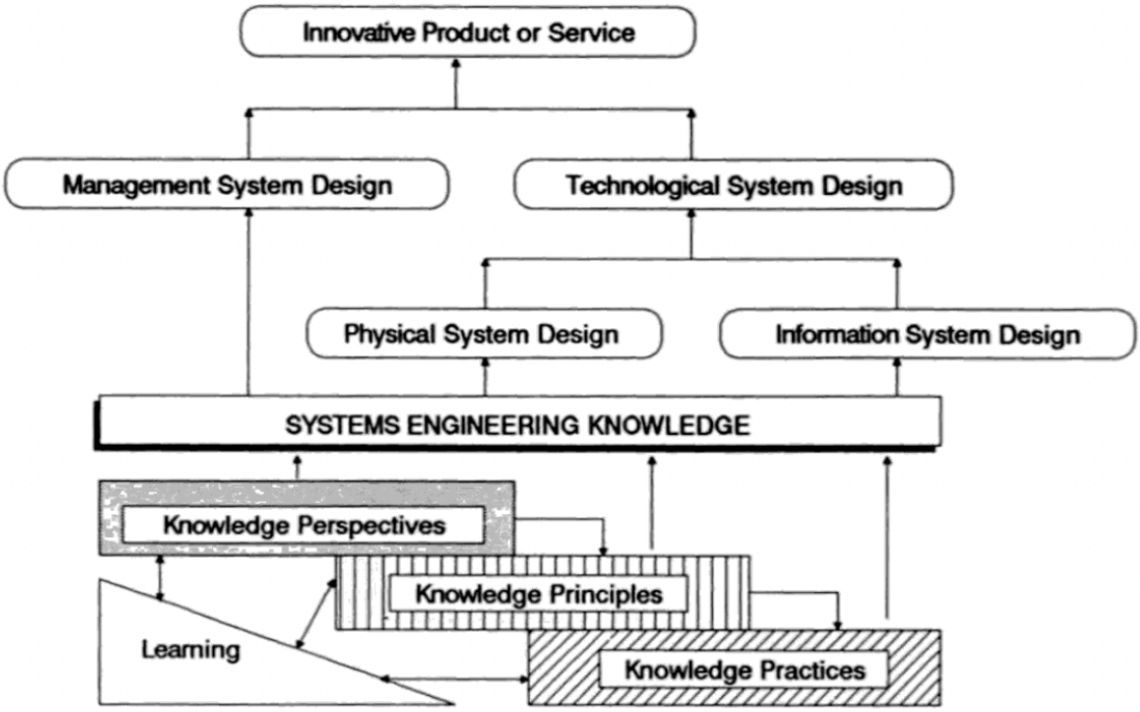

Figure 8: Systems Engineering in the Production of innovative products and services (Sage, 1992, p. 3).

In the field of systems engineering, different architecture frameworks for companies have been developed over time, such as Department of Defense Architecture Framework (DoDAF) and British Ministry of Defence Architecture Framework (MODAF), to support system engineering approaches. These serve to create representations of large companies and to develop methods for capturing their structure and dynamics. Some authors wish to generalize these frameworks to the current state of enterprise architectures in order to make them applicable to systems of system engineering (Nielsen et al., 2015, p. 17).

3.1.2 Empowerment Methods

The concept of systems thinking includes a holistic approach to system engineering, which should be applied to all decisions and considerations. The aim of systems thinking is to reveal complex relationships and expand thinking to achieve a comprehensive understanding of the facts and to find targeted solutions. Systems thinking allows one to detach from pressing daily tasks and focus on higher-level goals, much like an eagle, which uses its keen vision and great heights to see a comprehensive picture (Graessler & Oleff, 2022, p. 16).

Systems thinking is based on the realization that a move away from a linear and intuitive way of thinking is required and that non-linear relationships and feedback effects should be considered instead. The term "systems thinking" nowadays includes a way of thinking that not only considers complex dependencies, but also other dimensions.

The definition of systems thinking varies in the literature and depends on the scope and holistic approach required (Graessler & Oleff, 2022, p. 17). In addition, Systems thinking refers to a way of thinking that allows for an enhanced ability to understand and design complex phenomena or systems. This way of thinking includes concepts for describing complex entities and their relationships, model-based approaches for illustrating real-world complex phenomena without unnecessary simplifications, and approaches that promote holistic thinking (Haberfellner et al., 2019, p. 3).

In the context of systems engineering, particular importance is attached to the two goals "system integrity" and "life cycle justice" and they must be firmly anchored as points of reference in the thinking and decision-making process. Maintaining system integrity requires ongoing consideration and balancing of all aspects that contribute to project success, including business, financial, and technical goals. Lifecycle compliance complements system integrity by continuously considering the constraints of all phases of the system lifecycle during system development (Graessler & Oleff, 2022, p. 89).

System integrity is an important aspect of the entire system life cycle, which includes not only the development project but also all other life cycle phases. Consequently, lifecycle-friendly development is crucial as it has a close connection to system integrity. When planning, particular attention should be paid to how the decisions may affect the aftermarket business, after-sales service, reliability during use and disposal costs (Graessler & Oleff, 2022, p. 90). During technological development, the security of technical systems and system integrity were often considered separately. Fail-safe architectures should prevent errors in a system element from having a negative impact on the overall system. To do this, the system autonomously isolates faulty components and adapts to ensure adequate functionality (Schulze et al., 2017, p. 381). In addition, system integrity is an important aspect of the entire system life cycle, which includes not only the development project but also all other life cycle phases. Consequently, lifecycle-friendly development is crucial as it has a close connection to system integrity. In practice, the following four key questions serve to ensure system integrity (Graessler & Oleff, 2022, p. 91):

- How does the decision affect the basis of the business?
- How does the decision affect the funding?
- How does the decision affect the technical solution?
- Are the three aspects balanced or are corrective actions required?

To ensure a life cycle-oriented development, decisions regarding a system must not only be limited to the use phase but should cover all phases of the system life cycle to achieve an optimal result in terms of system integrity. When choosing materials, in addition to technical properties, factors such as reliability and recyclability must also be considered. It is necessary to consider all phases of the generic product life cycle, as recommended by INCOSE (Graessler & Oleff, 2022, p. 91):

1. Strategic planning
2. Development
3. Realization
4. Operation/Provision of Services
5. Decommissioning

As part of strategic planning, impulses are used to generate promising product ideas, which are then implemented in a development order. The type of planning depends on the entrepreneurial boundary conditions, with start-ups developing their first business models and established companies using product generation planning. During development, the successful product idea is implemented functionally and described in the form of geometry modelling, layout planning and software code. Depending on the discipline, different processes, methods, and tools are used. Realization leads to the creation of tangible and intangible components of the product. Mechanical and electronic subsystems move into production, including manufacturing planning, ramp-up management, and production execution (Graessler & Oleff, 2022, p. 91).

Production includes manufacturing, assembly and quality assurance and can be series production or made-to-order. Operation and delivery of services describes the use of the system, giving the company insights into the actual use of the product through contact points such as after-sales service and aftermarket. This results in impulses for the further development of the product, quality improvement measures and new product ideas. When the system is decommissioned, physical assets are taken out of service and the software is no longer used. The decommissioned systems are collected and checked with regard to their reuse and further use or recycling options, such as reuse, repair and maintenance of systems (Graessler & Oleff, 2022, p. 92–93).

3.1.3 Development Methodology

The development methodology serves to structure complex tasks systematically and to steer holistic thinking through a higher-level approach. It consists of related models, methods and tools that help to solve a specific task. The adjustment of the scope and characteristics of the development methodology is tied to the needs of the respective development task and contributes to the establishment of project-specific guidelines. In the landscape illustration, the development methodology corresponds to a topographical map with various alternatives to the goal and a symbol for the V-model, which clarifies the logical linking of the steps to one another (Graessler & Oleff, 2022, p. 17).

As part of the system engineering lifecycle, users are offered support through the V-model, which acts as a thought structure and enables a logical merging of the development tasks. Thinking along the lines of the V-model facilitates the direct integration of central principles of systems engineering into the individual development process (Graessler & Oleff, 2022, t. 109). The V-model graphically represents the systems engineering life cycle and is specifically designed to reduce the complexity involved in developing systems within a systems validation framework. It acts as a standardized methodology for product development and is based on the simple insight that a system can only be successfully validated if it is actually in operation (Elm et al., 2008, p. 254). This is illustrated in Figure 9.

In the V-model, the timeline is traced from left to right, with the left side representing the decomposition of requirements and the creation of system specifications, while the right side represents the integration of parts and their verification. A sequential approach is required, with the SE team first gathering requirements, then creating the design, then building the system, then testing, and finally validating the initial requirements to ensure all specifications are met (Elm et al., 2008, p. 254). The V-model thus represents a method for bringing the activities and process content into a logical dependency and thereby planning a chronological sequence. It enables both an agile approach and a classic milestone-driven project organization and thus acts as a bridge between the systems engineering processes and practical use. In this context, the V-model shows how this goal can be achieved (Graessler & Oleff, 2022, p. 155).

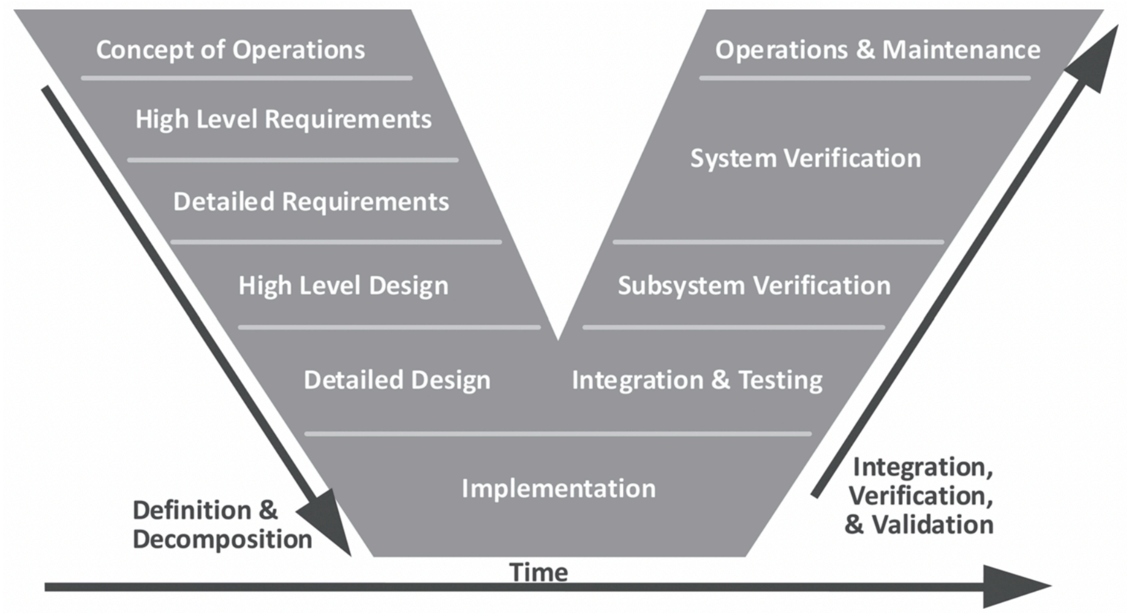

Figure 9: The V Modell of System Engineering (Elm et al., 2008, p. 254).

3.2 Tools

Since this project required the modelling and coordination of complex systems, all applications and technologies used during the project are presented below.

Microsoft SharePoint

Microsoft SharePoint is a collaboration and content management platform developed by Microsoft. It enables companies to store, manage and share documents, information, and other content in a centralized and organized environment.

Microsoft Power Automate

Microsoft Power Automate is a business process automation platform offered by Microsoft. With Power Automate, users can automate workflows related to data and processes within Microsoft applications such as Office 365, Dynamics 365, and more.

Confluence

Confluence is a collaboration and document management tool developed by Atlassian. It enables teams to create, organize and share documents and content together.

Jira

Jira is a software tool for project management and issue resolution administration. It is commonly used by software development teams and IT departments, but it can also be used in other industries and for projects of different sizes.

Draw.io

Draw.io is a free, web-based diagram and drawing tool. It is used to create and edit different types of diagrams and drawings like flowcharts, organization charts, network diagrams, mind maps, UML diagrams and many others.

4 Project: 3D Experience

The following section deals with the "3D Experience" project, which is presented. First, an introduction to the project is given and then the platform is presented. Furthermore, their functionalities, the conception and implementation as well as the characteristics of the issue management and the collaborative tasks are described.

4.1 Introduction

From the very beginning, I was immediately drawn to my work project with a German automobile manufacturer. While pursuing my bachelor's degree, I had the opportunity to complete an work project with an automotive supplier, which gave me a positive experience within the German automotive industry. In Germany, the automotive industry is the largest and most significant branch of the manufacturing sector in terms of sales. This industry is home to some of the most well-known car manufacturers such as Audi, BMW, Mercedes-Benz, Opel, and Volkswagen. It is noteworthy that the Volkswagen Group serves as the parent company of the Volkswagen Passenger Cars brand and its subsidiaries, including Seat, Skoda Auto, and Audi, as well as prestigious brands such as Bentley, Ducati (motorcycles), Lamborghini, and Porsche. As a result, the German automotive industry is often recognized as a thriving and rapidly expanding sector.

Nowadays it can be observed that the car is increasingly becoming a digital product. For a car to be able to drive partially or fully autonomously, it needs a lot of different information. These must be recorded by sensors and cameras, processed, and forwarded to a central interface, which in turn outputs information about what needs to be done. The automotive industry is in high demand and offers career opportunities in different areas, from the production of vehicles to research and development. Innovations, especially in the field of alternative drives, play a decisive role for the future. The given combination is very unusual because it combines all professional fields that interest me. In addition, the work project in German car manufacturer promises insights into various areas. As I am doing my master's degree in information management and was looking for a field to specialize in, this opportunity was ideal for me (IT-Berufe, n. d.).

After two interviews, I was given a full-time contract with a term of five months from September 3rd, 2022, to January 31st, 2023, followed by a working student position with a 18h/week contract if the expectations during the work project were met. Working as a student enables enrolled students to work alongside their studies, as in my case, to focus on relevant research topics and to work on the work project. The German car manufacturer gave me a warm welcome. Special surprises were three "get2know" lunches, which serve to get to know new colleagues from different departments, which makes it easier to get to know each other quickly. A 2-day tour of the car manufacturer's plants then began with a detailed explanation of all processes.

After the introductory round, we all got our computers and we had to take part in certain training courses on the learning platform to be able to start working. The learning platform is the central portal for technical and interdisciplinary qualifications in the relevant company. The platform is used to provide and manage internal and external qualification measures. The following six training courses were mandatory in total: financial processes, data protection, mobile working, general safety instructions, company fire protection instructions and digital security.

In addition, at the beginning of the work project, the newcomers were given two readings to give them a basis for their work. These readings were "Information Management" by Eberhard Stickel and "Development Accompanying Digital Mock-Up in Automobile Construction" by Roger Markworth. By reading these books, the newcomers gained a deeper understanding of the subject matter of the CAx coordinator in an automobile company and were thus better prepared for the upcoming tasks and projects in the coming work project. It is of great importance that newcomers prepare for their work to be able to carry out their work more effectively and efficiently. The first reading deals with the economic management of information. It imparts basic knowledge in the field of information management and focuses on economic aspects. The topics range from strategic tasks to administrative tasks, problems and concepts of project management and operational tasks of information management. It is important standard knowledge for students of business informatics or economics as well as practitioners. The second reading deals with the conception and implementation of a digital mock-up at a German automobile manufacturer. Real-world experiences are used to provide an in-depth look at the challenges that have arisen in adopting the digital mock-up approach, from conception to changing design flows at the car manufacturer.

Especially for the body development department, which I joined, it is important to understand how the different departments and their work are related. The org chart is a simple five-level pyramid with the CEO at the top, the board members, the heads of each major department at the third level, below theirs are the department heads, and at the last level are the team leaders. The body development department consisted at that time of three hundred colleagues who mainly focused on development and test engineers and special projects. The goals of the department and each employee are recorded quarterly with the team leaders to coordinate goals and go in the right direction together. At the end of each week, each Body Development team has their own team meeting where each employee gives a status report on the status of the projects, completed activities, next steps, and issues that might block the next steps. External IT service providers have been commissioned to support our team. These service providers focus on highly specialized solutions and IT services for virtual product development using computer-aided methods. In this way, the corresponding projects could be supported. In the next chapter, the work project is examined in more detail. Weekly jour fixe was planned with the supervisor, the IT service provider, and the employee to discuss personal tasks and problems that arose. In addition, there was daily jour fixe between the supervisor and the employee to discuss daily tasks and answer open questions. In-depth, face-to-face feedback sessions were conducted at three and five months, using a guide provided by the vendor, Small Improvements. In these feedback rounds, employees and their supervisors evaluate each other's personal and professional performance and recommend opportunities for improvement.

4.2 Dassault Systemes: 3D Experience

The project was the analysis and testing of a functionality “Issue Management” and “Collaborative Tasks” of the 3D Experience from Dassault Systems. The 3D Experience is newly implemented in this automotive group. The reasons for implementing 3D Experience are to increase productivity, improve collaboration, increase design quality, and increase innovation. This is discussed in more detail below.

4.2.1 Concepts

According to Dassault Systemes, 3D Experience is a "Business Experience Platform" accessible both on-premises and in a public or private cloud. Thus, the 3D Experience has a uniform interface that serves the different applications and enables access to the data required by different roles within a company. This means users can use a common platform to access the data they need, regardless of their specific role or task (a.Dassault Systemes, n. d.). With the 3D Experience from Dassault Systemes, users can create, visualize, and analyse three-dimensional data and models in real time thanks to its integrated platform. This helps users make their decisions based on accurate data. The platform uses the latest technologies, including virtual reality and augmented reality, to create a realistic and interactive user experience. These technologies allow users to experience and analyse their data in a realistic environment and is useful for applications in areas such as product development and manufacturing. Thus, this platform is an important part of the digital transformation and offers companies a unique opportunity to improve their business results. Thus, people, ideas, data, and solutions are connected in a single, collaborative environment and provide companies, from start-ups to large enterprises, with completely new possibilities for innovation and production (a.Dassault Systemes, n. d.).

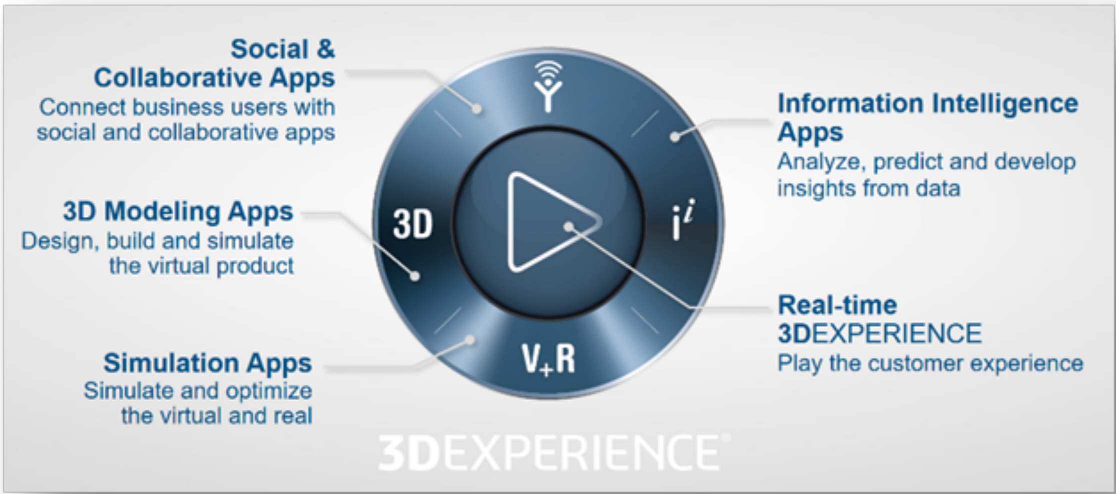

Figure 10: The 3D Experience compass (Medeiros, 2020).

The platform connects several applications and tools that enable companies to optimize processes and procedures, minimize risks and save time and money. In addition, the 3D Experience enables close collaboration and communication between different departments and locations, which improves efficiency and the quality of decisions. Accordingly, the 3D Experience acts as a central point of information and provides a solid basis for result-oriented processes and the uniform recording of all activities (a.Dassault Systemes, n. d.). The applications in this platform are relevant to 3D Modelling, simulation, collaboration, and information intelligence as shown in Figure 10. The applications accessible to a user are contingent upon their assigned role, as well as any extra applications that have been procured and are categorized into Social & Collaboration (North), Information Intelligence (East), Simulation (South), and 3D Modelling (West) (Medeiros, 2020).

As shown in Figure 11, the 3D Experience platform represents a more comprehensive solution than a traditional Product Lifecycle Management (PLM) system. The focus is on the customer instead of just the product. This integrated suite covers all aspects of product lifecycle management, providing a holistic perspective. As previously mentioned, the suite includes integrated software for three-dimensional modelling, management and sharing of information and data, product information and data intelligence, simulation, analysis, manufacturing, engineering and product design (Viraitc, n. d.).

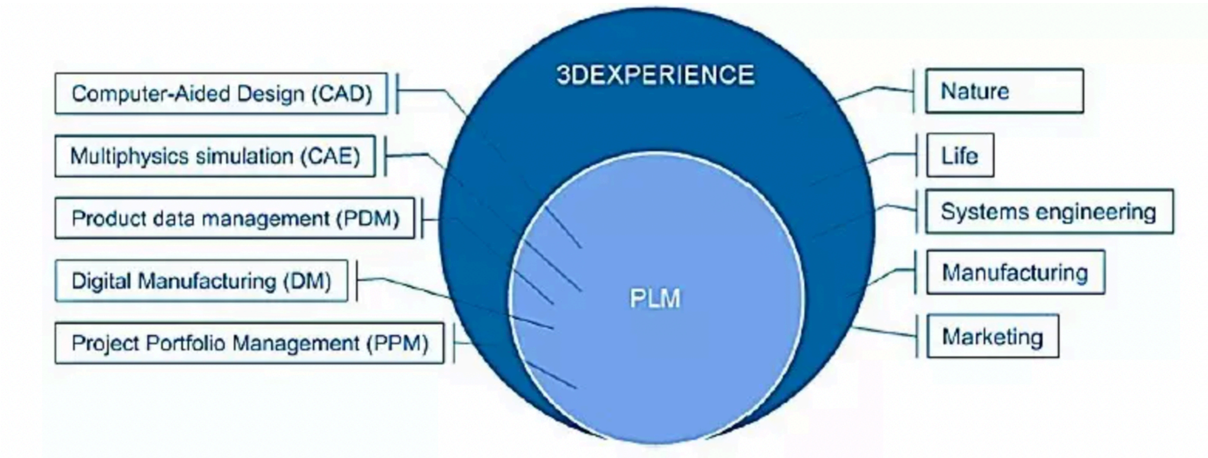

Figure 11: The idea behind the 3D Experience platform. Adapted from (Viraitc, n. d.).

The 3D Experience platform provides a central environment for the design, development and manufacture of next-generation products, services, and experiences. Accordingly, there is a need for a solid data model, an ontology for all business areas, functions for managing and processing the data, a common platform that facilitates and ensures the collaboration of all teams and a uniform, user-friendly experience that accelerates processes and collaboration (b.Dassault Systemes, n. d.). This means that there is no conventional file system in this system, but all product-related information is stored in a central location as data. Authorized users can continuously stream this data to their workstation while working with it. Unlike traditional product data management (PDM) systems that require users to check out files to work on them while simultaneously denying other users access, this system allows for parallel editing by multiple users (Stark, 2016, p. 237). In addition, cooperation is improved, and the development of complex products is accelerated by connecting different departments. The ability to develop designs in 3D enables virtual verification and simulation, resulting in improved assembly and reduced development costs. Potential manufacturing issues can be identified early, without the need for a physical prototype, and time to market is reduced (b.Dassault Systemes, n. d.).

The platform also connects a company to a broad network of industrial service providers. The 3D Experience Marketplace gives designers and engineers access to the largest online catalogue with millions of 3D components and numerous qualified suppliers. The development department can easily upload designs, request quotes for manufacturing projects, or engage technical experts who specialize in digitizing, designing, and certifying products. Another advantage is that the platform is based on a cloud infrastructure, which removes technical barriers for companies and allows them to integrate all areas of their organization in a centralized, cloud-based environment (a.Dassault Systemes, n. d.).

It provides instant access to modern applications and online services that make it easier for teams, customers, and remote employees to work together. The platform helps companies of all sizes bring innovative thinking and product development to market faster by providing proven, results-driven processes. In addition, the creation of environmentally friendly products, materials and processes is made possible through the conception, construction, and testing of new concepts. She supports companies in overhauling their value creation process, selling experiences instead of products and implementing new, environmentally friendly innovations. By promoting new forms of collaboration between sellers, buyers and customers, the platform contributes to the achievement of sustainable goals (a.Dassault Systemes, n. d.).

4.2.2 Roles

The 3D Experience platform is designed to unite all departments of a company and thereby reduce silo effects. In doing so, it enables smooth collaboration in the cloud, which enables improved communication and greater efficiency in various areas such as product design, data management and project management. Within the Platform from Dassault Systemes there are different roles that provide specific functions and tools. These roles can be assigned to a user as needed to enable them to access the required tools. In the context of the 3D Experience platform, the role of a user can essentially be described as a combination of different tools. Access to specific roles, each containing the required tools, depends on the tasks for which the user is responsible. Applications give you access to the functionalities of the platform. Based on your role, you get different widgets to provide all the tools you need. In the context of the 3D Experience, a distinction is made between the roles of Collaborative Business Innovator, Collaborative Industry Innovator, Collaborative Designer, and 3D Creator (Vemborg, n. d.). In the following, four common roles are presented, which are important for the widgets, which are discussed in the following chapters.

Collaborative Business Innovator

The primary purpose of the Collaborative Business Innovator role on the 3D Experience platform is to facilitate collaboration among internal resources, suppliers, partners, and customers to enable sustainable innovation in the automotive manufacturing space. This role is vital for all users who have access to the platform. This role allows users to access 3D Dashboards, 3D Swym, 3D Play, 3D Drive, 3D Search, User groups, Web Page Reader widgets, and collaborate in communities to share and innovate. Leveraging this role allows for a higher level of trust by involving customers early in the product development process and providing important feedback from stakeholders quickly and easily accessible, enabling faster time to market (Vemborg, n. d.).

Collaborative Industry Innovator

The Collaborative Industry Innovator is a basic but powerful role available to any engineer or designer in the automotive industry. By using this role, the engineering team can access an important collection of widgets that allow them to collaborate in real time. This role also supports safe and organized collaboration on product files. It was conceived as a scalable online environment for product design and manufacturing process planning, offering full traceability and flexibility.

In addition, this role ensures compliance with standard business processes such as changes, projects and quality and offers the possibility to expand with new roles. Using this role effectively connects the value chain. Among other things, it includes access to important widgets such as Bookmark Editor, Change Action, Collaborative Lifecycle, Collaborative Tasks, Compare, IP Classify & Reuse and Route Management (Vemborg, n. d.).

Collaborative Designer

The Collaborative Designer creates a connection between desktop CAD users and the 3D Experience Platform. This enables product designs and data to be managed directly on the developer's desktop. In addition, users have access to the platform's web-based applications, which allow them to control, review and visualize designs at any time and from any device. This facilitates the connection of desktop CAD users to the 3D Experience platform, enabling effective management of a vehicle's entire lifecycle including versions, revisions, and releases. It's also easier to navigate product structures to visualize designs and changes. The capabilities of this role include the Derived Format Converter widgets and connectors to Solidworks (Vemborg, n. d.)

3D Creator

The 3D Creator role embodies innovation, collaboration, and beautiful designs that can happen anytime, anywhere. This role integrates an easy-to-use interface with powerful design tools and enables cloud collaboration - all from a single browser window. This role is intended for users who do not have a desktop version of Solidworks or an integrated Solidworks and 3D Experience solution. Apps that users with the 3D Creator role can access include XDesign and a derived format converter (Vemborg, n. d.).

4.2.3 Virtual Twin

The Virtual Twin technology, powered by the powerful 3D Experience-platform by Dassault Systemes, allows companies to create and visualize realistic digital twins of physical objects, processes, and procedures. This innovative approach combines the virtual world in the form of an abstract object model with reality by integrating internal data sources, the Internet of Things (IoT), and the cloud. With Virtual Twin, companies can achieve efficiency gains, cost reductions, and innovation advantages by analysing, optimizing, and simulating complex products and systems in a virtual environment (d.Dassault Systemes, n. d.).

The Virtual Twin Experiences go beyond traditional digital twins by not only modelling the prototype of an object or system but mapping the entire environment in science-based models and simulations. Through seamless collaboration and advanced graphical representation, Virtual Twin enables the modelling of complex systems (c.Dassault Systemes, n. d.). This creates a realistic virtual representation of physical objects or systems in the form of a software model. A Virtual Twin Experience begins with the creation of an accurate 3D model that mirrors the real object in terms of its shape, dimensions, and properties. Simulations are performed using this virtual model to analyse the behaviour of the real object during operation. These simulations contribute to the optimization and validation of design, material, and production processes. By using virtual twin technologies, companies can address sustainability challenges and foster innovation by developing innovative models that accelerate cross-team collaboration and using simulation in the design process to assess performance, reliability, and safety (c.Dassault Systemes, n. d.).

As the manufacturing industry faces unprecedented transformation, driven by new technologies, the quest to reduce costs and minimize disruption, virtual twin technology plays a critical role in the successful transformation towards flexible, agile, and cost-effective manufacturing operations. Production line customization for new products is enabled by defining and simulating plant layout, flow, equipment, and resources required to manufacture products efficiently and safely. With virtual twin technology, normal production change requirements can be quickly validated, or operations can be quickly switched to alternative products due to disruptive events. In addition, through the Layout Optimization and Security in Supply Chain Planning & Optimization enables alternative delivery and production schedules to be modelled, simulated, and optimized to minimize disruptions (e.Dassault Systemes, n. d.). With the use of virtual twins, it enables companies to visualize, model, simulate and optimize the entire product life cycle. This process begins with the creation of a 3D model that represents the dimensions, properties, and dependencies of the physical object.

Through simulations on the virtual model, companies can analyse the behaviour of the object in different scenarios, be it during assembly, in operation or in relation to other systems. This enables the analysis and creation of sustainable business innovations over the entire life cycle of the product (PR Newswire, 2022).

By applying factory process optimization, manufacturers can improve their responsiveness and produce new products more efficiently. An example of this is the use of virtual twin technologies to accelerate the development of electric vehicles by using them in the evaluation and communication of mobility concepts and in the design and simulation of supporting systems such as applications and infrastructure (PR Newswire, 2022). The use of Virtual Twins in the manufacturing industry thus offers a promising approach to meet the challenges of change and to improve the efficiency, flexibility, and cost-effectiveness of manufacturing processes (e.Dassault Systemes, n. d.).

4.2.4 Collaborative Space

The 3D Experience platform encourages people from different disciplines to collaborate and enable them to deliver best-in-class solutions and experiences for their customers. It is a collaborative platform that allows access to different vendors of the company to work together on the development of products or solutions. Admission of vendors to the platform can be done through the use of Collaborative Spaces that serve as an interface for collaboration (Corey, 2020). This allows multiple users to simultaneously access and manage the data they need in real-time, starting with one user. An example of this is a worker can verify how a part fits into an assembly while the supplier is simultaneously changing the dimensions of the part. If a collision occurs, both parties will receive a notification on their screen with relevant information.

Shared workspaces are created to work on specific projects and allow multiple users to collaborate. Creating a collaborative space for the project allows the organization's members and providers to work together in the same space and facilitates the flow of information between the different stakeholders. Protecting the data used by the organization and the vendor in the shared collaborative space is of great importance, especially when multiple vendors are involved. The collaborative space owner is responsible for access control to ensure only authorized users can access the data (Corey, 2020).

Significant updates have been made in the 3D Experience affecting the visibility of collaboration rooms. Previously, visibility settings could be selected as Private, Protected, or Public. Now the admin can customize the visibility of private and protected areas, but not public areas.

With the latest platform changes, the supplier can be invited to the environment by an admin and the existing collaborative space can be turned into a private collaborative space. As a result, the supplier is never shown any data in the environment. Instead, all customer data can be added to a new private collaboration space and granted access to the supplier. Once this is complete, the supplier can only access the data in their collaborative space. When the supplier has completed their work in the environment, access to the supplier can be removed and changed back to public. This offers significant flexibility and no longer ties you to a specific visibility like before (Dalal, 2022).

4.2.5 Model Based Systems Engineering in Process Development

An improvement in the transition from traditional document-centric system development with specifications to a database-supported requirements engineering tool can be achieved by using Model Based Systems Engineering. Model Based Systems Engineering enables a comprehensive description of all requirements and specifications for the future product and coordinates its entire life cycle. Model-based also means that there is only one digital representation of the project that everyone involved is working on, even if they are spread across different locations around the world. This automatically creates the necessary collaboration and networking between the different teams involved in the digitized process of product development (Loeckel, 2018, p. 20).

In the area of product development, Systems Engineering offers an interdisciplinary approach to design the process effectively and successfully. A modern approach here is the so-called Model Based Systems Engineering, which models the complete system and accompanies the entire development process. With the help of simulation and virtual twins, as the 3D Experience Twin enables, realistic images of the products and systems can be created that show the behaviour of the products and integrate external framework conditions and regulations in complex product developments. In this way, the development process can be streamlined and higher quality products can be achieved (f. Dassault Systemes, n. d.).

Dassault Systemes offers companies support in the implementation and use of Model Based Systems Engineering software. The company provides comprehensive model-based systems engineering tools that make the application of model-based systems engineering methods more efficient. This can help simplify processes and significantly reduce the complexity of product development. In addition, Dassault Systemes offers support in applying Model Based Systems Engineering methods to improve process and product development. This includes the analysis of the current situation and the definition of a target state in close cooperation with the customer. Subsequently, the ideal approach and the appropriate model-based systems engineering methods for the implementation of improved processes and the correct application of the 3D Experience platform can be developed (f. Dassault Systemes, n. d.).

Every single change is on the working platform for every team immediately visible to everyone and there is always only one current version of the system (single source of truth) to avoid errors and save time and money. Model Based Systems Engineering enables the complete mapping of the system including its subsystems and enables an evaluation.

The developers derive the necessary processes and tools from the customer requirements and describe them comprehensibly with the help of various models. In addition, model-based systems engineering integrates the existing models of a system via suitable interfaces. There are different languages such as SysML, methods and IT tools used to create the system model (Loeckel, 2018, p. 20).

Another important tool in Model Based Systems Engineering for the development of complex systems, including those in the automotive industry, is the RFLP (Requirement, Functional, Logic, Testing). Together with the Modelling Methodology for Systems (MMS), RFLP ensures that the requirements for the system are complete, consistent, and traceable and that all functions of the system are linked to the requirements. By applying MBSE and RFLP, requirements can be analysed and managed in a comprehensive, systematic, and precise manner, which is crucial for the development of reliable and secure systems (Loeckel, 2018, p. 21).

The car manufacturer's project uses a Model Based System Engineering (MBSE) approach to guide the modular design process and support system requirements, design, analysis, verification, and validation. This approach is applied from the conceptual design phase to later life cycle phases. The 3D Experience platform provides the native MBSE approach, which follows a V model (Audoire, 2019). The V-model is based on systems engineering approaches and works in sequential mode, making it easy to understand and use. With this method, the various aspects of a system can be represented in different model variants (e.g., static, dynamic) and modelling levels. Both the system analysis from an external perspective (mission, service) and the detailed system design (functions, components) are recorded. By simulating the behaviour of prototype vehicles, developers can validate the selected models and their performance at an early stage (Loeckel, 2018, p. 21).

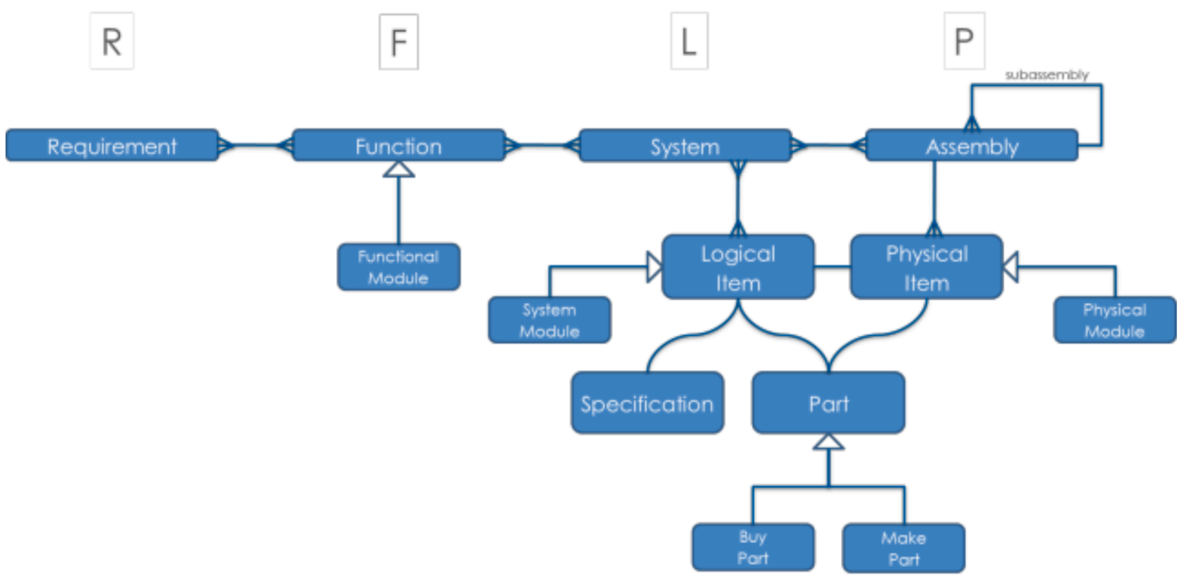

Figure 12: RFLP – Framework (Audoire, 2019).

The platform manages a single digital model that includes both Requirements (R), Functions (F), Logic (L) and Physics (P) on the left side of the V model. This process mainly follows a top-down approach, considering the needs of the stakeholders to achieve a system design and implementation. A benefit of the RFLP approach is that it allows product teams to independently analyse design elements, identify reusable components, and create a logical integration path to get a comprehensive view of the product definition (Audoire, 2019). The RFLP framework provides support for the Model Based Systems Engineering process which is illustrated in Figure 12.

The requirements (R) include all requirements that the system must meet, from stakeholder requirements to system and design requirements. It is about defining what the system, or the product should achieve. The functional (F) requirements describe the system services and the functional architecture with functions and processes that the components of the system must provide. The point here is to describe what the system or product is supposed to do. The logical (L) requirements describe the component architecture with the components of the system, their interfaces and the assigned functions and processes. It describes which technology is to be used and what the system or product will be like. The Physical (P) requirements define the lifelike system components, including the 3D modelling disciplines (mechanical, electrical, fluidic). The aim here is to describe how the real system is to be implemented (Audoire, 2019).

The RFLP data structure acts as the central foundation within the systems engineering and is seamlessly integrated into the current 3D experience platform. The data structure can be adapted to the specific needs and requirements of a company or a development and thus allows, for example, the integration of additional nodes into the structure. In model-based systems engineering, all relevant models are integrated into a higher-level system model from which different views of the system can be derived. Changes to a subsystem or a component always affect the surrounding areas and components, which are always visible through the overall system model. Due to the complete integration of the different disciplines, system-wide analyses and validations can be carried out, which enables cross-domain simulations (Loeckel, 2018, p. 21).

The image below shows this concept with an example in the form of a vehicle seat in the 3D Experience platform. First, the requirements, the functional architecture, the logical level in 2-D and 3-D as well as the physical level and then implemented in a physical product (Loeckel, 2018, p. 22).

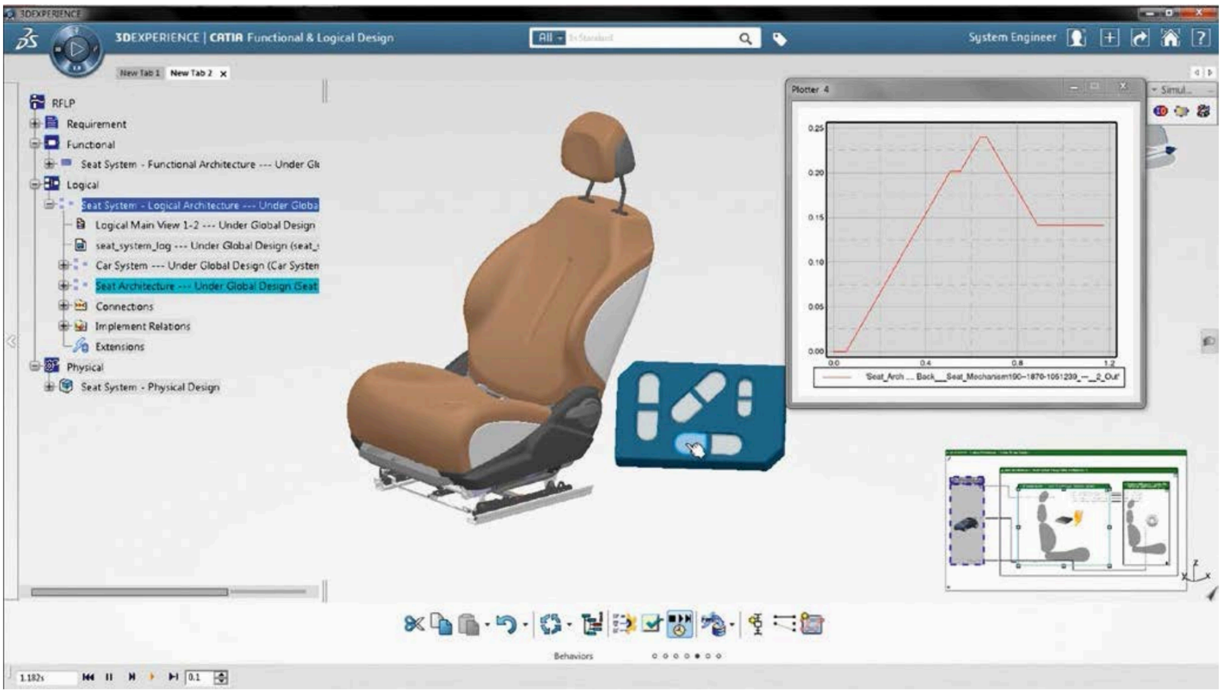

Figure 13: Vehicle seat in 3D Experience based on the RFLP approach (Loeckel, 2018, p. 22).

4.3 Issue Management

In the following, the functionalities of the "Issue Management" widget as well as the challenges faced by developers and the corresponding proposed solutions are presented.

4.3.1 Functionalities

Issue Management is a widget in the Social and Collaborative Apps section of the 3D Experience Platform. It is responsible for problem management in the 3D Experience environment and is an important part of the toolset for collaborating in a virtual 3D environment. It is used to record, manage, and monitor problems and challenges that may arise during project work. Thus, the work processes in a development project for a vehicle can be optimized and it is suitable for companies of all sizes and enables more efficient task processing (CATI-Marketing, 2021). Thus, no e-mail traffic between the person responsible for the component and development engineers as well as the supplier is necessary to request changes. Accordingly, change requests can no longer be overlooked by those responsible for components, since those responsible for components make the request directly within the platform. In addition, a notification is sent to the respective person within the platform. The following image illustrates the Issue Management widget on a 3D Experience dashboard.

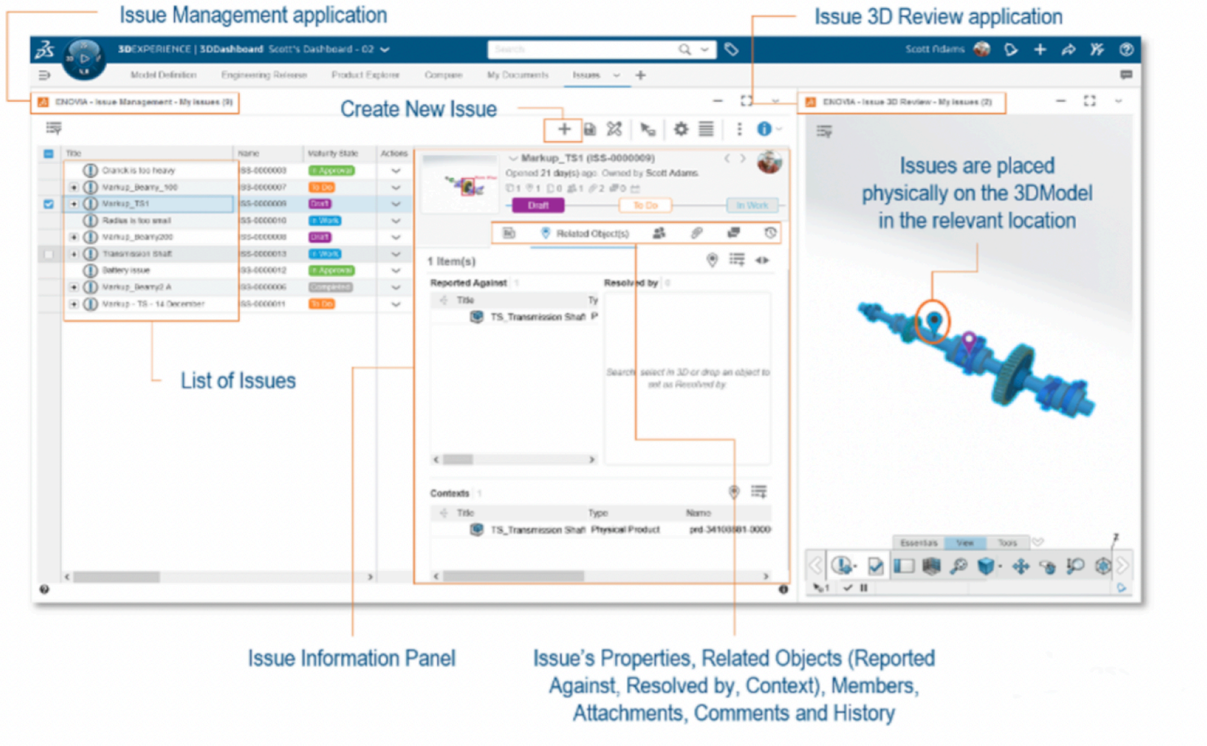

Figure 14: The Issue Management Widget. Adapted from (Daga, 2020).

The widget described represents functionality within the 3D Experience platform that allows users to identify and manage issues. The widget offers various features that make it easier for users to better understand the context of the problem and to react to it quickly. An important feature of the widget is the ability to create problems and link them to objects in the virtual environment. This allows affected parts to be identified and checked quickly and easily. Additionally, attachments such as images, documents, and screenshots can also be added to the issue to provide additional information. To ensure effective management of issues, member settings can be made in the widget. Various roles such as owner, co-owner, officer, contributor, and the responsible organization can be assigned. As a result, responsibilities and competencies can be clearly defined and distributed (CATI-Marketing, 2021).

Thus, issue management allows anyone with access to the corporate platform to make suggestions that may lead to changes, without having to provide the technical details needed to resolve the issue. It is up to the part manager to evaluate this part to decide if a change is needed and what specific changes need to be made by whom to which CAD file. This capability is extremely useful for the entire organization as employees who may have information of value to the product development team can report issues directly with the data pertaining to the issue without having to worry about the resolution (Plmgroup, n. d.).

This allows the responsibility for processing the issues to be clearly defined. Users can also add comments to keep track of progress and responsibilities. The issue management widget also supports monitoring and managing the lifecycle of an issue. Users can add information like "Action Taken", "Resolution Statement" and "Extensions" to each issue and change the status of the issue to track the progress. The Issue Management widget also manages CAD or non-CAD issues that may arise in the product development process and can be used together with a formal change management process.

Accordingly, by recording and distributing problems based on user permissions, collaboration is simplified, and the overview of daily tasks is improved.

If an issue is discovered during a project, by a component manager or in another development context, it is recommended to use the "Issue Management" widget. The widget provides the ability to create an issue with contextual information, associate it with an object, and then escalate it to the appropriate organization or person. In this context, context information or objects can relate to any component of a prototype vehicle. Issues can be created directly on a part, through markup, or independently of both. They can be edited later, and their life cycle can be changed by the "Maturity State". Problems can also create routes and tasks. The issue management thus enables information to be entered as "properties" (e.g., title, description, priority, due date, processing suggestion, etc.). It is also possible to add components and installation space environments ("Contents") as well as attachments ("Attachments"). Screenshots, images, and markups can be inserted here. It is also possible to add contributors ("members"), including the owner (owner and creator of the issue), co-owner, assignee (processor), and contributor (shareholder). Comments can also be inserted ("Comments"). The panel of an output is shown in the figure below.

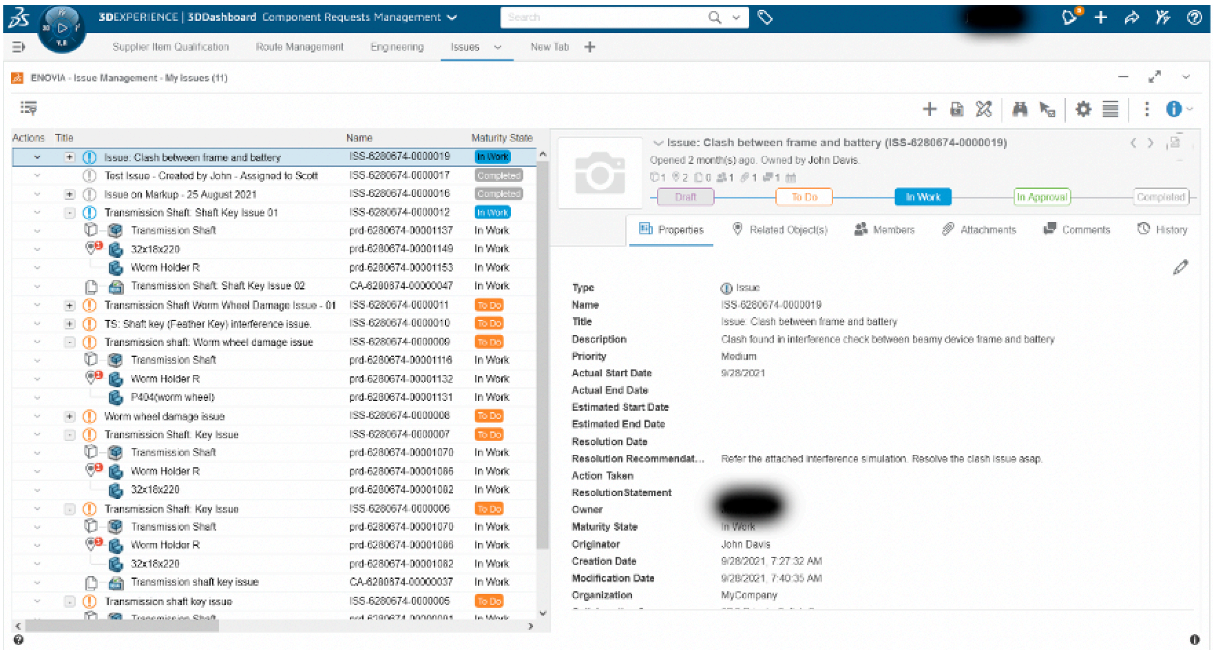

Figure 15: Overview of issues (Plmgroup, n. d.).

4.3.2 Definition of Requirements

The following are specific requirements that must be met to enable effective management of issues within the virtual environment. These requirements were developed using use cases that were designed to be as realistic as possible. There were two meetings with the designer to create the use cases and a final meeting for verification and validation. It is important to mention that each use case has been assigned to a widget and a workflow. Care was taken to ensure that the use cases cover different scenarios to ensure that issue management can react to different requirements.

Title	Clean flow of Information
Description	Designers need the ability to forward parts and conflicts to a service provider to ensure a clean flow of information. The platform must be connected to the service provider and the exchange of information must take place within the platform. It is also important that the platform ensures that the exchange of information takes place within the platform to ensure the protection of sensitive data.
Proposed solution	This use case can be carried out with the basic workflow of issue management.

Title	Collision problem of components
Description	The designers need a channel of communication to report issues related to the installation of the design to the responsible person. The responsible person must be informed of the reported problems, conflicts must be documented, and solutions must be able to be communicated effectively. Here it is important that the person responsible can prioritize the reported problems and, if necessary, make resources available to find a solution. Effective collaboration between the designers and the responsible person is required to ensure that component collision issues can be resolved quickly and effectively.
Proposed solution	This use case can be carried out with the Approval Workflow of Issue Management.

Title	Inform about the results of the calculations
Description	The department for calculations needs the possibility to inform those responsible for the component about the results of the calculations to trigger follow-up tasks/corrections on the component. There must be clear communication between the Calculation Manager and Part Manager and the results must be clearly communicated to the appropriate person. The issue management system must be able to capture the results of the calculation, document the issue, and automatically send the issue to the appropriate manager to ensure fast and effective issue resolution. In addition, the system must provide the ability to track the status of the issue to ensure it has been fully resolved.
Proposed solution	This use case can be carried out with the Approval Workflow of Issue Management.

4.3.3 Design of the Solution

There are three recommended ways to create a problem in 3D Experience. The first way is within the issue management, by selecting "New Issue" at the top of the widget and opening the "New Issue" dialog. The second option is as part of the 3D review of issues, right-click on the affected part and then select "New Issue", which also opens the "New Issue" dialog box. The third way is to start from a markup, create a markup and then select Generate Issue from the action bar, which opens the New Issue dialog.

It is important to note that the selected component or markup is automatically populated as Affected Article or Attachment under the Content or Attachments tab of the New Issue dialog. This saves time and ensures accurate documentation of the problem. Additionally, attachments such as images, documents, and screenshots can be attached directly to the issue to provide more information and better understand the context of the issue.

The "New Issue" dialog box provides advanced options for configuring a new issue. To access these options, the settings menu must be opened. Clicking on "Assign content owner to the issue automatically" will register the part owner as a contributor in the "Members" tab when a part is selected. By clicking on "Enable approval to ensure validation and verification of this issue," the "Approval workflow" is selected. If this option is not enabled, the issue will start with the "Basic workflow."

The option to "Save the issue as a reusable template" allows the issue to be saved as a template. It should be noted that templates are user-specific and can only be shared through a link. Additionally, there are two different workflows for creating issues within the Issue Management. To distinguish between the workflows, activate "Enable approval to ensure validation and verification of this issue" when creating the settings. Both workflows are described in more detail below. To ensure a continuous and traceable process, the recommendations and guidelines for workflows should be followed.

Basic Workflow

The Basic Workflow is used to report a problem when no review of the problem solution is required by the creator. The owner (creator) and the assignee (handler) of the problem can close the issue after it has been processed. To create the workflow, a new issue is created in the issue management system. In the settings, "Enable approval to ensure validation and verification of this issue" is disabled. Once all the information has been filled in, the issue can be moved directly to the "To Do" status by clicking on "Start".

The assignee is responsible for processing the issue, which can be assigned by either the assignee themselves or a collaborator. After processing, the issue is set to "In Approval" status. If the problem solution is acceptable, the issue can be closed. In the "Basic Workflow", both the owner and the assignee can close the issue themselves. The basic workflow is illustrated in the following figure, which shows the status of the workflow in the delineated areas.

Approval Workflow

If the owner needs to approve the output, the "Approval Workflow" must be selected. Both the responsible person and the owner must confirm the task of the workflow and accept the solution to the problem. The problem is created in the same way as the basic workflow, but with the "Enable approval to ensure validation and review of this problem" setting activated. It is important to note that if this checkbox is set, it is usually saved. If a new workbook is created that includes the basic workflow, the setting must be manually changed beforehand. After the output is started, a route is automatically created and assigned to the agent for confirmation of processing.

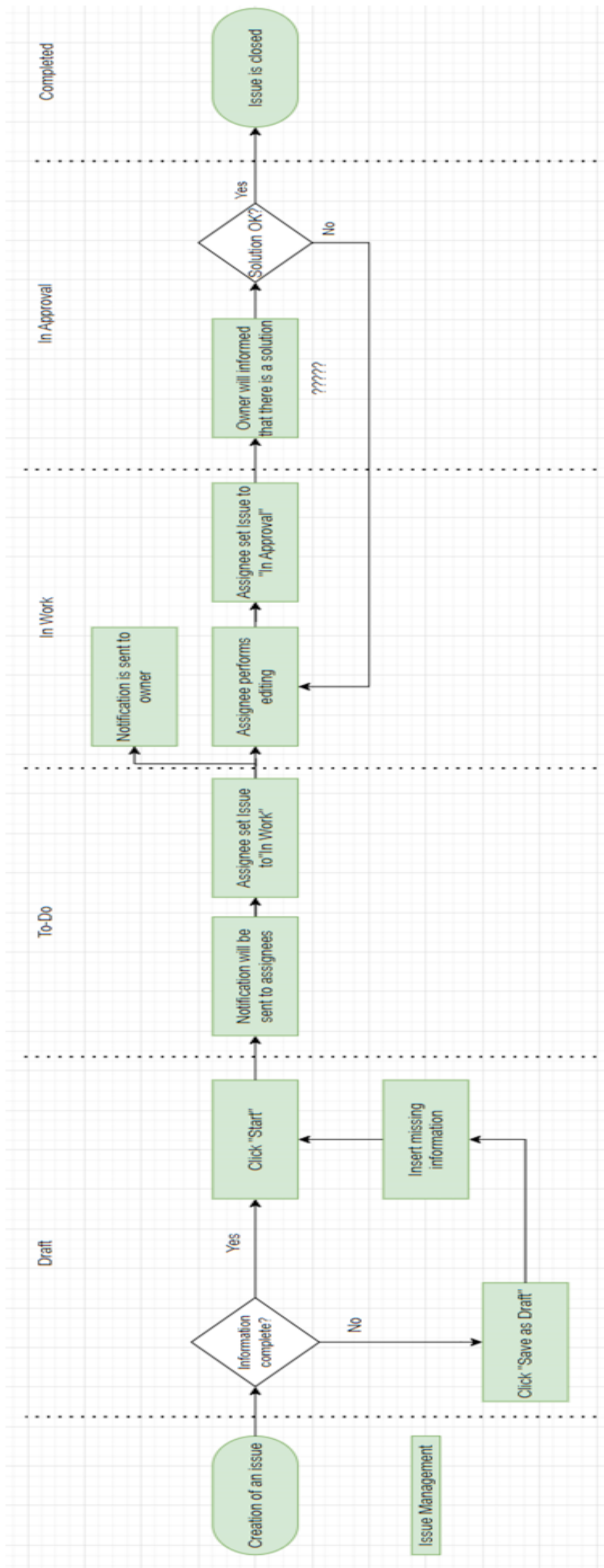

Figure 16: Basic workflow in issue management (prepared by the author).

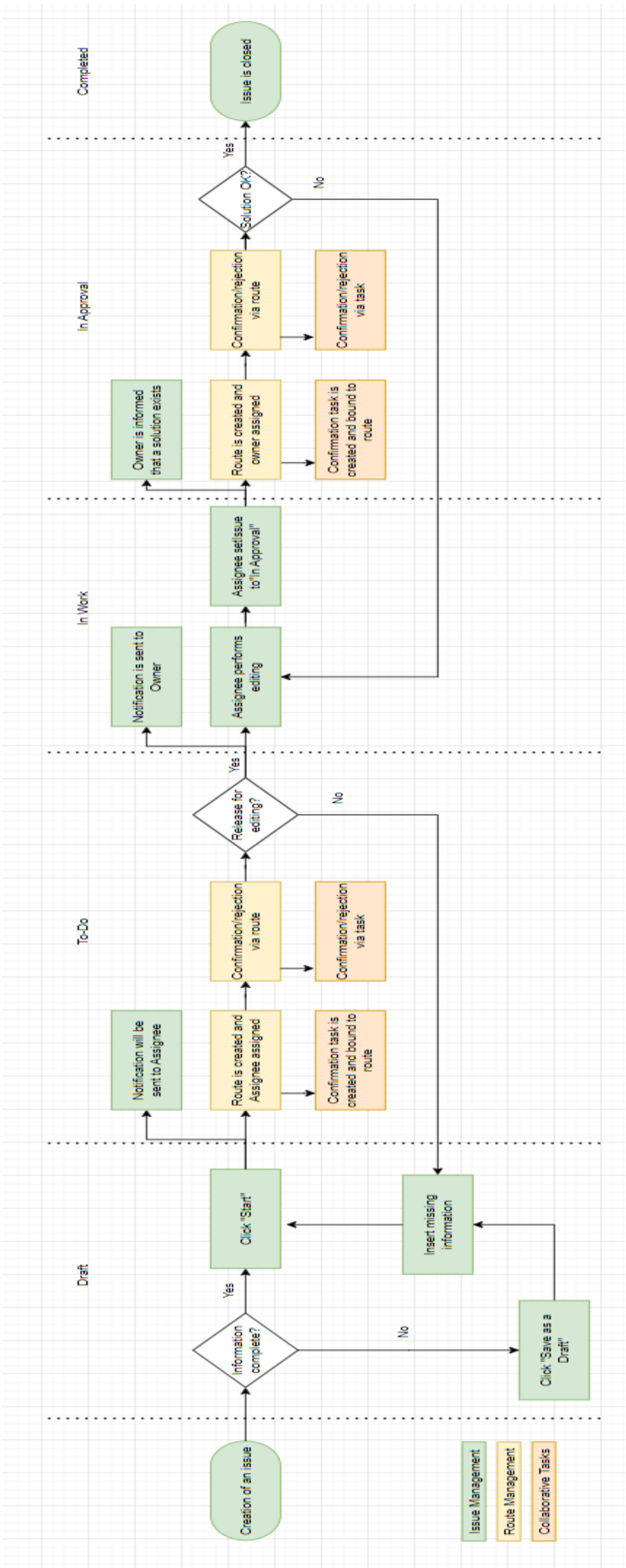

Figure 17: Approval workflow in issue management (prepared by the author).

Once approved, the assignee or contributor can perform the processing. When the processing is completed, the problem is set to "In Approval", and the owner (creator) of the problem automatically receives a route to close the problem if no further processing is required. The solution may be rejected for various reasons. In this case, the agent/contributor must resume processing. The following figure shows the approval workflow, and the status of the workflow can be seen in the delineated areas.

Two workflows were presented to manage the specific requirements in the 3D Experience platform mentioned in the previous chapter within a project. Accordingly, users must follow the respective workflow to mark, forward and solve the corresponding issues.

Also, Issue 3D Review allows to open the user to view properties of models such as related objects and affected model. With this review, the user can locate problems directly on the model, which helps the reviewer to identify components with problems. For example, if an assembly has multiple components but does not have a problem, a related component could still have a problem (Alani, 2022). Issues are displayed within the 3D Review. The widget enables existing and closed issues to be displayed within the 3D context and new issues to be created directly on the component.

The respective vehicle environment can be loaded into the Issue 3D Review by drag & drop. The issues referenced to this vehicle can then be displayed. The Issue 3D Review contains a filter function that groups the relevant issues according to the criteria "me", "my organization", "my project", "assignee", "owner" and "completed". In addition, this widget offers a 3D view that allows the selection of components and issues. Finally, there is an action bar with essential functions such as creating new issues, creating 2D/3D markup, showing, and hiding issues, as well as access to View (Analog 3D Compose) and Tools (Analog 3D Compose). In the Issue 3D Review, the existing issues are indicated by pins. To display the pins, click the "Show/Hide Issues" button (1) in the action bar. There is also the option to inspect issues more closely using the "Inspect Issue(s)" (2) function. The "Focused View" (3) highlights the components with an issue.

Figure 18: Buttons in the widget 3D Review (prepared by the author).

In addition to the visualization functions, functions for creating and editing issues are also available in the action bar. New issues can be created with "New Issue" (1), but it is recommended to use one of the issue creation methods above. There is also the option of adding a screenshot or 3D markup to an existing issue via "2D Markup" (2) or "3D Markup" (3).

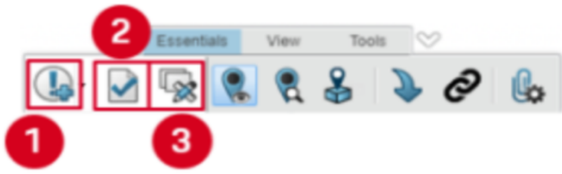

Figure 19: Buttons in the widget 3D Review (prepared by the author).

4.4 Collaborative Tasks

In the following, the functionalities of the "Collaborative Tasks" widget as well as the challenges for the developers and the corresponding proposed solutions are presented.

4.4.1 Functionalities

The Collaborative Tasks widget provides a useful tool to share tasks within a platform. It allows you to manage your own tasks easily and intuitively and those of the project team. When the user clicks on a task, all information is displayed, e.g., Descriptions, comments, and other important information related to that task. The tasks can be specifically assigned to a specific person or group of people. Also, deliverables, related tasks, and projects can be added directly to tasks using the Collaborative Tasks app (Vemborg, n. d.). Accordingly, the tasks can be tracked and communicated with other instances, while there is also the possibility to attach data and describe problems.

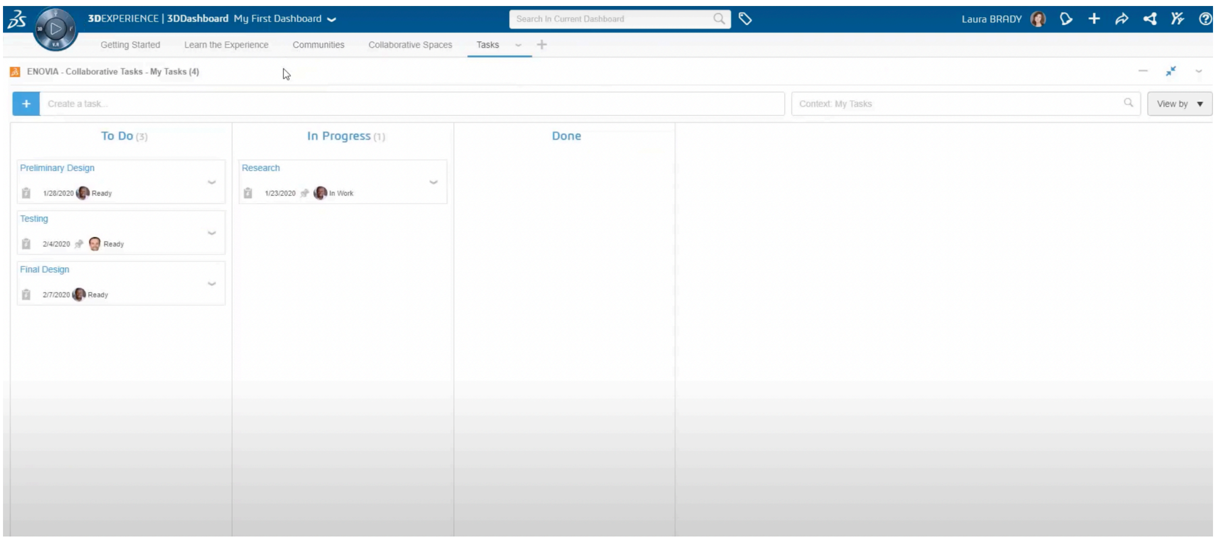

Figure 20: The Issue Management Widget (g. Dassault Systemes, n. d.).

The widget is divided into four columns. The first column, "Draft," contains all tasks that have not yet been approved by the task owner. In contrast, the "To Do" column includes all tasks that have been approved by the task owner and appear in the assignee's collaborative tasks. The "In progress" column contains tasks that have been accepted by the respective assignee and are in progress. Once the task is complete, it will be moved to the "In Approval" column to give the task owner the opportunity to review and approve the solution. If the solution is approved, the task is marked as complete by the owner and moved to the Completed column. If the owner does not approve the resolution, the task will be moved back to the "To Do" column and will need to be revised by the assignee. It is important to mention that the Collaborative Tasks widget is available in the Collaborative Industry Innovator role. The Figure 20 illustrates the Collaborative Tasks widget on a 3D Experience dashboard.

4.4.2 Definition of Requirements

To enable effective task management within the virtual environment, certain requirements based on realistic use cases must be met. These requirements were developed during two meetings with the designer and validated in a final meeting. Each use case has been mapped to a specific widget and workflow, and care has been taken to ensure that the use cases cover different scenarios to ensure a more flexible response to different needs in collaborative task management.

Title	Successful task management
Description	The user needs the ability to quickly distribute information and tasks in order to initiate follow-up tasks or corrections to the component. The task is successfully completed when there is clear communication between those involved.
Proposed solution	This use case can be performed with the Collaborative Tasks widget.

Title	Transparent communication
Description	To ensure transparent communication with colleagues within the platform, users need the ability to send parts. It is important that the data remains constant during transmission and that there is no distortion or data loss. In addition, the parts should be able to be sent within the platform to ensure secure transmission. The recipient should receive a notification when it is sent so that they can quickly access the received message and related parts. The ability to send parts within the platform thus contributes to efficiency and transparency when collaborating with colleagues.
Proposed solution	This use case can be performed with the Collaborative Tasks widget.

Title	Forwarding parts and disputes to service providers
Description	Designers must be able to escalate parts and conflicts quickly and efficiently to a service provider to ensure a smooth flow of information. A seamless integration of the platform with the service provider and the ability to perform the information exchange within the platform are crucial to ensure effective collaboration between the designers and the service provider.

	In addition, the platform should be able to track and update the status of the delegated tasks and the corresponding feedback in real time, to ensure that the designers and the service provider are always informed about the progress of the project. By implementing effective task management within the platform, designers and service providers can improve their collaboration and increase their efficiency, which can lead to faster project completion and higher customer satisfaction.
Proposed solution	This use case can be performed with the Collaborative Tasks widget.

4.4.3 Design of the Solution

As mentioned in the previous chapter, the Collaborative Tasks widget can be used to share tasks within the platform. These tasks are assigned directly to a specific person or group of people. To generate new tasks in the Collaborative Tasks widget, the recommended procedure is as follows: To create new tasks in the Collaborative Tasks widget, it is recommended that the task owner first drag and drop the Shared Tasks application from the application area to the dashboard. After the application has loaded, the task owner can create and assign a new task either via the blue "+" button at the top or by typing in the field next to it. The following figure shows this procedure.

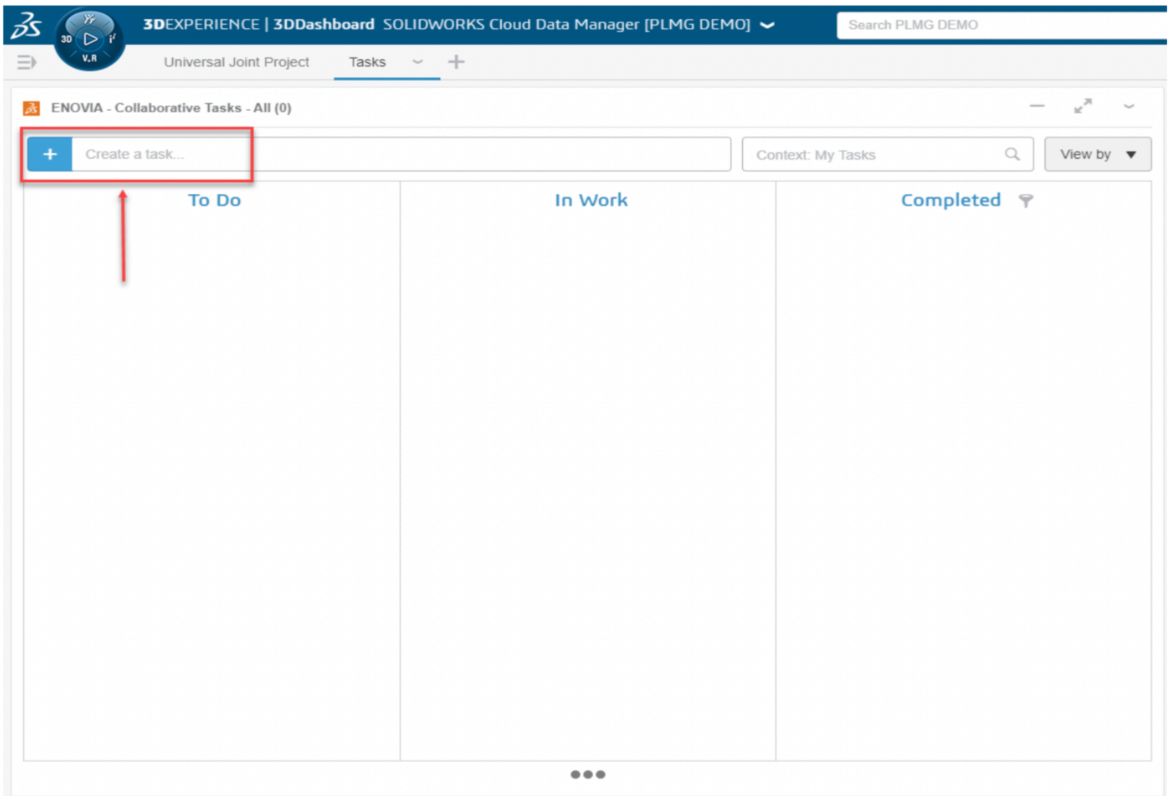

Figure 21: Dashboard of the Collaborative Tasks (prepared by the author).

After entering a name for the task to be completed, the user has two options: The first option "Add" simply adds the task under the specified name. The second option "Add and open" opens the task for further editing possibilities, for example to assign it to another person. However, there is also an option to edit the task after selecting the first option. These and other features of the 3D Experience Platform eliminate additional steps to streamline operations and make them smoother. The following figure shows this procedure.

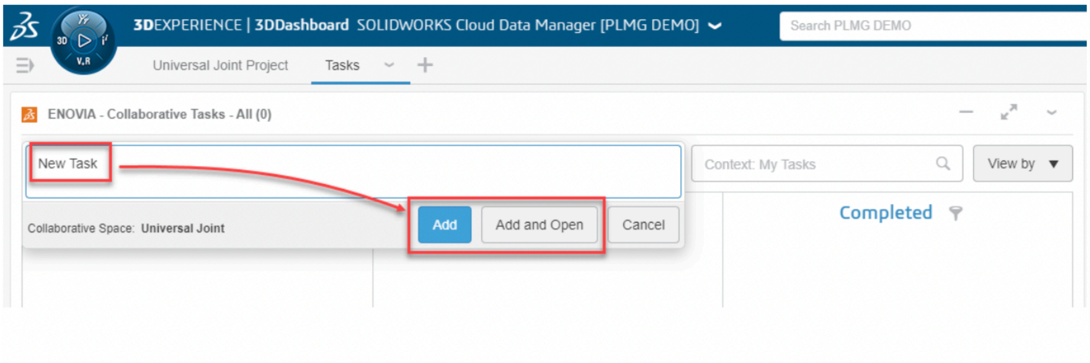

Figure 22: Creating new Tasks (prepared by the author).

Various options are available in the task settings area. For example, it is possible to add a description to the task to be more specific about the expectations or requirements. In addition, the degree of maturity of the task can be determined, which indicates whether it has already been completed, is in progress or still needs to be completed. It is also possible to estimate and control the time required to complete the task. The following figure shows this procedure.

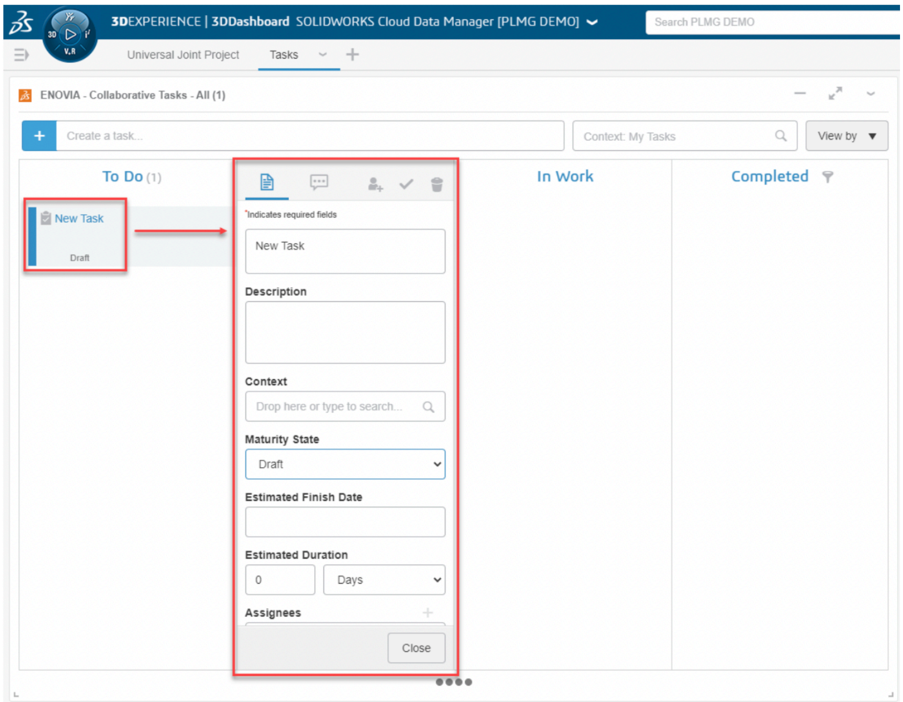

Figure 23: Task settings area (prepared by the author).

However, it should be noted that with a vertical scrolling movement of the user interface there are further options for assigning a task. Another option is to add attachments such as requirements in the form of PDF files. It is also possible to attach deliverables to the respective task, which can include CAD files that were created as part of the project. The following figure shows this procedure.

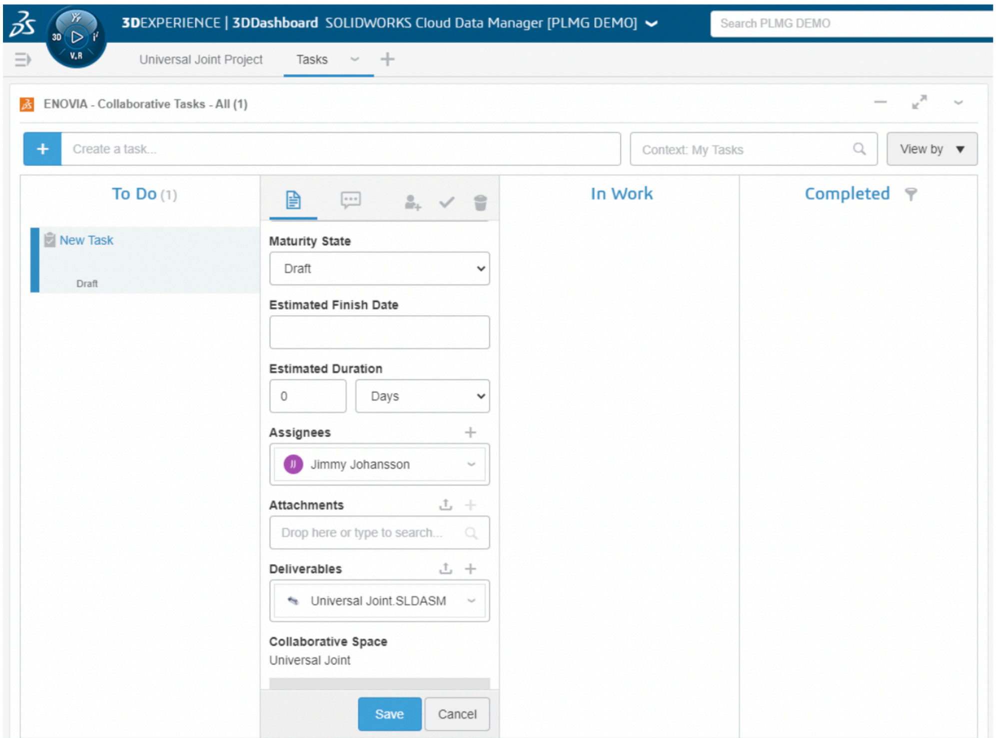

Figure 24: Further options of the task setting area (prepared for the author).

After all settings have been completed, the configuration can be saved with a simple click on the corresponding button. The person responsible for this then receives a notification about the task to be assigned, which becomes visible to him in the "Collaborative Tasks" application. There is an option for the client to activate the option "Automatic assignment of the content owner to the problem". Enabling this option automatically registers the part owner as a contributor in the Members tab when a specific part of a vehicle is selected.

The Collaborative Tasks widget allows tracking of tasks, communication with other instances and offers the possibility to attach data and describe problems. It consists of four columns: The first column "Draft" contains tasks that have not yet been approved by the task owner. The “To Do” column contains approved tasks that appear in the assignee's task pane. The assignee will be notified on the 3D Experience platform once a new task has been assigned to them. The "In progress" column contains tasks that have been accepted by the assignee and are currently being processed. Once editing is complete, the task is moved to the "In Approval" column, notifying the task owner on the 3D Experience platform that the task has been resolved by the assignee. The task owner can review and approve the solution. Approved tasks are moved to the “Completed” column, while unapproved tasks are moved back to the “To Do” column and require review by the assignee. The assignee will be notified again on the 3D Experience platform.

4.5 Jira Connector with 3D Experience

In the following, the 3D Experience to Jira Connector as well as a solution and the configuration of the connector are presented.

4.5.1 Concept

Jira is a tool used for project management and agile working methods. It allows the users to plan, track and manage projects and tasks. It has proven itself as an established market standard for the implementation of larger and more complex agile projects. The application offers the possibility to record all essential artefacts and events of the agile process in digital form. The powerful software is designed to enable agile teams to plan, monitor and release software or product developments. Furthermore, the tool offers real-time reporting, which makes it possible to track the progress of the project. The administration of Jira can be flexibly configured so that the tool can be adapted to the needs of the respective teams and projects to optimally map them (Boss, 2020). Jira provides users with a flexible platform that allows them to customize workflows and processes to their specific needs. The system offers a variety of functionalities, including the ability to create, track, and manage tasks and projects. In addition, it includes a clear view of project schedules and resource management information. It is able to generate automated reports and analytics to monitor the progress of projects (ATLASSIAN, n. d.).

Jira also promotes flexibility and transparency within companies, teams, and projects. The tool can be adapted to a wide variety of requirements using various plugins and variants. To be able to work successfully with the software, the user should have some prior knowledge (Boss, 2020). The tool primarily fills users with tickets, each representing a task and following a specific workflow, represented by the ticket's status. A ticket can have multiple statuses, the most common being “Open”, “In Progress”, “Rejected”, “Under Review”, “Closed”, and “Approved”. This means that the progress of processing the task can be read at any time. In addition, comments, attachments, and insight into the history of changes enable seamless collaboration within the ticket and ensure that no relevant information is lost. Compared to Jira, the 3D Experience is a platform that specializes in digital design, engineering, manufacturing, and maintenance of products in a virtual environment. Both systems offer extensive functions in their respective areas. However, a combination of the data and functions of both systems can be advantageous. The following section presents various ways to integrate 3D Experience and Jira, with one of these options being explained in more detail in the next sub-chapter.

In addition, Jira can be used as part of an Application Lifecycle Management (ALM). ALM typically involves managing the entire lifecycle of an application, from planning through development, testing, and deployment to maintenance and support. In general, hardware and software teams work differently and use different tools, making seamless collaboration difficult. As mentioned in the previous chapters, Product Lifecycle Management is a tool for managing parts, 3D models and documents, while software development is about managing the code and working agile. These diverse needs typically require the use of different tools and platforms to ensure effective collaboration between team members. Jira supports various phases of the ALM process, including planning, tracking, and managing requirements, development, testing and troubleshooting. This enables fully traceable, frictionless collaboration between the mechanical, electrical and software teams throughout the product lifecycle in a car manufacturer (Forsberg, n. d.).

4.5.2 Solution approach of the Jira Connector with 3D Experience

In the following the solution for the integration of Jira with the 3D Experience platform is presented. The steps and functionalities that are necessary to enable seamless cooperation between both systems are explained.

A proven way of connecting the two systems and using them in projects is the solution developed by the software manufacturer Technia. Technia offers its customers seamless collaboration across all disciplines. For this purpose, a plugin was developed that creates a connection between the 3D Experience and Jira to close the gap between hardware and software development. The plugin enables fully traceable and smooth collaboration between the mechanical, electrical and software teams throughout the product life cycle. The integration of Jira into the 3D Experience offers the advantage of integrated and consistent project management, which allows close cooperation between the different departments and at the same time ensures increased efficiency and improved quality. However, implementing such a system requires careful planning and configuration to ensure that the unique requirements of the organization and its projects are addressed (TECHNIA, n. d.).

The 3D Experience to Jira Connector offers specialized web services that make it easy for project teams to exchange information between 3D Experience and Jira. For this purpose, preconfigured and flexible bidirectional connections are used, which make it possible to synchronize almost any type of data between the two systems. The plugin is designed to map change actions, requirements, tasks, and issues within 3D Experience and can be mapped into Jira standard issue types such as epics, stories, tasks, and bugs. In addition, almost any other type of mapping can be configured to meet specific needs and requirements. The plugin also has a monitoring feature that can be used by the admins of both platforms. Administrators have access to an administrative user interface to monitor traffic between the systems and quickly identify and fix problems, even if one of the systems goes down. Technia has focused on specific areas of information to ensure changes in 3D Experience are effectively synced to Jira. The connector thus enables effective collaboration between the two platforms and improves the flow of information in agile project teams (Forsberg, n. d.). The following figure shows this procedure.

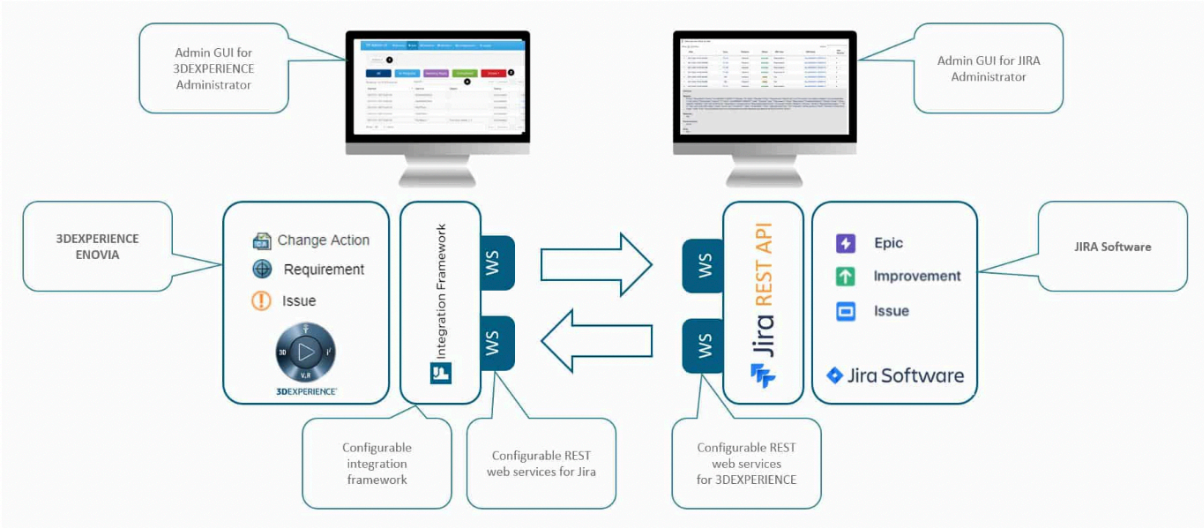

Figure 25: Overview of the 3D Experience to Jira connector (Forsberg, n. d.).

4.5.3 Configuration of the Jira Connector with 3D Experience

As already mentioned, the 3DX Connector for Jira is a plugin developed by Technia that allows users to integrate their 3D models directly into Jira. The 3DX Connector for Jira enables the use of 3D models in business processes and thus promotes collaboration and communication in interdisciplinary projects. This tool allows users to launch a Jira ticket directly from a 3DX object or vice versa. The properties of the 3DX objects can be synchronized with the fields of the Jira ticket throughout their lifecycle. In addition, the connector enables the visual identification of linked objects at the Jira ticket level. The connector consists of two components: the "3DX Connector for Jira" cloud app and the "TIF 3DX Jira Connector" module, which must be installed on the 3DX server. The TIF 3DX Jira Connector module is based on the Technia Integration Framework software and provides a predefined configuration for the Jira Connector.

To implement the connector, it is necessary to install the "3DX Connector for Jira" from the Atlassian Marketplace. After installation, Technia Support must be contacted to request the "TIF 3DX Jira Connector" package and an evaluation license. The package is then installed and configured on the 3D Space Server according to the installation instructions. After the connector has been successfully installed, it still has to be configured accordingly (TECHNIA, n. d.). The "TIF 3DX Jira Connector" should be configured on the Jira platform by an administrator. Here, the corresponding URL of the TIF 3DX

Jira Connector must be entered and the login data of the administrator. The following figure illustrates this procedure.

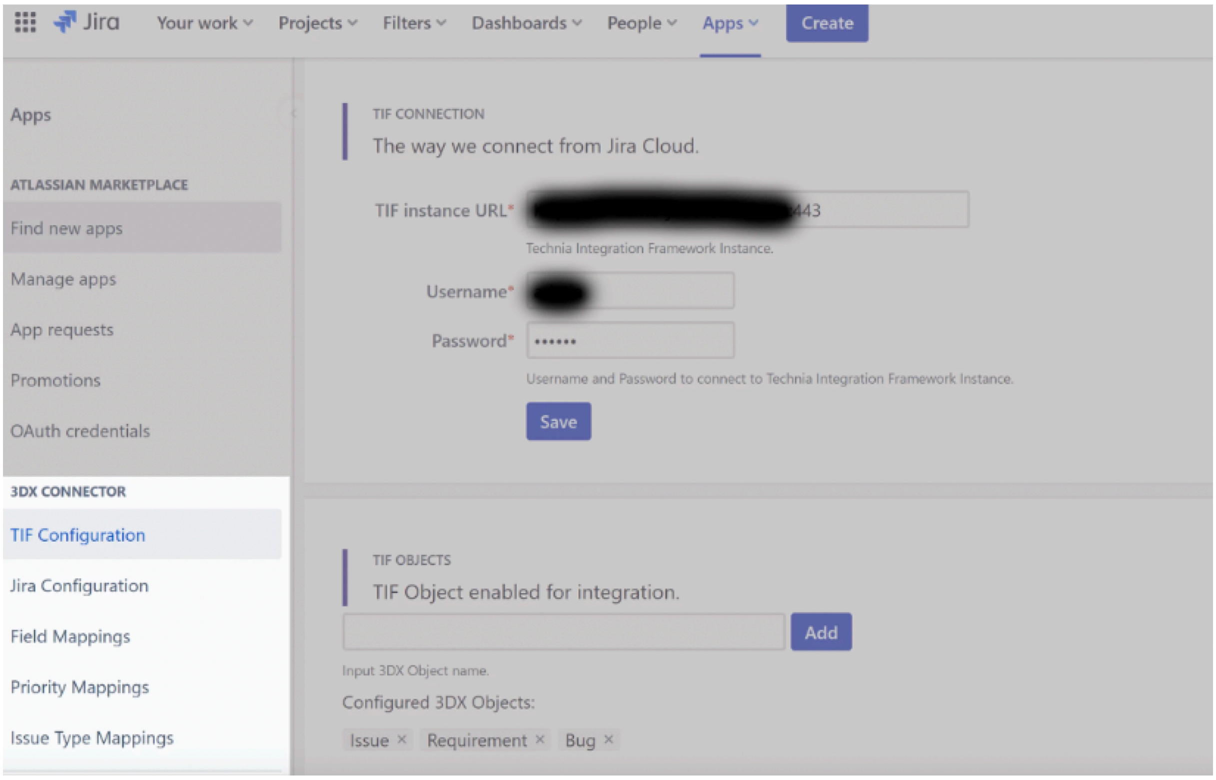

Figure 26: TIF settings in Jira (prepared by the author).

Once the configuration is complete, the 3D Experience platform allows developers to forward component and software requirements directly to the appropriate software developers. An example of this is the battery requirement for an electric car, shown in the attached figure. The description of the requirement has been revised and saved in the database. The requirement is then published to Jira along with the rich text content and images used in the description (Forsberg, n. d.).

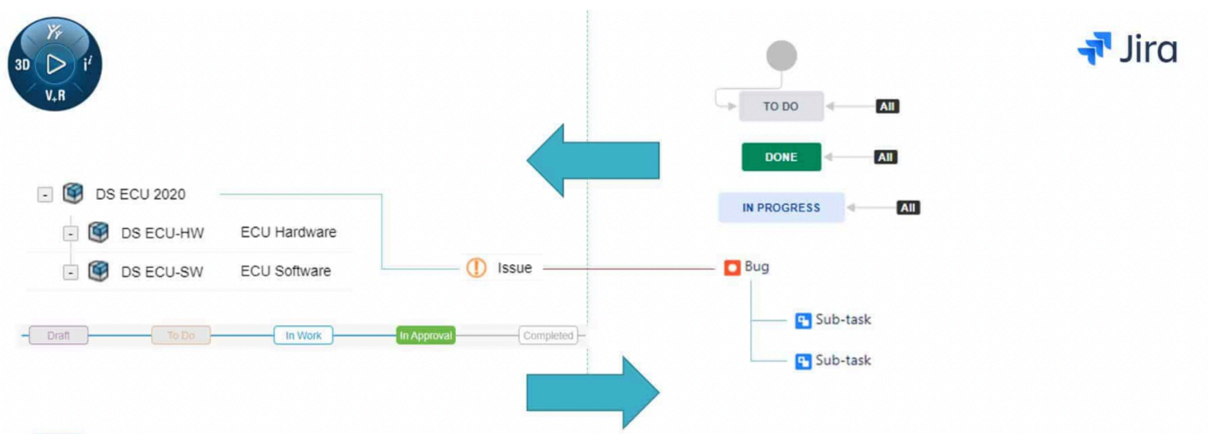

Figure 27: Overview about Issues and Epics (Forsberg, n. d.).

5 Challenges

The following section shows the difficulties associated with the project and how they were overcome. It is undeniable that challenges are an inevitable aspect of projects. The project that was carried out at a German car manufacturer was no exception in this respect and gave me the opportunity to deal with the difficulties of project management and the customer perspective.

5.1 General Difficulties

When I first started working for a German car manufacturer, I faced the same challenges as many newcomers to a company. In the first few weeks I had to get to know the company and its internal processes to create a sound basis for my future tasks. In doing so, I was confronted with a lot of new information about the business logic, development processes and the use of different software products. In addition to personal difficulties, such as the use of technical terms in development and internal processes, there were other problems to overcome. The role of a CAx coordinator requires extensive subject knowledge and organizational skills as this position acts as a liaison between the development and IT departments. Being successful requires a good understanding of projects and the ability to keep an up-to-date to-do list, keep track of progress, and define responsibilities for tasks. Another challenge was to understand projects and their requirements since the theory of a project often differs greatly from practice. As the interface between development and the IT department, it is therefore important to be flexible and adaptable as technology and project requirements are constantly changing. Looking back, I can say that I was very well prepared for the tasks and challenges during the introductory weeks and therefore didn't have any major difficulties. Thanks to the intensive induction measures, I was able to successfully carry out my role as CAx coordinator.

5.2 Planning Difficulties

Improved planning can avoid unrealistic schedules and unforeseen changes can be identified in advance. CAX coordinators are often under a lot of stress to successfully complete projects. Therefore, managing stress effectively is important to avoid mistakes and optimize performance. To complete projects on time, priorities must be set. This can be a challenge in project management, especially with tight deadlines. Another challenge is to correctly estimate the task duration. In the case of IT development projects, misjudgements can occur if IT development is not sufficiently included in the planning process. In addition, it is important to consider unforeseen events such as the development of a staging system in the schedule. Predicting all the details of the implementation of a new product represents a major challenge for project management. A helpful measure is the incremental approach, which enables changes through open communication and continuous coordination with the project management. This allows for more flexible adaptation to unforeseen changes and improves the project's chances of success.

5.3 Lack of Expertise

One of the biggest challenges in the project as CAX coordinator was the lack of expertise. Without sufficient knowledge of project management, IT, and technology, it is difficult to coordinate projects effectively and complete them successfully. A particularly significant hurdle was decision-making. The decisions of a CAX coordinator have a significant impact on the progress of the project. Without the right expertise, it becomes difficult to make the right decisions and solve problems quickly and efficiently. Close cooperation between the CAX coordinators, the IT developers and the management is required as part of the communication with the team members. Without the appropriate expertise, it becomes difficult to understand and effectively communicate the needs and requirements of team members. In addition, it is the responsibility of the CAX coordinator to continuously monitor the progress of the project and adjust as necessary. Without the required expertise, it is difficult to make the appropriate adjustments and effectively monitor project progress. At the beginning of the 3D Experience project, creating an effective work plan was a challenge due to the lack of a basic understanding of the main process and its sub-processes. This led to ambiguity regarding the connections between the processes and the steps required to successfully complete the project.

5.4 Execution Difficulties

Various challenges were identified and overcome during the implementation of the project. One of the main difficulties was dealing effectively with the time pressure. Since the project was subject to tight time constraints, it was essential to work efficiently and to manage several tasks in parallel. To be successful, careful organization and prioritization of tasks was necessary to meet the time pressure. Another obstacle in the project was taking on responsibility. Team members have often been given responsibility for their own projects and tasks, which can be a significant challenge. To be successful, it was therefore essential to take responsibility, work independently and make decisions. In addition, it was crucial to be open to learning new skills in the project. The project provided an excellent opportunity to acquire new skills and knowledge that can be of great importance for professional development. These skills included project management, communication, teamwork, and technical know-how. It is important to emphasize that the 3D Experience project can be particularly challenging for a person from the IT field. By working on the "front end" you are closer to the customer and can look at the implementation of new platforms from the customer's point of view. This requires paying special attention to the needs of the customers and adapting the way of working accordingly.

6 Conclusion

This chapter summarizes the work developed, highlights the lessons learned and discusses the limitations and future directions of the research project. The lessons learned offers the reader the gained insights that arose during the project as well as possible solutions. Furthermore, the limitation of this project is entered, and the future directions of the research project are presented.

6.1 Synthesis of the Developed Work

This project was created with the aim of implementing a new product data management system in the development of an automobile manufacturer and to optimize the flow of information between the departments and external suppliers. This enables developers to communicate with other departments and suppliers within one platform and efficiently distribute tasks related to components of a vehicle project.

To ensure that this project follows the best practices in the field, it was necessary to conduct an extensive literature review on the relevant technologies, methodologies and approaches involved in the development of the product data management system. It was assumed that four steps were required to successfully implement the project. The first step was to understand the existing processes that the developers found useful. Here it was important to collect information about each process and to model it in its current form. The use of use cases enabled the creation of requirements to implement the workflow in the car manufacturer. The configuration of the 3D Experience to Jira tool played a crucial role as it allowed the developers to distribute tasks directly with the software developers. This gave the software developers a more comprehensive overview of the requirements set by the developers in a vehicle project. In addition, an approach was developed using Model Based Systems Engineering to guide the modular design process and support various aspects such as system requirements, design, analysis, verification, and validation. The use of Model Based Systems Engineering enables an integrated and consistent modelling of the system and its components. This approach is applied from the conception phase to later lifecycle phases to ensure a continuous and holistic view of the system.

By implementing the PDM system and linking it to Jira, collaboration between the different departments and external suppliers is improved. Developers can now communicate more efficiently, delegate tasks and track development progress. This leads to better coordination, increased efficiency and ultimately to optimized development of vehicle projects. The implementation of the new PDM system and the connection with Jira provide a comprehensive solution to optimize the flow of information and enable effective collaboration in the development process. Improving communication and coordination helps reduce bottlenecks, minimize errors, and increase overall productivity.

In addition, two workflows for issue management were presented, which make it possible to categorize the corresponding tasks in the workflows. By implementing these workflows for issue management, companies in the vehicle project can benefit from improved organization, more efficient processing of issues and clearer communication. This helps streamline the flow of information, minimize bottlenecks, and ensure effective problem resolution. In addition, the workflows enable a complete tracking of the issues, which enables comprehensive documentation and analysis to derive possible improvements for future projects.

Overall, this project represents an important step for the car manufacturer to enable more efficient development processes and ultimately improve quality and customer satisfaction. By implementing the PDM system and using the 3D Experience to Jira tool, the company can strengthen its competitiveness and further expand its position in the market.

6.2 Lessons Learned

During my five-month stay at a German car manufacturer, I had the opportunity to gain extensive knowledge in various subject areas. My focus was on the 3D Experience project, where I was able to put my theoretical knowledge from my master's degree into practice. I also expanded my knowledge through concrete application examples. The incremental model, which was also discussed in the IT architecture lectures, was chosen as part of the development approach. I was able to deepen the concept of business process management in various applications. Business process management played a crucial role, especially when creating the use case. A thorough understanding of the digitization strategies and trends in the industry 4.0 environment was required for a comprehensive functional analysis of the 3D Experience platform. This knowledge allowed me to evaluate and optimize the platform. Furthermore, I got the opportunity to apply agile project management methods and to understand the importance of Scrum methods through team projects. I was able to deepen my understanding of effective collaboration and flexible project management. Another important area that I was able to work on intensively was quality management. I was responsible for implementing testing processes and applying testing methods to ensure the functionality of the platform. These practical experiences contributed significantly to the deepening of my skills and knowledge in the IT field. Overall, these experiences have allowed me to further expand my expertise and develop practical skills in the IT field.

The project was extremely complex and multi-layered. Significant attention was paid to integrating the platform into the company's existing systems and processes and to training employees in how to use this platform. Projects marked by variation and expected uncertainty allow for better planning, while projects marked by high levels of unexpected uncertainty and chaos should place the emphasis on learning. In such situations, rapid iterations and regular reviews prove to be effective methods for modern software development (De Meyer et al., 2002). During the work project, I not only got to know the use of tools and techniques in project management, but also learned from the mistakes made and the more suitable tools. Using these tools and techniques has given me an understanding of how to organize a team efficiently. Using the SAFe methodology, high goals were set for teams and individuals, and daily stand-ups, weekly alignment and management meetings, and regular retrospective meetings were held to track progress. In addition, I was able to gain experience from the customer's perspective during software development. It often happens that developers do not create the software according to customer requirements.

During the work project, I was able to gain extensive experience as a link between the department and IT. I gained valuable insights into the role of a translator. A crucial factor that can lead to software developers developing software that is different from what the customer wants is often due to poor communication. Furthermore, unclear customer requirements and a lack of specialist knowledge on the part of the developers in the customer's specific business area can lead to the customer's requirements not adequately matching the software to be developed (Diaz et al., 2015). Getting started with the project proved to be extremely instructive on a methodological level. The complexity of the project required careful planning, organization, and supervision. Since my focus was on "Issue Management" and "Collaborative Work", I was able to quickly familiarize myself with the project. Thanks to my practical experience, I acquired an effective tool to analyse future business ideas. Using a to-do list proved extremely useful for structuring and reprioritizing tasks. Overall, these tools have proven to be valuable tools to support communication and provide a comprehensive overview of the tasks at hand.

The project was characterized by rapid and efficient communication due to a flat hierarchical structure and the possibility for the CAx coordinator to contact the product manager directly. The only problem was limited access to the 3D Experience platform due to lack of licenses. Fortunately, this obstacle was quickly removed by the project management. Collecting feedback is crucial to ensure that all information is conveyed and understood correctly. Retrospectives have proven to be an effective way to identify weaknesses and uncover inefficiencies. Another positive aspect of the project was the integration of the designers into the development process of the Minimum Viable Product. The features and benefits of the 3D Experience Platform were vividly presented to the designers who would use the product. This allowed realistic use cases to be developed together, effectively utilizing the experience and know-how of the designers.

The incremental model was deliberately chosen as it offers a flexible way to accommodate requirements and changes throughout the project. This approach makes it possible to react to new requirements and changes without affecting the overall project. However, it's important to note that an overabundance of changes can lead to confusion and ambiguity. It is therefore of great importance to regularly check the project goals and adjust them if necessary. In addition, a thorough understanding of related projects and their dependencies is required to define realistic goals and successfully complete the project. Project management experience has not only provided specific business knowledge, but also developed transferrable skills that can be of great value in similar projects or work environments. As a result, I am confident that the knowledge I have gained will enable me to perform better in future projects or professional activities. Through my discussions with management and stakeholders, I was able to take my interest in entrepreneurial processes to a new scientific level. These discussions proved to be extremely valuable as they broadened my professional horizons and gave me a strategic perspective. A key insight I gained from these meetings is the importance of a customer-centric approach and the continuous testing of assumptions through practical methods such as customer surveys or market research. It has been shown that simple questions to customers can often provide deeper insights than complex analysis methods. In addition to my knowledge gain, I have also acquired industry-specific knowledge in the areas of mechanical development and software development. This knowledge has broadened my scientific perspective and helped me to develop a more comprehensive understanding of the entrepreneurial processes in these areas.

6.3 Limitations and Future Work

The following section outlines the limitations of this work and possible future research opportunities. The focus of this work is on the functionalities of the widgets "Issue Management" and "Collaborative Tasks" on the 3D Experience platform. With the help of these widgets, various methods based on systems engineering approaches were developed to realistically integrate the use cases of the developers from body development into everyday work. It is important to emphasize that the use cases were created in collaboration with the developers. The techniques developed were tested on the 3D Experience platform as part of a specially designed project aimed at testing these functionalities. However, it should be noted that in this work only the functionalities of the widgets mentioned were considered, without considering other widgets of the 3D experience platform. This could potentially reveal further possibilities and limitations. The project itself focused primarily on simplifying communication regarding a prototype with service providers, software engineers and component managers. Furthermore, the developed methods and their applicability were tested exclusively based on cooperation with the body developers. It should be noted that other development domains may have different use cases and requirements, which can lead to different results. Finally, the effects of the implementation of the developed methods on the everyday work of the developers were not extensively examined. It therefore remains an open question how the integration of these processes would affect the development process and workflows in the long term.

These limitations leave room for future research. For example, further investigation could include other widgets of the 3D Experience Platform to further explore their potential for product development. In addition, the developed methods could be tested in other development areas to validate their generality and applicability. A more comprehensive analysis of the effects on the daily work and work processes of the developers would also be of interest to gain a better understanding of the long-term effects. In addition, one could analyse the impact of these two methods on the processes. It would also be interesting to study the long-term impact of implementing these practices on the productivity, collaboration, and efficiency of development teams. Finally, the possibility would be to extend the Jira to 3D Experience Connector to enable an approval workflow for the relevant issues.

Overall, this thesis offers an insight into the functionalities of the "Issue Management" and "Collaborative Tasks" widgets on the 3D Experience platform and presents first approaches to the integration of systems engineering into classic product development processes. However, it is important to consider the above limitations and conduct further research in these areas to gain a fuller understanding and realize the full potential of these approaches.

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